ONTARIO POWER GENERATION

Report

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DARLINGTON NUCLEAR ENVIRONMENTAL RISK ASSESSMENT

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DARLINGTON NUCLEAR ENVIRONMENTAL RISK ASSESSMENT

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DARLINGTON NUCLEAR ENVIRONMENTAL RISK ASSESSMENT

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LIST OF ACRONYMS AND SYMBOLS

ACRONYMS

AAQC	ambient air quality criteria
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee's Dispersion Model
ALARA	as low as reasonably achievable
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	bioaccumulation factor
BB	Boiler Blowdown
BCF	bioconcentration factor
BC MOE	British Columbia Ministry of the Environment
BM	Birds and Mammals
BTEX	benzene, toluene, ethylbenzene, and xylenes
BV	benchmark value
CANDU	CANada Deuterium Uranium
CCME	Canadian Council of Ministers of the Environment
CCW	condenser cooling water
CDWG	Canadian Drinking Water Quality Guideline
CN	Canadian National Railway Company
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owners Group
COPC	contaminant of potential concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
COSSARO	Committee on the Status of Species at Risk in Ontario
CSM	Conceptual Site Model
CSA	Canadian Standards Association
D_2O	deuterium oxide (heavy water)
DC	dose coefficient
DFO	Department of Fisheries and Oceans Canada
DN	Darlington Nuclear
DQO	data quality objectives
$DQRA_{CHEM}$	detailed quantitative risk assessment for chemicals
DRHD	Durham Region Health Department
DRL	derived release limit
DRPD	Durham Region Planning Department
DSC	dry storage container
DWMF	Darlington Waste Management Facility
EA	environmental assessment
EC	Environment Canada
EC_{50}	median effective concentration

ECA	environmental compliance approval
EcoRA	ecological risk assessment
EIS	Environmental impact statement
EMP	environmental monitoring program
ERA	environmental risk assessment
ESA	Endangered Species Act
ESDM	Emissions Summary and Dispersion Modelling
EV	exposure values
FCSAP	Federal Contaminated Sites Action Plan
FEQG	Federal Environmental Quality Guideline
FFAA	fuelling facilities auxiliary areas
HC	Health Canada
HHRA	human health risk assessment
HQ	hazard quotient
HT	elemental tritium
HTO	tritium oxide
HTS	heat transport system
HVAC	heating, ventilation and air conditioning system
HWS	hot water soluble
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
ICSQC	Interim Canadian Soil Quality Criteria
IFB	irradiated fuel bay
ILCR	incremental lifetime cancer risk
ILW	intermediate level waste
Imfp	radioiodine mixed fission products
ISO	International Organization for Standardization
JSL	jurisdictional screening levels
LCV	lowest chronic value
LC_{50}	median lethal concentration
LEL	Lowest Effect Level
LLW	low level waste
LOAEL	Lowest Observed Adverse Effect Level
LOEC	lowest observed effect concentration
$logK_{ow}$	hydrophobicity
LPSW	Low Pressure Service Water
LSA	local study area
MDL	Method Detection Limit
MISA	Municipal/Industrial Strategy for Abatement
MOE	Ontario Ministry of the Environment
MOECC	Ontario Ministry of the Environment and Climate Change

MOEE	Ontario Ministry of Environment and Energy
MTE	maximum temperature for embryos
MWAT	maximum weekly average temperatures
NCRP	National Council on Radiation Protection and Measurements
NEW	nuclear energy worker
NND	New Nuclear-Darlington
NOEC	no observed effect concentration
NOAEL	No Observed Adverse Effect Level
NSCA	Nuclear Safety and Control Act
OBT	organically bound tritium
OG	operational guideline
OMNR	Ontario Ministry of Natural Resources
OPG	Ontario Power Generation
O.Reg	Ontario Regulation
OTR_{98}	Ontario Typical Range
PAH	polycyclic aromatic hydrocarbon
PHC	petroleum hydrocarbons
PHTS	primary heat transport system
POI	point of impingement
PQRA	preliminary quantitative risk assessment
PRA	probabilistic risk assessment
PVC	polyvinyl chloride
PWQO	provincial water quality objective
QA	quality assurance
QA/QC	quality assurance/quality control
QSAR	Quantitative Structure-Activity Relationship
RBE	relative biological effectiveness
RCO	Refurbishment and Continued Operation
RfD	Reference Dose
RLW	Radioactive liquid waste
RLWMS	Radioactive Liquid Waste Management System
ROP	Records of Proceedings
SARA	Species at Risk Act
SARO	Species at Risk in Ontario
SHTS	secondary heat transport system
SIO	safety improvement opportunities
SQG_E	Soil Quality Guidelines for Environmental Health
SSA	site study area
SPS	Sewage Pumping Station
SWM	Storm Water Management
SWMP	Storm Water Management Planning and Design Manual
TCEQ	Texas Commission on Environmental Quality

TF	transfer factor
TOC	total organic carbon
TRC	total residual chlorine
TRCA	Toronto and Region Conservation Authority
TRF	Tritium Removal Facility
TRV	toxicity reference value
TSD	technical support document
TSS	total suspended solids
UCLM	upper confidence limit on the arithmetic mean
UF	uncertainty factor
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
US EPA	United States Environmental Protection Agency
VEC	valued ecosystem component
VOC	volatile organic compounds
WHO	World Health Organization
WSP	water supply plant
WTP	Water Treatment Plant
WWMF	Western Waste Management Facility

SYMBOLS

Human Non-radiological Parameters

C	=	concentration of contaminant in drinking water (mg/L)
IR	=	receptor intake rate (L/d)
RAF_{GIT}	=	absorption factor from the gastrointestinal tract (unitless)
D_2	=	days per week exposed•(7 days)$^{-1}$ (d/d)
D_3	=	weeks per year exposed•(52 weeks)$^{-1}$ (wk/wk)
D_4	=	total years exposed to site (years) (for carcinogens only)
BW	=	body weight (kg)
C_{foodi}	=	concentration of contaminant in food i (mg/kg)
IR_{foodi}	=	receptor ingestion rate for food i (kg/d)
RAF_{GITi}	=	relative absorption factor from the gastrointestinal tract for contaminant i (unitless)
D_i	=	days per year during which consumption of food i will occur (d/a)
365	=	total days per year (constant) (d/a)
LE	=	life expectancy (years) (for carcinogens only)

Ecological Radiological Dose Parameters

D_{int}	=	internal radiation dose (µGy/d)
D_{ext}	=	external radiation dose (µGy/d)
DC_{int}	=	internal dose coefficient ((µGy/d)/(Bq/kg))

DC_{ext}	=	external 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_m	=	media concentration (Bq/L or Bq/kg)
C_f	=	average concentration in food (Bq/kg fw)
C_w	=	water concentration (Bq/L)
C_s	=	soil/sediment concentration (Bq/kg fw)
C_t	=	whole body tissue concentration (Bq/kg fw)
C_x	=	concentration in the ingested item x (Bq/kg fw)
OF_w	=	occupancy factor in water (unitless)
OF_{ws}	=	occupancy factor at water surface (unitless)
OF_s	=	occupancy factor in soil/sediment (unitless)
OF_{ss}	=	occupancy factor at soil/sediment surface (unitless)
BAF	=	bioaccumulation factor (L/kg or kg/kg)
BMF	=	biomagnification factor (unitless)
I_x	=	ingestion rate of item x (kg fw/d)
TF	=	ingestion transfer factor (d/kg)
DW_a	=	dry/fresh weight ratio for animal products (kg-dw/kg-fw)
$1\text{-}DW_a$	=	water content of the animal (L water /kg-fw)
$1\text{-}DW_p$	=	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)
$BAFa_{C14}$	=	C-14 BAF for aquatic animals, invertebrates, and plants (L/kg-fw)
$P_{C14food\_animal}$	=	transfer of C-14 from food to animals

Ecological Non-Radiological Parameters

C_x	=	concentration in the ingested item (x) (mg/kg)
D_{ing}	=	dose from ingestion pathway (mg/kg body weight/d)
I_x	=	ingestion rate of item x (kg/d)
W	=	body weight of consumer (kg fw)
ΔT	=	change in temperature (ºC)

Executive Summary

The following document is the Environmental Risk Assessment (ERA) for Darlington Nuclear (DN), meeting the requirements of the Canadian Standards Association (CSA) N288.6 standard on environmental risk assessment for Class I nuclear facilities (CSA, 2012). The standard calls for both human health risk assessment (HHRA) and ecological risk assessment (EcoRA), for both radiological and non-radiological contaminants and physical stressors. The results of the ERA inform the environmental monitoring programs (EMP) and effluent monitoring programs, as per N288.4 (2010) and N288.5 (2011). These programs can also inform the ERA by providing information on effluent concentrations and loadings, and by providing environmental data to assist in model calibration and validation.

This ERA focuses on activities that occurred during the 2011 to 2015 period that encompass normal operations at DN during the operations and preparation for refurbishment phases of the facility.

The DN site is located in the township of Darlington, on the north shore of Lake Ontario at Raby Head. The DN site is about 5 km southwest of the community of Bowmanville and about 10 km east southeast of the City of Oshawa. The DN site is comprised of the DN Generating Station, with four operating CANada Deuterium Uranium (CANDU) pressurized heavy water generating reactors, the Tritium Removal Facility (TRF), and Darlington Waste Management Facility (DWMF).

The overall goals of this ERA are:

- To establish an updated baseline condition for the DN Site.
- To update the ERA in general accordance with the CSA N288.6-12 Standard.
- To provide focus for the environmental monitoring program on relevant contaminants of potential concern (COPCs), media, and ecological and human receptors.

The specific objectives of this ERA, consistent with CSA N288.6-12 are:

- To evaluate the risk to relevant human and ecological receptors resulting from exposure to contaminants and stressors related to the DN site and its activities.
- To recommend potential further monitoring or assessment as needed based on the results of the ERA.

Environmental data for the ERA were generally obtained from existing DN environmental assessments (EAs), Environmental Compliance Approvals (ECAs) from 2011 to 2015, environmental monitoring data from 2011 to 2015, and the 2016 effluent characterization study.

Human Health Risk Assessment (HHRA)

Predicted exposures to sources from DN were evaluated on the basis of toxicological effects from non-carcinogenic COPCs, potential cancer risk from carcinogens, and potential radiation exposure from radionuclides.

Human Receptors

Human receptors evaluated in both the radiological and non-radiological assessment included off-site members of the public, specifically those critical groups used for dose calculations in the OPG Annual EMP Reports, including:

- Urban Residents (Oshawa/Courtice, Bowmanville, West/East Beach)
- Farm
- Dairy Farm
- Rural Resident
- Industrial/Commercial Worker
- Sport Fisher
- Camper

On-site receptors were not addressed in the HHRA, since human exposures on the site are kept within safe levels through OPG's Health and Safety Management System Program and Radiation Protection Program.

Screening of COPCs for Human Health

The DN facility emits chemical and radiological contaminants to air, water, soil, and groundwater in the normal course of operations. Measurements and modeled concentrations of contaminants of potential concern (COPCs) were screened against available screening benchmarks that are protective of human health to determine if any COPCs required further study in the context of human health risk assessment. Table ES-1 provides a summary of the COPCs carried forward for further quantitative assessment in the HHRA.

Selected radiological stressors are considered of public interest and therefore are carried forward quantitatively in the HHRA and do not undergo a formal screening assessment. The radionuclides selected for use in Derived Release Limit (DRL) calculations were considered appropriate for assessment in the HHRA.

Table ES-1: Summary of COPCs Selected for Human Health Risk Assessment

Category	Radiological COPC	Chemical COPC
Air	C-14, Co-60, HT, HTO, noble gases, I(mfp)	None
Surface water	C-14, Cs-137+, HTO	nitrate, hydrazine, morpholine

Category	Radiological COPC	Chemical COPC
Soil	C-14, Co-60, Cs-137+, HTO, I-131	None
Groundwater	HTO, Co-60, I-131	None
Sediment (beach sand)	C-14, Cs-137+, HTO	None
Other Stressors	None	

Results of HHRA

Non-radiological HHRA

The complete exposure pathways that were assessed in the non-radiological HHRA included:

- Water ingestion for the Urban Residents, Rural Resident, Industrial/Commercial Worker, and Camper; and
- Fish ingestion for the Sport Fisher, Urban Residents, Rural Resident, Farm, Dairy Farm, and Camper.

Potential risks to human receptors were characterized quantitatively in terms of Hazard Quotients (HQs) for non-carcinogens (morpholine, nitrate) and Incremental Lifetime Cancer Risks (ILCRs) for potential carcinogens (hydrazine). The target risk threshold is 0.2 for non-cancer risk (HQ) and an incremental lifetime target cancer risk limit of 10^{-6} (ILCR). The hydrazine risks were conservatively estimated based on concentrations in effluent that were mostly non-detect, and assumed to be present at the detection limit, as explained in Section 3.2.6. Therefore, the results are conservative and may be over-estimating actual risk levels. The results of the quantitative HHRA are as follows.

- No increased risk to human receptors is expected resulting from exposure to morpholine.
- The target risk for non-cancer risk was exceeded for the Oshawa/Courtice and Bowmanville Urban Residents due to exposure to maximum nitrate in drinking water, based on surface water data collected in 2009. Mean water concentrations of nitrate did not exceed the target risk. Additionally, based on the 2016 effluent characterization study, all measured nitrate concentrations in the effluent were below the drinking water quality guideline for nitrate of 10 mg/L.
- The target for cancer risk was exceeded for the Oshawa/Courtice and Bowmanville Urban Residents and for Campers due to exposure to maximum and mean estimated concentrations of hydrazine in drinking water,
- The target for cancer risk was exceeded for the Industrial/Commercial Worker due to exposure to maximum concentration of hydrazine in drinking water, but not based on the mean hydrazine concentration. Since exposure to the mean concentration is

considered more representative of long-term exposures, health risks to the Industrial/Commercial Worker due to hydrazine are not expected.
- The target for cancer risk was exceeded for the Sport Fisher due to exposure to maximum and mean estimated concentrations of hydrazine in fish. Sport fishers were assumed to eat all of the fish portion of their diet from Lake Ontario fish caught at DN, which is very conservative.

Overall, health risks are not expected for human receptors due to nitrate and morpholine in water and in fish. Risks could not be ruled out for the Sport Fisher due to hydrazine in fish, and to the Oshawa/Courtice and Bowmanville Urban Residents as well as Campers due to hydrazine in drinking water.

Radiological HHRA

For exposure of human receptors to radiological COPCs, the relevant exposure pathways and human receptors (critical groups) were those presented in the annual OPG EMP reports. Radiological dose calculations followed the methodology outlined in CSA N288.1-08. The 2011-2015 public dose estimates for the critical groups are at most approximately 0.06% of the regulatory public dose limit of 1 mSv/a, and at most approximately 0.04% of the dose from background radiation in the vicinity of DN. Since these critical groups receive the highest dose from DN, demonstration that they are protected implies that other receptor groups near DN are also protected.

Ecological Risk Assessment (EcoRA)

Valued Ecosystem Components

The assessment for the EcoRA focused on the nearshore Lake Ontario (generally in the area surrounding the outfall from the DN diffuser) and the DN site and surrounding area. The assessment has been divided into polygons (AB – Coots Pond, C, D – Treefrog Pond, and E), consistent with past EcoRAs.

Valued ecosystem components (VECs) were selected for dose and risk analysis because they are known to exist on-site, and/or are representative of major taxonomic/ecological groups, major pathways of exposure, or have a special importance or value. The model used for assessment of dose and risk is either specific to the selected VEC species, or is a more generic biota assessment model that is appropriate to a number of VECs with similar exposure characteristics. Table ES-2 shows the selected VECs and the assessment models used in estimating their COPC exposure, dose and risk. Protection of the VECs implies that other species in the same VEC category are also protected.

Table ES-2: Summary of VECs and their Assessment Models used in the EcoRA

VEC Category	Assessment Model	VEC
Fish	Bottom Feeding Fish	Northern Redbelly Dace
		Round Whitefish
		White Sucker
	Pelagic Fish	Alewife
		Lake Trout
		American Eel
Reptiles and Amphibians	Bottom Feeding Fish	Turtles
		Frogs
Aquatic Plants	Aquatic Plant	Aquatic Plants
Aquatic Invertebrates	Benthic Invertebrate	Benthic Invertebrates
Riparian Birds	Bufflehead	Bufflehead
	Mallard	Mallard
Riparian Mammals	Muskrat	Muskrat
Terrestrial Invertebrates	Soil Invertebrate	Earthworm
Terrestrial Birds	American Robin	American Robin
	Bank Swallow	Bank Swallow
	Song Sparrow	Song Sparrow
	Yellow Warbler	Yellow Warbler
Terrestrial Plants	Terrestrial Plant	Grass
	Terrestrial Plant	Sugar maple
Terrestrial Mammals	Eastern Cottontail	Eastern Cottontail
	Meadow Vole	Meadow Vole
	White-tailed Deer	White-tailed Deer
	Common Shrew	Common Shrew
	Raccoon	Raccoon
	Red Fox	Red Fox
	Short-tailed Weasel	Short-tailed Weasel

A number of threatened and endangered species have been identified within the DN Site Study Area during the 2011 to 2015 time period, including Bank Swallow, Barn Swallow, Olive-Sided Flycatcher, Bobolink, Eastern Meadowlark, Wood Thrush, Canada Warbler, Little Brown Myotis, Butternut, and American Eel. Each of these species was considered by reference to a representative species already assessed in the EcoRA.

Assessment endpoints are attributes of the receptors that we wish to protect in environmental programs (Suter *et al.*, 1993). The purpose of an ERA is to evaluate whether these environmental protection goals are being achieved or are likely to be achieved. Consistent with CSA N288.6, the assessment endpoint for all receptors in this ecological risk assessment is population abundance. The assessment endpoint for the identified species at risk is the individual, since effects on even a few individuals of species at risk would not be acceptable.

Screening of COPCs for Ecological Assessment

The same monitoring data sources previously screened for the HHRA were screened for the EcoRA using the more conservative of available federal and provincial guidelines and objectives as screening criteria. If there was no such guideline or objective, screening criteria were obtained from literature, and/or derived using federally and/or provincially accepted methods. For COPCs where these criteria are not available, upper estimates of background concentrations or conservative toxicity benchmarks (e.g., no effect levels) are used as screening criteria. Maximum measured concentrations of parameters in surface water, sediment, soil, and air are compared to the selected screening criteria to determine the list of COPCs. Contaminants are also retained as COPCs if no screening criteria are available or if they are considered of public interest (e.g., radionuclides). Table ES-3 provides a summary of the COPCs carried forward for further quantitative assessment in the EcoRA.

Thermal stressors and entrainment and impingement were carried forward for assessment in the EcoRA since they are widely recognized as being of primary concern in nuclear power plants, as recommended by CSA N288.6-12. Other physical stressors such as noise, wildlife strikes with vehicles, and bird/bat strikes on buildings screened out and were not carried forward for further assessment in the EcoRA.

Table ES-3: Summary of COPCs and other Stressors Selected for the Ecological Risk Assessment

Environmental Medium	Radiological COPC	Chemical COPC
Air	None	None
Surface water	C-14, Co-60, Cs-134, Cs-137+, HTO, I-131	Aluminum, copper, nitrate, TRC, hydrazine, morpholine (Lake Ontario) pH, aluminum, ammonia, barium, calcium, cobalt, iron, magnesium, potassium (Polygon AB) Barium, boron, calcium, cobalt, iron, magnesium, manganese, nitrate, potassium, zirconium (Polygon D)

Environmental Medium	Radiological COPC	Chemical COPC
Soil	C-14, Co-60, Cs-134, Cs-137+, HTO, I-131	Barium for birds and mammals in polygons AB, C, D, and E; hot water soluble boron for plants and soil organisms in polygon AB; lead for birds and mammals in polygon AB; tin for plants, soil organisms, birds, and mammals in polygons C and D; strontium for plants, soil organisms, birds, and mammals in polygons AB, C, D, and E.
Groundwater	None	None
Sediment	C-14, Co-60, Cs-134, Cs-137+, HTO, I-131	copper, manganese, phosphorus, vanadium (Polygon AB) chromium, copper, iron, manganese, nickel, phosphorus, vanadium (Polygon D)
Other Stressors	Thermal effects, entrainment, and impingement	

<u>Results of the EcoRA</u>

<u>Non-radiological EcoRA</u>

The potential for ecological effects was assessed by comparing exposure levels to toxicological benchmarks, and characterized quantitatively in terms of HQs. A HQ greater than 1 indicates a need to more closely assess the risk to the concerned VEC.

Lake Ontario

Maximum surface water concentrations in the nearshore of Lake Ontario exceeded the benchmarks for copper and nitrate for fish and the benchmark for nitrate for benthic invertebrates, whereas the mean concentrations did not exceed the fish and benthic invertebrate benchmarks for copper and nitrate. The HQs for mean water concentrations for copper and nitrate are more representative of fish exposure than maximum concentrations, because fish are mobile and are not expected to be continuously exposed to maximum concentrations (this is true for all fish, including species at risk). As such, fish are likely not at toxicological risk from DN operations.

The HQ for mean nitrate surface water concentration is more representative of chronic exposure to benthic invertebrates than that based on a maximum nitrate water concentration because nitrate concentrations are not expected to remain at these high concentrations in the environment. As such, benthic invertebrates may not be at risk to nitrate exposure via water exposure on a long term basis.

Maximum sediment concentrations for Lake Ontario exceeded the sediment benchmark for copper for benthic invertebrates. The mean sediment concentrations for Lake Ontario did not exceed the sediment benchmarks. Although, a few benthic invertebrates may be exposed to the maximum copper in sediment, the benthic community as a whole is not expected to be affected.

The HQ target of 1 was exceeded for the Bufflehead when exposed to the maximum, but not mean concentrations of aluminum in water and sediment. The Bufflehead is more likely to be exposed to mean concentrations in the long-term because it is unlikely that the Bufflehead will spend most of its time at the DN diffuser.

There were no toxicological data to determine nitrate benchmarks for birds, so health risks to birds due to nitrate exposures could not be ruled out. Based on the results of the 2016 Effluent Characterization Study (EcoMetrix, 2016), and the storm water studies of 2010 and 2011, however, station effluent and storm water are not significant contributors of nitrate to Lake Ontario, and as such, any health risks to birds due to nitrate exposure are not expected to be due to DN.

Polygon AB

An aquatic and terrestrial assessment of VECs located in Polygon AB (Coots Pond) was performed.

The results of the aquatic assessment in Coots Pond showed exceedances of the HQ target of 1 for:

- aluminum for aquatic plants, benthic invertebrates, bufflehead, mallard, and muskrat based on maximum and mean aluminum concentrations in water and sediment;
- copper, manganese (maximum only), phosphorus, and vanadium for benthic invertebrates based on maximum and mean concentrations in sediment;
- iron for benthic invertebrates based on maximum and mean concentrations in water; and
- ammonia for fish and turtle/frog based on maximum and mean concentrations in water.

Although potential risks were identified to aquatic and riparian receptors at Coots Pond from a number of COPCs, the source of these COPCs in Coots Pond is not the result of emissions from the DN site, but likely from construction debris placed in the landfill and subsequent stormwater runoff since the pond is designed to be a settling pond for stormwater runoff. Based on field studies conducted during the Darlington NND EA and subsequent biodiversity studies, Coots Pond has provided and continues to provide valuable habitat and breeding areas for fish (Northern Redbelly Dace), amphibians, birds, and mammals.

The results of the terrestrial assessment in Polygon AB showed exceedances of the HQ target of 1 for boron (hot water soluble, HWS) for terrestrial plants exposed to maximum boron (HWS) soil concentrations, but not for plants exposed to mean boron (HWS) soil concentrations. This suggests that soils on site that exceed the boron (HWS) maximum are localized on site, and do not represent deposition from atmospheric sources. Although individual plants may be affected, the plant population should not be affected.

Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium, strontium, and lead. There were no data to determine strontium benchmarks for birds. Strontium competes with calcium but it does not have a toxic effect on bone in chicks. A study (cited in Skoryna, 1981) found that there were no deleterious effects on chicks until very high doses were given. This dose is reported to be much higher than the benchmark value used to assess strontium effects on mammals. If the benchmark value for birds were set to the mammal benchmark, which could be interpreted as a NOAEL, there would be no exceedances.

Polygon C

Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium, strontium, and tin. No risks were identified for terrestrial biota for polygon C.

There were no data to determine strontium benchmarks for birds. As discussed above, when strontium benchmark values for birds are conservatively set to strontium benchmarks for mammals, there are no exceedances for polygon C.

There were no data to determine tin benchmarks for soil invertebrates. As such, there are uncertainties associated with the effects assessment for soil invertebrates exposed to tin concentrations in soil. However, it is unlikely that there would be adverse effects to soil invertebrates due to tin, because the maximum tin soil concentration in Polygon C is 15 mg/kg dw, well below the derived sediment effects concentration of 130 mg/kg dw (used as a surrogate for soil), as discussed in detail in Section 4.4.2.2.3..

Polygon D

An aquatic and terrestrial assessment of VECs located in Polygon D (Treefrog Pond) was performed.

The results of the aquatic assessment in Treefrog Pond showed exceedances of the HQ target of 1 for:

- boron for turtle and frog based on the maximum water concentration but not the mean water concentration; and
- iron for turtle, frog, and aquatic plants based on the maximum water concentration but not the mean water concentration.

Overall, turtles and frogs move around; therefore, exposure to mean concentrations is more representative of exposure than the maximum concentrations. Adverse effects to turtles and frogs in Treefrog Pond are not expected.

The results of the terrestrial assessment in Polygon D showed that where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium, strontium, and tin. No risks were identified for terrestrial biota for polygon D.

There were no data to determine strontium benchmarks for birds. As discussed above and based on the study cited in Skoryna (1981) when the benchmark value for birds is set to the mammal benchmark, there are no exceedances for Polygon D.

There were no data to determine tin benchmarks for soil invertebrates. As such, there are uncertainties associated with the effects assessment for soil invertebrates exposed to tin concentrations in soil. However it is unlikely that there would be adverse effects on soil invertebrates due to tin, because the maximum tin soil concentration in Polygon D is 11 mg/kg dw, well below the derived sediment effects concentration of 130 mg/kg dw (used as a surrogate for soil).

Polygon E

Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium and strontium. No risks were identified for terrestrial biota for polygon E.

There were no data to determine strontium benchmarks for birds. As discussed above, when the strontium benchmark value for birds is set to the mammal benchmark, there are no exceedances for Polygon E.

Radiological EcoRA

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 assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in the CSA N288.6-12 standard (CSA 2012).

Polygons AB, C, D, E, and Lake Ontario

There were no exceedances of the radiation dose benchmarks for aquatic and terrestrial receptors located in polygons AB, C, D, E, and nearshore Lake Ontario.

Although the radiation dose to all receptors located in Coots Pond (Polygon AB) was below the radiation dose benchmarks for aquatic and terrestrial receptors, there is uncertainty regarding the contribution of DN emissions to the tritium concentration measured in Coots Pond. Although Coots Pond receives runoff from the DN landfill it does not receive effluent from the DN site, other than through atmospheric deposition. The maximum tritium concentration measured in Coots Pond to support the 2009 NND EA was 78 Bq/L compared to 7.5 Bq/L in Lake Ontario in the vicinity of DN. Lake Ontario receives tritium emissions from DN, but has a much lower tritium concentration than Coots Pond.

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The maximum dose rate to any ecological VEC residing in close proximity (5 m) to the DWMF could be up to 0.024 mGy/d, lower than the 2.4 mGy/d radiation benchmark for terrestrial biota. The dose also remains below the radiation benchmark if the maximum dose from the DWMF is combined with the dose to ecological VECs from being exposed to radionuclides through other existing DN operations.

Thermal Effects

An assessment of thermal effects from the warm cooling water discharged by DN was conducted in 2011 and 2012 by Golder (2012b) at 31 locations in and around the discharge, and at reference (ambient) locations. These data indicate that a ΔT of 3^{o}C is a rare occurrence within the mixing zone, and never occurs outside this zone.

The Golder (2012b) assessment of thermal effects focused on the round whitefish because its sensitive embryonic life stage is expected to be present in the diffuser area from January through March. Eggs are typically deposited sometime in December, at water depths of 5-10m, and hatch in late March or early April. After hatch, the larvae move inshore to feed over the summer, and then move offshore in the fall. Golder cited an optimal temperature range of 1^{o}C to 5^{o}C for round whitefish embryos (Wismer and Christie, 1987) and a continuous ΔT of 3.5^{o}C or a periodic (6h/day) ΔT of 5^{o}C (Griffiths, 1980) as being consistent with adequate embryonic survival.

Since the studies by Griffiths used an unrealistic temperature regime (base temperature for 16 h/day followed by an abrupt shift to the increased temperature for 8h/day) and had relatively poor survival even at ambient temperature (88%), the CANDU Owners Group (COG) funded new studies of round whitefish embryo survival using a naturally varying base temperature. In these studies (Patrick et al., 2014), survival was 99% under the ambient temperature condition. The COG study found that a reduction to 90% survival required a temperature increase of 3.7ºC above ambient. The ΔT values around the DN diffuser are well below this level.

Round whitefish survival for any sequence of temperatures measured over the embryonic period can be predicted. The predicted survival over the winter of 2011-2012 was greater than 95%.

Impingement/Entrainment

Fish impingement sampling was conducted between May 2010 and April 2011 (SENES, 2011b). Thirteen fish species were taken at DN, with alewife and round goby representing 97% of the counts. The estimated annual total was 274,931 fish impinged. By fish biomass, alewife and round goby represented 97% of the biomass taken. The estimated annual total was 2,362 kg of fish biomass.

Studies of fish egg and larval entrainment at DN were conducted in 2004 (June – August) and 2006 (March – September), and April and July 2010. As a follow-up program to the environmental assessment for DN refurbishment and continued operation, more intensive studies of fish (eggs and larvae) and macro benthic invertebrate entrainment are being completed in 2015/2016 (OPG, 2015d) and will be reported in a separate report.

Summary and Recommendations

Based on the results of the ERA some recommendations have been proposed for the monitoring programs.

1. Lake water samples should be collected along and at the outlet of the DN diffuser as part of a supplementary study, analyzed using a lower detection limit for hydrazine to help reduce the uncertainty surrounding human exposure to hydrazine through drinking water and fish ingestion.

2. Filtered and unfiltered aluminum effluent samples in the CCW should be collected as part of a supplementary study to clarify risks to ecological receptors in Lake Ontario.

Overall, the DN site is operating in a manner that is protective of human and ecological receptors residing in the surrounding area.

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1.0 INTRODUCTION

1.1 Background

The *Nuclear Safety and Control Act* (NSCA) mandates the Canadian Nuclear Safety Commission (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 NSCA, and in the CNSC (2001) Regulatory Policy on Protection of the Environment. 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".

The Canadian Standards Association (CSA) has completed its N288.6 standard on environmental risk assessment (ERA) for Class I nuclear facilities (CSA, 2012). The standard calls for both ecological risk assessment (EcoRA) and human health risk assessment (HHRA), for both radiological and non-radiological contaminants and physical stressors. The CSA has completed its N288.4 (2010) and N288.5 (2011) standards on environmental monitoring programs (EMPs) and effluent monitoring programs. These standards recommend that effluent and environmental programs are designed, in part, to address risk issues identified by the ERA. These programs can also inform the ERA by providing information on effluent concentrations and loadings, and by providing environmental data to assist in model calibration and validation.

1.1.1 Summary of Previous Environmental Assessments, Environmental Risk Assessments, and Follow-up Monitoring Programs

ESG International Inc. prepared an Ecological Effects Review (EER) for the DN site in 2000 and 2001. This report considered potential ecological effects associated with construction and operation of the DN site. Existing monitoring data, atmospheric dispersion modeling, and surface water dilution calculations were used in the report to develop a conclusion that no risks to biota were expected due to chemical or radiological exposure (SENES, 2009a).

OPG conducted an Environmental Assessment (EA) in 2002 and 2003 for the Darlington Used Fuel Dry Storage (DUFDS), which was renamed the Darlington Waste Management Facility (DWMF) when it was built. The EA examined site preparation, construction and operation activities for three proposed fuel bundle storage buildings and a processing building. The Follow-Up Monitoring Program (FUMP) for this EA included four recommendations, which included the tasks presented in Table 1.1 (OPG, 2011a).

Table 1-1: DUFDS EA FUMP Recommendations and Status (OPG, 2011a)

Environmental Component	Brief Description	Status
Terrestrial	If DUFDS Facility is located at Site B, and construction is planned between April and July, conduct a walkover survey by a qualified biologist to recommend mitigative actions should active bird nests be identified.	Two breeding bird surveys were undertaken in 2004 and 2005. The biologist recommended clearing the site between August and March and undertaking weekly surveys to minimize disturbances to active nests. The recommendations were followed.
Geology and Hydrogeology	Develop and execute a soil sampling and analysis program for areas where potentially contaminated soils will be disturbed or redistributed by construction (e.g. roadways sited to access the DUFDS Facility). Develop and execute a soil sampling and analysis program for the drainage ditch east of the parking lot.	A soil sampling program was carried out in 2005. All results were less than MOECC Site Condition Standards for non-potable groundwater conditions.
Socio-economic Conditions	Develop a program to monitor public attitudes and the effectiveness of mitigation. Emphasize ongoing communication and consultation with members of the public. Public attitude research should provide results directly comparable to those from the 2002 survey. Research to be undertaken one year after Proclamation of Bill C-27 (Nov 2003), and one year prior to commissioning of the first storage building at the DUFDS Facility. Surveys of users of the sports fields and the Waterfront Trail on the DNGS property should be undertaken to identify any changes attributable to the DUFDS project in the use and enjoyment of these recreational amenities.	One public attitude research survey was completed in 2009. OPG and CNSC agreed that no further survey work was necessary.
Aboriginal Interests	Inclusion of six First Nation communities and Metis Nation of Ontario on the Darlington Nuclear Community Stakeholder list (Mississaugas of Scugog Island First Nation, Ojibways of Hiawatha First Nation, Alderville First Nation, Curve Lake First Nation, Chippewas of Georgina Island First Nation, Mississaugas of the New Credit First Nation, and the Metis of Ontario).	Complete.

In 2005, SENES prepared a risk assessment for the drainage ditch system south of the Bowmanville switching yard at the DN site. This risk assessment considered both human and ecological health. The approach was consistent with risk assessment provisions in the original (2004) version of Ontario's Record of Site Condition (RSC) regulation, Ontario Regulation 153/04, which was amended in 2011. The risk assessment concluded that potential risks may have been expected for warblers and earthworms in the drainage ditch system, but subsequent field investigations indicated that the ecosystem in the area was fully functioning and healthy (SENES, 2009a).

As part of the EA conducted for the New Nuclear – Darlington (NND) project (SENES, 2009a), an ecological risk assessment (EcoRA) for the project was undertaken. The assessment of potential effects due to the project was undertaken in two steps: the first was a characterization of baseline concentrations of chemical contaminants and radionuclides in the environment around Darlington Nuclear (DN), whereas the second was a determination of potential incremental exposures due to the construction and operation of the NND project. Overall, this EcoRA followed a typical table of contents for an EcoRA, including Problem Formulation, Exposure Assessment, Hazard Assessment, and Risk Characterization. The EcoRA concluded that radionuclide doses to ecological receptors were all below reference dose rates, and that no ecological health risks would be expected in the existing environment. In addition, no adverse effects were predicted for ecological receptors due to radionuclide and chemical emissions from the operating NND project.

The NND EA also included a Human Health Technical Support Document (TSD), part of which was an HHRA for each of conventional contaminants and radiological contaminants. The former HHRA concluded that although short-term exceedances of inhalation health benchmarks were identified for nearby human receptors during the proposed construction phase, no increase in health effects due to the NND project were predicted for the Site. The latter HHRA concluded that no residual effects from radiation doses to members of the public were anticipated as a result of the NND project.

In 2011, SENES conducted an EA for the Darlington Nuclear Generating Station Refurbishment and Continued Operation (RCO) project. An EcoRA formed part of this EA. This EcoRA referenced the 2009 EcoRA as a source of data, but used a study area consistent with Refurbishment and Continued Operation. This EcoRA also followed a typical table of contents for an EcoRA, including Problem Formulation, Exposure Assessment, Hazard Assessment, and Risk Characterization. The EcoRA determined that estimated radionuclide doses were below reference dose rates for ecological receptors, and that conventional Contaminant of Potential Concern (COPC) exposure would not result in any adverse effects to ecological receptors, as a result of Refurbishment and Continued Operation.

The 2011 EA also included a Human Health TSD, in which the 2009 HHRA for conventional contaminants was summarized for reference. No additional human health conclusions due to chemical contaminants or radionuclides were drawn in the 2011 Human Health TSD.

The EA for Refurbishment and Continued Operations concluded in March 2013, when the Record of Proceedings (ROP), including *Reasons for Decision* (CNSC, 2013) was published. The ROP (CNSC, 2013) reiterated the requirement for a follow-up program that had initially been raised by the CNSC and Department of Fisheries and Oceans Canada (DFO) in their EA screening report (CNSC/DFO, 2012). Moreover, the ROP (CNSC, 2013) required that the basis for the follow-up program be as described in the screening report (CNSC/DFO, 2012), which included broad spectrum characterization of DN liquid effluents to confirm EA predictions of no residual adverse effects on surface water. The follow-up program comprised the elements (OPG, 2013c) summarized in Table 1.2.

Table 1-2: RCO EA FUMP Recommendations and Status

Environmental Component	Brief Description	Timeline/Status
Surface Water	1. *Review the DNGS effluent monitoring program relative to that of applicable CSA standards and subsequent confirmation through applicable ERA results to verify EA predictions related to liquid effluents. At a minimum, this shall include:* a. *broad spectrum characterization of effluents (parameters beyond those currently contained in license/permits).* b. *screening of the parameters for inclusion in the site's operational ecological risk assessment (ERA).* c. *review of the adequacy of existing effluent and environmental monitoring programs based on the site's ERA.*	Completed as part of this project. See discussion below.
Surface Water	2. *Conduct a Stormwater Control Study for areas subject to refurbishment activities within the Protected Area during the Refurbishment of the first unit for two representative storm events (spring and summer storm) to confirm that the Project has not adversely affected storm water quality. Analyze the stormwater based on historical findings, including, but not limited to, Municipal/Industrial Strategy for Abatement (MISA) parameters such as total suspended solids, total phosphorus, aluminum, iron, oil and grease, ammonia and ammonium and biological oxygen demand.*	One season of monitoring during the Refurbishment phase. Determine need for additional monitoring based on results.
Aquatic Habitat / Biota	3. *Monitor data on cooling water discharge temperature and plume characteristics and interpret in relation to fish habitat and susceptibility of Valued Ecosystem Component (VEC) species. Compare temperature criteria and other assessment metrics based on Griffiths (1980) with the results of the CANDU Owners Group study examining thermal effects to round whitefish eggs.*	Two monitoring periods: One winter during Refurbishment Phase; One winter following restart of reactors
Aquatic Habitat / Biota	4. *Monitor entrainment and impingement mortality associated with DNGS intake.*	In progress

Environmental Component	Brief Description	Timeline/Status
Malfunctions and Accidents	5. *Design changes related to safety improvement opportunities (SIOs) will reduce accident frequency achievable. The assignment of probabilities to represent the SIO design changes is judged to be sufficient to approximate the reduction in accident frequency achievable. Per the requirements of CNSC S–294, the station PRA will be updated to reflect the detailed design and as-installed configuration prior to bringing refurbished units back on-line.*	Prior to bringing refurbished units back on-line with updates provided to CNSC as part of this process.
Effects of the Environment on the Project	6. *Undertake a full review of available documentation regarding fill materials and their liquefaction potential in the Protected Area. Should sufficient verification not be realized for the prediction of low liquefaction potential, undertake a liquefaction assessment of fill materials as appropriate.* (OPG, 2013c)	Prior to bringing refurbished units back on-line.

An effluent sampling plan, the Darlington Nuclear Refurbishment and Continued Operation Environmental Assessment Follow-up Program – Effluent Characterization Sampling Program, was designed to be consistent with the framework provided in OPG (2013a). The program included the effluent streams to be sampled, the parameters to be measured and the sampling frequencies. The program provided sufficient detail to guide the implementation of the sampled collections and was consistent with both the needs and requirements for liquid effluent characterization as identified in the CNSC/DFO (2012) screening report and the requirements and suggested format for an effluent sampling program as described by the CSA (2011) N288.5 standard on effluent monitoring for Class 1 nuclear facilities and uranium mines and mills. The program was submitted in May 2015. It was reviewed and accepted by CNSC prior to implementation of the program starting in March 2016. The data resulting from this sampling plan have been incorporated into this ERA (see Section 3.1.2.2.2.3).

1.2 Goals, Objectives, and Scope

The overall goals of this ERA are:

- To establish an updated baseline condition for the DN Site.
- To update the ERA in general accordance with the CSA N288.6-12 Standard.
- To provide focus for the environmental monitoring program on relevant contaminants of potential concern (COPCs), media, and ecological and human receptors.

The specific objectives of this ERA, consistent with CSA N288.6-12 are:

- To evaluate the risk to relevant human and ecological receptors resulting from exposure to contaminants and stressors related to the DN site and its activities.
- To recommend potential further monitoring or assessment as needed based on the results of the ERA.

The scope of the ERA encompasses normal operations at DN during the operations and refurbishment phases of the facility. It does not include decommissioning activities and does not address acute or high-level exposures resulting from accidents. The scope looks at the potential effects of releases from the facility on the human and ecological environment, as well as physical stressors. The ERA focuses on the five-year period from 2011 to 2015, but incorporates other years of data when necessary.

Spatial boundaries define the geographical extent(s) over which likely or potential environmental effects will be considered. The spatial scale for humans includes identified human receptors (potential critical groups) within about 10 km of the DN site, as shown in **Error! Reference source not found.**. This study area also includes a portion of Lake Ontario abutting the property and used by those communities for activities such as recreation and community water supply and waste water discharge.

The spatial scale for ecological receptors includes receptors on-site and within the immediate site boundary and the near-field receiving waters, known as the site study area (SSA). The SSA for the EcoRA is presented in Figure 4-1.

1.3 Changes to Facility since Last ERA

No existing ERA has considered the DN site in its entirety. The last ERA conducted for DN was published by SENES in 2011 as part of the EA for RCO. The risk assessment work conducted for this EA, however, was limited to the south-west corner of the DN site. The NND EA assessed a larger site area since it considered a proposed location for facility expansion, but the NND EA also did not consider certain areas of the DN site, such as the portion of the site south of the rail line and west of the proposed new build area. The site boundaries for this updated ERA encompass the entirety of the DN site.

The summary of changes to the facility has focused on the 2011 to 2015 period, but some information prior to 2011 was used when looking at the larger DN site area. More specifically, Table 1-3 **Error! Reference source not found.** presents the changes since the last ERA, consistent with clause 11.1 of CSA N288.6-12.

Table 1-3: Summary of Results of Periodic Review of the ERA

Periodic Review Element	Results from the 2011 to 2015 Period
Changes to site ecology or surrounding land use	Site ecology and surrounding land use focusing on the 2011 to 2015 period where available is detailed in Section 2.3. No major changes have occurred since the last ERA.
Changes to the physical facility or facility processes	A description of the physical facility and processes is provided in Section 2.2. DN Refurbishment activities that have been completed including infrastructure upgrades, such as new road works, parking lots, project offices, work annexes, and waste management facilities (OPG, 2016a). See Section 2.2.1 for more details on the Refurbishment activities.
New environmental monitoring data	The majority of the available environmental monitoring data were used in the ERAs forming parts of the 2009 and 2011 EAs. However, the results from the 2016 Effluent Characterization Study have been included in the ERA. See Section 3.1.2.2 and its subsections for further details. 2011-2015 Environmental Monitoring Program data are available. The above data are appropriate for use in the ERA.

Periodic Review Element	Results from the 2011 to 2015 Period
New or previously unrecognized environmental issues	No new or previously unrecognized environmental issues have been identified. A review of radiological emissions data from 2011 to 2015 is presented in Section 3.1.2.6. Non-radiological emissions data are available from the 2016 effluent characterization study.
Scientific advances	CSA N288.6-12 was published in 2012. CSA N288.1-14 was published in 2014, however it was not yet implemented at the time this report was prepared.
Changes in regulatory requirements	Ontario Regulation (O. Reg) 153/04 (Records of Site Condition-Part XV.1 of the Act), the Ontario regulation for obtaining a record of site condition was amended in 2011. Although the soil and groundwater standards from O.Reg. 153/04 are not regulatory requirements for OPG, these updated standards are useful guidelines that can be used for identification of COPCs to be monitored.

1.3.1 Spills

No Category A or Category B spills occurred at DN during the period from 2011 to 2015. Five Category C spills occurred during this period, as follows:

1. *August 19, 2011: An operator overfilled the boiler chemical feed system amine tank and a maximum of 10 litres of 2% NH_3 solution was discharged to the cooling water discharge duct.*
2. *April 2, 2013: Approximately 10 litres of oil was discharged from the Unit 4 generator seal oil system to Lake Ontario. The system was being placed in service when rapid pressurization of the air space in the seal oil piping caused a heat exchanger tube sheet to rupture. Oil then leaked to service water piping connected to the condenser cooling water discharge duct.*
3. *October 5, 2013: An estimated 6,000 litres of oil was discharged to Lake Ontario from early August to early October due to a leak in a Unit 1 generator seal oil heat exchanger. The oil leaked from the heat exchanger to service water piping that discharges to the condenser cooling water discharge duct.*
4. *May 7, 2014: A chiller at the Tritium Removal Facility released 128 kilograms of refrigerant to the air.*
5. *August 6, 2014: An estimated 1,850 litres of oil was released from a Unit 3 generator seal oil heat exchanger to Lake Ontario from July to August. Oil leaked*

from the heat exchanger tubes to service water piping that discharges to the condenser cooling water discharge duct. (C. Cheng, pers. comm., March 30, 2016)

1.4 Organization of Report

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

- Section 2.0: Site Description
- Section 3.0: Human Health Risk Assessment
- Section 4.0: Ecological Risk Assessment
- Section 5.0: Conclusions and Recommendations
- Section 6.0: References

1.5 Quality Assurance/Quality Control

The ERA makes extensive use of effluent and environmental monitoring data. These data are derived from chemical and radiochemical analyses of samples collected from effluent streams and environmental media around the DN site.

The 2016 samples for the effluent characterization study were collected by the station chemistry laboratory, and analyzed by Maxxam Analytics which conforms to the quality assurance requirements of International Organization for Standardization (ISO) 17025.

The environmental data provided by OPG were collected by qualified staff and analyzed by qualified performing laboratories, such as the station chemistry laboratory and the Whitby Health Physics Laboratory. The EMP has its own quality assurance (QA) program that encompasses activities such as sample collection, laboratory analysis, laboratory quality control, and external laboratory comparison (OPG, 2007). The station chemistry laboratory also has its own QA program and analyses sent externally utilize accredited laboratories. Other environmental samples such as water, sediment, soil, stormwater, and noise were collected as part of the baseline environmental sampling programs for the NND and RCO EAs. These sampling programs also had their own associated QA programs.

Throughout the planning and preparation of the ERA, 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. Comments have been dispositioned and addressed as appropriate by report revisions. The review process has been documented through a paper trail of review comments and dispositions.

2.0 SITE DESCRIPTION

2.1 Site History

The DN site is located in the Province of Ontario, in the Regional Municipality of Durham, in the Municipality of Clarington, in the township of Darlington, on the north shore of Lake Ontario at Raby Head. The DN site is about 5 km southwest of the community of Bowmanville and about 10 km east southeast of the City of Oshawa. The site location and vicinity are shown in Figure 2-1**Error! Reference source not found.**.

The DN Generating Station is located on the DN site and is comprised of four reactor units, owned and operated by OPG. The reactors are CANada Deuterium Uranium (CANDU) pressurized heavy water generating reactors, commissioned according to the schedule presented in Table 2-1**Error! Reference source not found.**. The DN Generating Station has a total output of 3,524 MWe, providing about 20% of Ontario's electricity needs. Since they have been placed in service, all DN units have operated safely. In 2015, DN produced 23.3 terawatt hours (TWh) of electricity. The production performance of DN stations was 75.8% of its rated capacity (OPG, 2016b).

DN also operates the Tritium Removal Facility (TRF) since 1988, where tritium is extracted from tritiated heavy water, and the Darlington Waste Management Facility (DWMF) for used fuel dry storage and processing.

Table 2-1: In-Service Dates for Darlington Units 1 to 4

Unit #	Net Electrical Output (MWe)	In-Service Date
Unit 1	881	November 11, 1992
Unit 2	881	October 9, 1990
Unit 3	881	February 14, 1993
Unit 4	881	June 14, 1993

The DWMF is located within its own protected area east of the DN Site. DWMF received its first operating licence in November 2007, and began operating in 2008 to provide storage for approximately 500 dry storage containers (DSCs) (or 192,000 used fuel bundles) in DSC Storage Building #1.

Figure 2-1: DN Site Location and Vicinity

2.2 Engineered Site Facilities

2.2.1 Site Overview

The DN site is comprised of a four-unit CANDU station, a TRF, and a DWMF, as discussed in Section 2.1. The DN site also includes a Visitor Information Centre, a Hydro One switching station (leased to Hydro One) connecting DN Generating Station to the 500 kV east-west transmission corridor, security facilities and technical and administrative support facilities. The DN site also accommodates recreational features outside the Protected Area that are available to the public, including soccer fields in the northwest corner and a 7.5-km section of the Waterfront Trail which traverses the DN site north of the rail line.

An overview of the facilities on the DN site is presented in Figure 2-2**Error! Reference source not found.** and identifies the major facilities and structures on the DN site. During the past five years DN Refurbishment activities have been completed including infrastructure upgrades, such as new road works, parking lots, project offices, work annexes, and waste management facilities (OPG, 2016a). The principal DN buildings and a brief discussion of their purpose are described below. The majority of the description has been obtained from the DN Generating Station Refurbishment Project Environment Impact Statement (EIS) (SENES and MMM, 2011) with updated information from refurbishment activities where relevant (OPG, 2016a).

- Four Reactor Buildings (U1 to U4)
- Four Reactor Auxiliary Bays – adjacent to Reactor Buildings
- Two Fuelling Facilities Auxiliary Areas – one at each end of the station, including Irradiated Fuel Bays
- Powerhouse – housing for Turbine-Generator sets, Turbine Auxiliary Bays and a Central Service Area
- Vacuum Building – connected by a pressure relief duct to all four reactor units
- Four Standby Generators and associated fuel storage tanks
- Emergency Electrical Power and Water Supply Building including an Emergency Water Supply pumphouse
- Two Emergency Electrical Power Generator Sets and associated fuel management (with a third being installed to support safety improvements)
- Four Pumphouses for combined cooling and service water
- Administration and Engineering/Operations Support Building
- Water Treatment Plant located between pumphouses P2 & P3;
- Hazardous Material Storage Facility
- Flammable Materials Storage Building
- Gas Cylinder Storage Building
- Fire Hall
- Emergency Response Team Facility
- Security Buildings
- Switching Station

- Tritium Removal Facility (TRF) and new Heavy Water Management Building
- Darlington Waste Management Facility (DWMF)
- Refurbishment Project Office
- Auxiliary Heating Steam Facility
- Retube Waste Processing Building
- Retube Waste Storage Building
- Retube and Feeder Replacement Island Support Annex

A Vehicle Screening Facility and a Heavy Water D_2O Storage and Drum Handling facility are expected to be in service in 2017. The systems that make up DN are housed within the buildings, facilities and structures listed above. A description of the major systems and components of the station are provided below.

Four Reactor Buildings (U1 to U4) and Reactor Auxiliary Bays

The DN reactors are housed in four rectangular, reinforced concrete Reactor Buildings that serve as a support and enclosure for the reactors and some of their associated equipment. The Reactor Vault is that portion of the Reactor Building which forms part of the containment envelope. The vault contains a Reactor Core consisting of the Reactor Assembly (a cylindrical reactor vessel with horizontal fuel channel assemblies) and a number of Reactivity Control Devices. A Reactor Auxiliary Bay containing reactor auxiliaries and secondary circuits of low temperature, low pressure and generally low radioactivity levels surrounds each Reactor Vault.

The containment envelope includes the four Reactor Vaults, a fueling duct connected to each Vault and running the entire length of the station, a pressure relief duct connecting the fueling duct to the Vacuum Building, and a fuel handling and service area at each end of the fueling duct.

Reactor Process Systems

The Reactor Process Systems comprise a number of auxiliary systems associated with reactor cooling and heat transport, moderator and heavy water management systems. The principal objective for the Primary Heat Transport System (PHTS) is to provide reliable cooling of the reactor. The PHTS circulates pressurized heavy water through the reactor fuel channels to remove the heat produced there. This heat is transferred to light water in the Steam Generators located inside the Reactor Building. The Moderator fluid, also heavy water, is circulated through the reactor vessel, entirely separate from the PHTS. The Heavy Water Management Systems includes heavy water supply, collection and transfer, cleanup and upgrading; and vapour recovery and resin handling systems. The TRF includes processes to remove tritium from the heavy water, and store the tritium that results. The new Heavy Water Management Building will provide enough heavy water storage for ongoing operation of the TRF and DN station.

Special Safety and Safety Related Systems

A multiple barrier system (based on the "defence-in-depth" concept) has been designed and built into the reactors and their support systems in order to prevent or control releases of radioactivity to the environment in the event of a malfunction or accident. DN reactors have four independent safety systems, including two emergency shutdown systems (SDS1 and SDS2), the Emergency Coolant Injection System, and the negative pressure Containment System. In addition, a number of other plant systems have important safety-related functions, including the Shutdown Cooling System, Emergency Service Water, and the Emergency Power System. Permanent fire water pumps have been installed to supplement the Emergency Service Water.

New and Used Fuel Handling

Each DN reactor includes 480 fuel channels, with each channel containing 13 fuel bundles (for a total of 6,240 fuel bundles per reactor). DN uses approximately 23,000 fuel bundles per year depending on the level and extent of station operation. New fuel is delivered to the station in special containers and stored within the Fuelling Facilities Auxiliary Areas (FFAAs), one of which is located at each end of the station. The DN reactors are refuelled on-power by remotely controlled fuelling machines which remove used (irradiated) fuel as new fuel is inserted into the reactor fuel channels.

The used fuel removed from the reactor is transferred by the fuelling machines to one of two Irradiated Fuel Bays located in the FFAAs. The used fuel is stored in these in-station bays for at least 10 years before being loaded into DSCs and transferred to the DWMF.

Secondary Heat Transport and Turbine-Generator Systems

The function of the Secondary Heat Transport System (SHTS) is to transport the steam produced in the secondary side of the Steam Generators (using heat delivered by the PHTS) to the Turbine-Generator set, causing the turbine and the attached generator to rotate. After passing through the turbines, the steam is condensed back to liquid form (water) in the main condenser. The Turbine-Generator sets comprise the power generating equipment of the station. They are located in the Powerhouse, which includes four Turbine Halls, four Turbine Auxiliary Bays, and a Central Service Area.

Central Service Area

The Central Service Area serves the entire station and is divided into two parts, Nuclear and Conventional. The Nuclear area includes facilities for fuelling machine service, treatment and storage of heavy water, spent ion exchange resins and other active wastes. The Conventional area includes stores, laboratories, workshops, electrical and air conditioning equipment. The Main Control Room is located above the Nuclear part of the Central Service Area.

Station Water Systems

Excluding the heavy water and Domestic Water Systems, water for all other purposes is drawn from Lake Ontario through the intake tunnel and into the forebay, which is common to all four units, and from the forebay through separate pumphouses to the individual unit. The Condenser Cooling Water (CCW) System and the Service Water System are served by separate pumps. In addition, a separate pumphouse at the southwest end of the forebay supplies water to the Emergency Service Water System. The main water systems supporting DN operation include the following:

- CCW System, including intake and discharge structures;
- Service Water System (including Powerhouse Upper Level Service Water and Low-Pressure Service Water systems);
- Emergency Service Water System;
- Recirculated Cooling Water System (including Water Treatment Plant); and
- Domestic Water and Wastewater.

To support DN refurbishment and continued operation, the site water and sewer infrastructure have been upgraded and are now connected to the municipal system.

Electrical Power Systems

Power used internally at DN is supplied both from the reactor units themselves and from the electrical grid. Each unit has its own power distribution system which serves all loads directly associated with that unit. Station electrical loads, which are common to all units, are supplied from a common power distribution system. The electrical power system associated with DN includes the Main Transformers located adjacent to the Powerhouse through which the outputs from the generators are incorporated into the provincial 500 kV system (grid) via a Switching Station located immediately north of DN. Four Standby Generator sets provide back-up power in the event of loss of power from the grid and two independent generator sets (part of the Emergency Power System) provide emergency power to ensure safe shutdown of the plant if necessary. A third Emergency Power System generator is being installed as an element of ongoing system safety improvements at DN.

Site Services and Utilities

In addition to the station water systems described above, site services and utilities include systems for active ventilation, radioactive and non-radioactive liquid waste management, stormwater management, the on-site road network and parking lots, security facilities (including fencing), fire protection, building services (lighting, heating, ventilation and air conditioning), compressed air, industrial gas (i.e., hydrogen, CO_2, nitrogen, etc.), mechanical handling equipment, maintenance facilities and shops, and miscellaneous systems such as communication facilities.

Infrastructure improvements to support DN refurbishment include a new Auxiliary Heating Steam Facility, Refurbishment Project Office, Retube Feeder Replacement Island Support Annex, and Retube Waste Processing Building (Figure 2-3). The new Auxiliary Heating Steam Facility has been constructed to supply back-up heating steam to DN, and to support future containment and vacuum building outages. The Refurbishment Project Office is located on the west side of the DN station outside of the protected area and will be a central location for construction staff to enter and exit the site during refurbishment and outage activities. The Retube Feeder Replacement Island Support Annex will house the reactor components prior to installation in the reactor and will support DN maintenance activities. The new Retube Waste Processing Building is located on the east side of the DN station, next to Unit 4. It will provide volume reduction for removed reactor components during refurbishment, where it will be stored in retube waste containers and transferred to the Retube Waste Storage Building for storage.

Darlington Waste Management Facility

The DWMF consists of an amenities area, a DSC processing building and the first storage building (DSC Storage Building #1). This facility is intended to provide interim site storage for the used fuel bundles until a long term storage site for used fuel bundles is operational. The first storage building holds up to about 500 DSCs, equivalent to around 9 years of station operation (OPG, 2013a).

Lands south of DSC Storage Building #1 have been reserved for the future construction of used fuel DSC Storage Buildings #2 and #3. Construction of additional DSC storage buildings will be staged as additional storage space is required. When all three DSC storage buildings are constructed there will be storage capacity for up to 1,500 DSCs (or 576,000 used fuel bundles) (OPG, 2011b).

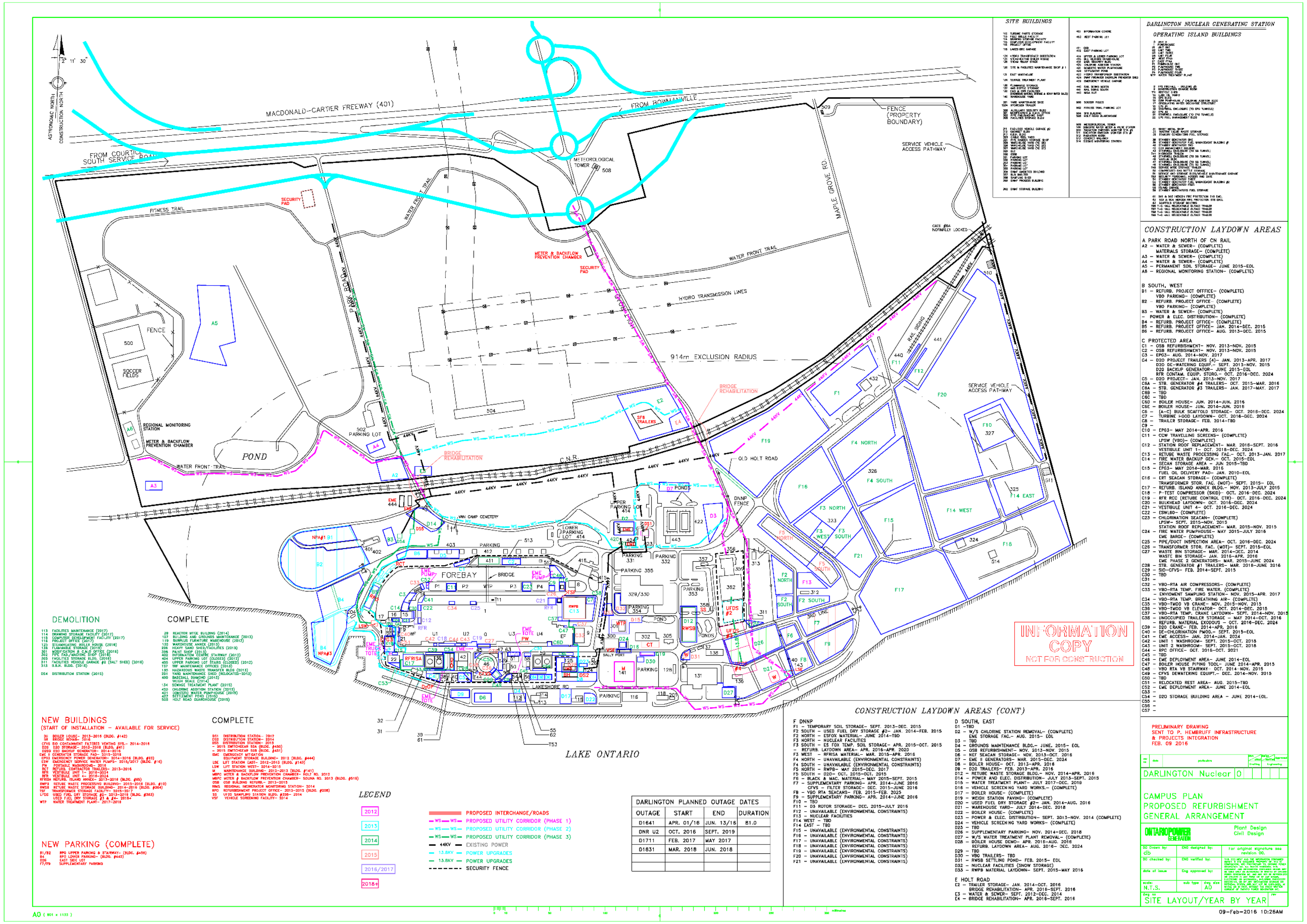
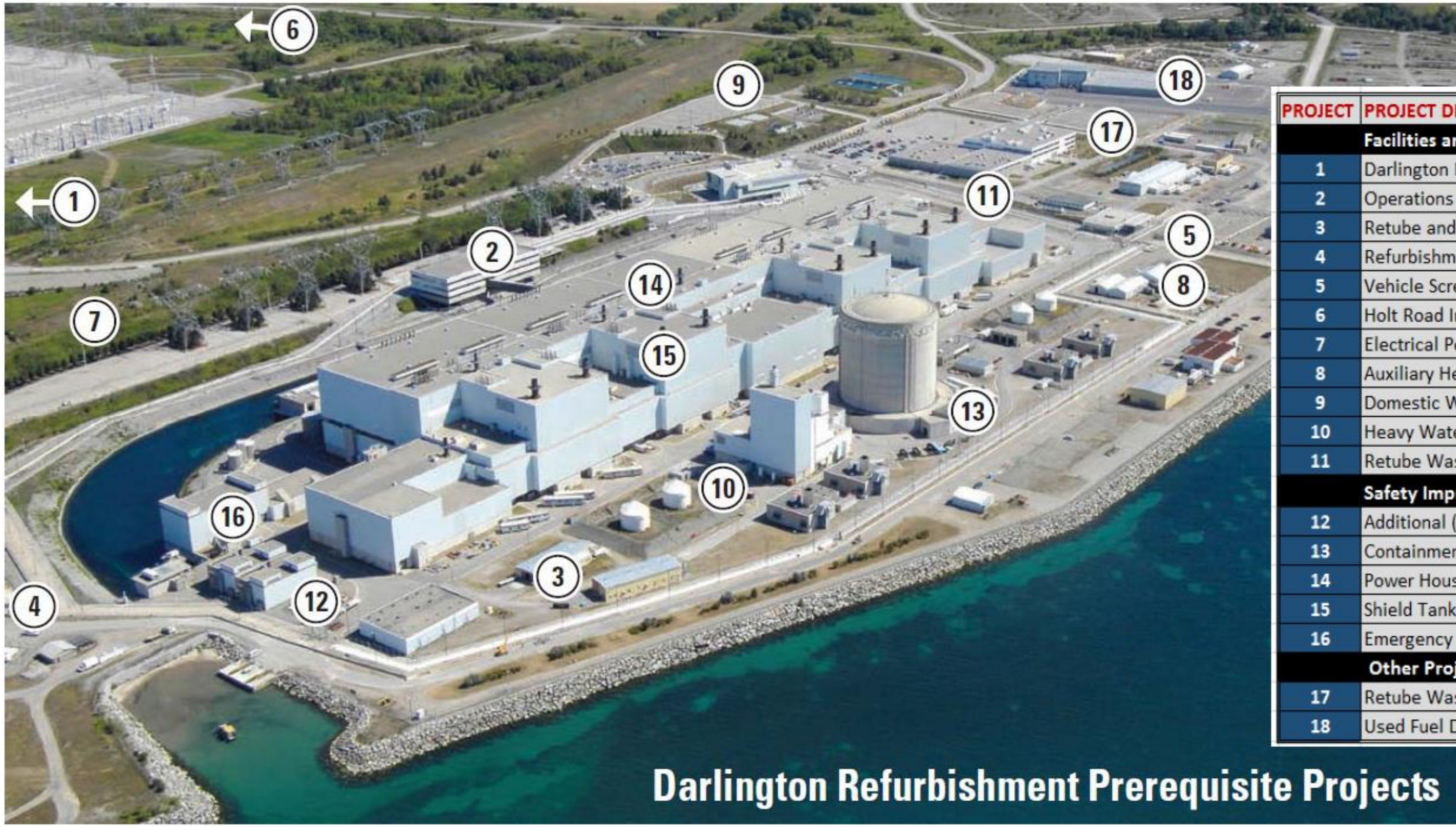


Figure 2-2: Darlington Nuclear Generating Station (OPG, 2016)



PROJECT	PROJECT DESCRIPTION
	Facilities and Infrastructure Projects
1	Darlington Energy Complex
2	Operations Support Building Refurbishment
3	Retube and Feeder Replacement Island Support Annex
4	Refurbishment Project Offce
5	Vehicle Screening Facility
6	Holt Road Interchange Improvements Site
7	Electrical Power Distribution
8	Auxiliary Heating System
9	Domestic Water and Sewer
10	Heavy Water (D2O) Storage and Drum Handling Facility
11	Retube Waste Processing Building
	Safety Improvement Opportunities
12	Additional (3rd) Emergency Power Generator
13	Containment Filtered Venting System
14	Power House Steam Venting System
15	Shield Tank Overpressure Protection
16	Emergency Service Water Projects
	Other Projects
17	Retube Waste Storage Building
18	Used Fuel Dry Storage

Figure 2-3: Darlington Refurbishment Prerequisite Projects

2.2.1.1 Site Drainage

Water on the DN site originates from the following systems:

- CCW System;
- Service Water Systems;
- Steam and Feedwater System;
- Water Treatment Plant (WTP);
- Radioactive Liquid Waste Management System (RLWMS);
- Inactive Drainage System;
- Sewage System; and
- Stormwater Management System.

All water released from DN is discharged into the CCW system – either via the intake forebay or directly into the CCW discharge duct. The only exception is effluent from the sewage system and stormwater which is discharged to Lake Ontario through storm sewers or drainage swales/creeks (Golder, 2011a).

Condenser Cooling Water

Cooling water is drawn into the station from Lake Ontario through an intake structure located on the bottom of the lake via a tunnel and forebay. The water is pumped through travelling screens to remove debris and weeds before entering the CCW System. Cooling water is discharged back into Lake Ontario via the CCW discharge duct. During the winter, warm discharge water is redirected into the intake to prevent the development of frazil ice that may plug the travelling screens

Service Water Systems

The service water systems include the Low Pressure Service Water (LPSW) Open System, the Powerhouse Upper Level Service Water, and the Recirculating Cooling Water System. Radioactive liquid waste from the Recirculating Cooling Water System drains to the active plant drainage system, and the other systems discharge back in the CCW discharge duct.

Steam and Feedwater System

The Steam and Feedwater System boils feedwater to produce steam for turbine operation. The primary source of liquid effluents from the Steam and Feedwater System is boiler/feedwater blowdown which is discharged directly to the CCW System. Boiler blowdown, which can be continuous or intermittent, is used to remove dissolved and suspended sediments and accumulated sludge from the system and aids in chemical control on the secondary side of the boiler. The blowdown from the four boilers at each unit is directed to a header, which then discharges from each unit to the CCW. Generally one to two hours of intermittent blowdown occurs on a station-wide basis daily and is most often related to start up or reduced power and process steam supply.

Water Treatment Plant

The WTP produces high-purity demineralized water by removing particulates and dissolved impurities from influent lake water. The demineralized water mainly supplies the make-up water for the Steam and Feedwater System of all four units at DN.

The demineralization system involves passing filtered water from the pretreatment step through an activated carbon filter (to remove chlorine), decarbonator, and a series of ion exchanger columns to produce demineralized water. The ion exchange columns are regenerated in-situ with sulphuric acid and sodium hydroxide.

The WTP Neutralization Sumps collect backwash water from regeneration of the ion exchanger columns. The backwash water is collected at the Neutralization Sumps and neutralized by addition of caustic or acid to ensure that pH is within administrative limits (6.5 to 9.0) prior to being released to the CCW. The two sumps (main and emergency) each have a volume of 1,585 m^3 and are pumped to the CCW at a rate of 81 L/s. During the zebra mussel chlorination season, the emergency sump is dedicated for use as spill containment for the chlorination equipment located in the WTP.

Radioactive Liquid Waste Management System (RLWMS)

The RLWMS also consists of a series of floor and equipment drains, as well as sumps, pumps and piping, which collects normally radioactive liquid waste (RLW), segregated according to the degree of radioactivity and chemical composition, and directs the waste to the receiving tanks of the RLWMS. Sources of the RLW include Reactor Building, the Reactor Auxiliary Bay, the Central Service Area, the FFAA, the chemical laboratory Health Physics sink, the Heavy Water Management Building, and the TRF Annex chemical laboratory and laundry. Tanks in the RLW are individually discharged to CCW in batch mode reactor. The RLWMS includes filters and ion exchange columns to purify the waste. After treatment the waste is sampled and chemically analyzed to ensure it meets radioactive and chemical limits prior to discharge. The treatment can also include the addition of sodium bicarbonate and calcium bicarbonate for hardness adjustment and potassium hydroxide for pH adjustment, if required. To prevent anaerobic conditions, all tanks are aerated, with the exception of TK1.

Radioactivity monitors on the discharge piping automatically stop discharge flow if the detected activity is above prescribed limits.

Inactive Drainage System

Building effluents from inactive areas in all four units, and from the Central Service Area, are collected, and combined in a common header prior to discharging to two lagoons (each approximately 4000 m^3) operated in series. Forced aeration occurs in the first lagoon to promote mixing and reaction between air and low levels of hydrazine. The effluent from the first lagoon overflows to the second lagoon, which allows sufficient retention time for settling. The lagoon water eventually discharges to the Forebay by a polyvinyl chloride (PVC) pipe, to be circulated with CCW and eventually discharged. The Building Effluent Treatment System was originally designed to include a treatment process for hydrazine through the addition of sodium hypochlorite followed by a dechlorination step using sodium bisulphate. Since this treatment system has not been needed as the lagoons are effective in managing hydrazine concentrations, the chemical addition tanks were emptied and removed from service.

Sewage System

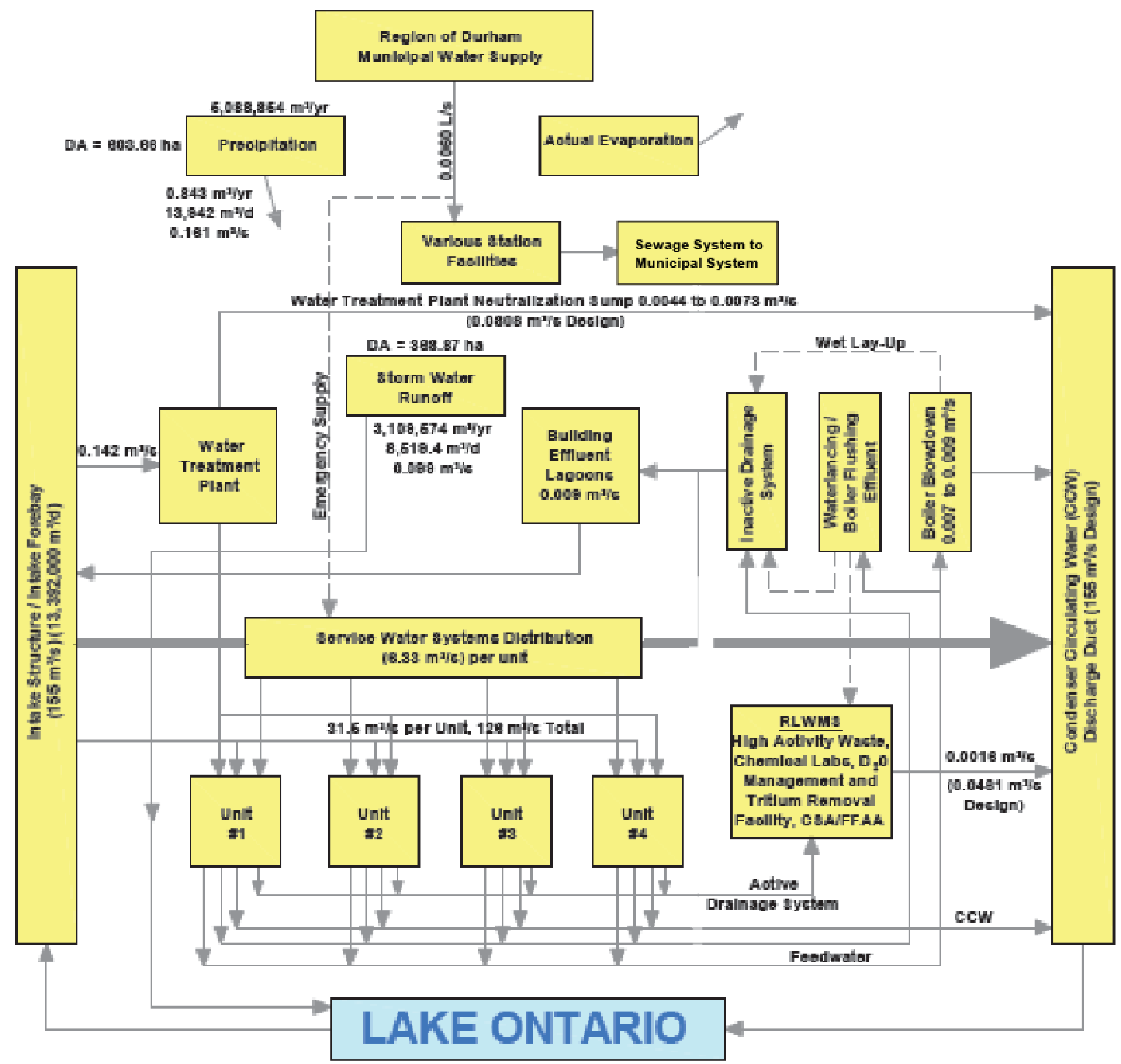
Under normal operating conditions, the Sewage System collects discharge by gravity from all washrooms, wash fountains, sinks inside workshops, drinking fountains, and showers (excluding the emergency showers). Sewage collected by gravity drainage at the various sump pumps is pumped to the gravity sewer system where it drains to either the East Sewage Pumping Station (SPS) or to the West SPS. The collected sewage from the East and West SPS is pumped north through forcemains to outlet manholes and gravity sewers north of the Canadian National Railway Company Railroad at Holt Road and Park Road, respectively. From there, it drains westerly to the Courtice Water Pollution Control Plant where it gets treated and discharged to Lake Ontario.

Stormwater Management System

The Stormwater Management System, or Yard Drainage System, collects storm runoff from the entire DN site and discharges to Lake Ontario either directly through the storm sewer drainage system or through drainage swales/creeks/retention pond via culverts which eventually discharge to the Lake.

Other Systems

Around the DWMF site, there is a grade of approximately 2.5 percent southwest to the lake. Perimeter ditches tie into existing site drainage ditches and discharge via a storm water containment pond to Lake Ontario. Inactive drainage from the DSC storage areas is sent to the sewage system. Active drainage is not expected or is minimal.



Notes
1. RLWMS: Radioactive Liquid Waste Management System.
2. CSA/FFAA: Central Services Area / Refueling Facility Auxiliary Area.
3. DA: Drainage Area
4. Flowrates are historical flowrates, not based on 2011-2015 data

Figure 2-4: Darlington Site Water Balance (Golder, 2011a)

2.2.1.2 Heating and Ventilation

The heating systems are designed to provide comfort to individuals working in the plant, to prevent equipment from freezing, and to provide steam to process systems such as the D_2O upgrader, domestic water heaters, and CSA laundry (OPG, 2013a). Steam and electricity are used for heating. Ventilation and air conditioning systems control temperature, moisture, and atmospheric conditions as required for employees and plant equipment. The ventilation systems remove heat from various buildings/areas, provide general ventilation to all areas, and minimizes cross contamination of radioactive materials between zones. Exhaust from areas that may contain radioactive materials are filtered and monitored prior to discharge.

Steam is supplied from the common steam header running along the entire length of the powerhouse to various heating and air conditioning components. Steam is supplied from this header to various heating loads. Under normal operating conditions, turbine extraction steam supplies the Heating Steam System.

2.2.2 Materials Management

The DN site has a multitude of systems that are designed to manage both radioactive and non-radioactive materials. The main radioactive material managed at the DN site is heavy water.

The heavy water management system is used to store, transfer and recover heavy water for use in the heat transport system and moderator systems. The system includes the heavy water supply system as well as collection, cleanup, and vapour recovery systems (SENES and MMM, 2011). The collection system collects heavy water leakage from points in the Moderator and associated systems. Collected heavy water (D_2O) is either sent back to the Moderator for reuse or sent for upgrading.

The D_2O vapour recovery system is a closed loop system comprised of dryers, ductwork, heavy water collection tanks, transfer pumps and piping. Collected heavy water by the D_2O vapour recovery system is sent for upgrading. The upgrading process uses distillation to remove light water from the heavy water.

The D_2O clean-up processes remove impurities from heavy water collected from the air or water system using charcoal filters, ion exchange columns and an ultraviolet oxidation unit.

A brief summary of the use(s) and the associated management methods for chemicals used across the site are presented in Table 2-2Error! Reference source not found..

Table 2-2: Chemical Usage and Disposal

Chemical	Use	Disposal
Gadolinium nitrate	Reactivity control in the moderator system.	Removed by ion exchange in the moderator purification system. For disposal, see Ion exchange resins, below.
Helium gas	A cover gas preventing the ingress of air for the moderator, liquid zone controllers, annulus gas, TRF.	Periodically purged to reactor building or TRF exhausts for chemistry control.
Oxygen gas	Cover gas for moderator, liquid zone control; annulus gas; TRF.	Consumed and emitted to reactor building or TRF exhausts.
Hydrogen gas	Added to remove oxygen gas from the heat transport system (HTS) and to cool generators, refrigerant and flame combiner (TRF).	Consumed in the HTS and vented to the reactor building exhaust. Vented to the atmosphere from the main generators. Burned in recombiner and vented to the atmosphere.
Argon gas	Used as cover gas in the TRF.	Vented to TRF exhaust.
Nitrogen gas	Used as cover gas during draining HTS to low level drained state (LLDS), used to purge heat transport (HT) D_2O Collection Tank; used for steam generator during lay-ups.	Vented to atmosphere or exhaust (TRF).
Liquid nitrogen	Used for cryogenic purposes, ice plugging activities.	Vented to atmosphere.
Hydrazine	Removes oxygen and used for pH control in the emergency coolant injection system, boiler feedwater, condensate feedwater, recirculating cooling water system, and end shield cooling water.	Consumed, but residual may be discharged to the atmosphere or to the lake. Ammonia is a breakdown product in feedwater.
Lithium hydroxide	Controls pH in the HTS, end shield cooling system, emergency coolant injection system, and the recirculating cooling water system.	Removed on ion exchange column or discharged.
Ion exchange resins	Used for pH control and removal of impurities in the moderator system, heat transport system, liquid zone control, irradiated fuel bay, radioactive liquid waste system, water treatment plant, stator cooling system, D_2O clean up system, end shield cooling, and recirculating cooling water system.	The resin is temporarily held within spent resin tanks and is placed in interim storage at the Western Waste Management Facility (WWMF) at the Bruce site.
Ion exchange resins (Sulphite)	Removes oxygen gas in the stator cooling water system.	Disposed as waste by licensed contractors based on analysis.
Granular activated carbon (charcoal)	Used in production of demineralized water at the water treatment plant, and to remove organics and residual chlorine in the active liquid waste systems and D_2O cleanup system.	Disposed as industrial waste by licensed contractors based on analysis. Radioactive waste from D_2O cleanup system placed in interim storage at the WWMF.
Filter sand	Used in production of demineralized water at the water treatment plant.	Disposed as waste by licensed contractors based on analysis.
Slaked lime (calcium hydroxide hydrate lime)	Used in production of demineralized water at the water treatment plant.	Disposed as waste by licensed contractors based on analysis.
Sulphuric acid	Used in production of demineralized water at the water treatment plant.	Consumed during usage.

Chemical	Use	Disposal
Sodium hypochlorite	Used in production of demineralized water and zebra mussel control in the low pressure service water and WTP.	Consumed during usage in demineralized water production. When applied for zebra mussel control, it is consumed and the residual is discharged to Lake Ontario.
Sodium metabisulphite	Used in production of demineralized water and to de-chlorinate effluent.	Consumed during usage.
Sodium hydroxide; Aluminex-3; aluminum sulphate	Production of demineralized water at the WTP.	Consumed during usage.
Carbon dioxide gas	Used in the annulus gas system as a carrier gas and in the generators as a purging gas.	Vented from the annulus gas system to the reactor building exhaust and vented to the atmosphere from the generators.
Morpholine	pH and corrosion control in the boiler feedwater and in the condensate feedwater.	Partly consumed in its usage and the balance is lost to atmospheric discharge and boiler blowdown.
Aqua ammonia	pH and corrosion control in the boiler feedwater and in the condensate feedwater.	Partly consumed in its usage and the balance is lost to atmospheric discharge and boiler blowdown.
Nitric acid	Used in moderator system to prevent gadolinium precipitation.	Consumed during usage.
Hydrogen peroxide	Process Total organic carbon (TOC) contaminated D_2O in heavy water management building, control algae and microbials in irradiated fuel bay (IFB).	Consumed during usage.
Potassium hydroxide	Electrolyte for deuterium production in TRF.	Consumed during usage.
Sulphur hexafluoride	Leak detection in the CCW system.	Released to Lake Ontario or air in small volumes.
CGSB-3.2 Type 1 stove oil	Fuel for standby generators and emergency power generators.	Consumed and results in waste gases including CO_2, NO_x, SO_2, etc.
Lubricating oil and generator seal oil	Lubrication and sealing of the turbine system and the generator system.	Reused and removed by licensed contractor.
Reolube Turbo fluid 46 (Fire Resistant Fluid)	Hydraulic fluid for turbine governor valves.	Reused or placed into drums for disposal by licensed contractors.
Insulating oil	Transformer cooling in the main output and service transformers.	Removed by licensed contractor.
Ethylene glycol	Air conditioners in the battery rooms, heating, ventilation and air condition (HVAC) systems.	Removed by licensed contractor.

2.2.2.1 Waste Management

Waste Management Facilities

Waste produced on-site includes used fuel, radioactive solid waste, radioactive liquid waste, radioactive gaseous waste, and non-radioactive solid, liquid, and gaseous waste.

2.2.2.1.1 Used Fuel

Used fuel bundles are initially stored in the irradiated fuel bays for at least 10 years and then transferred to DSCs for interim storage in the DWMF until a long-term waste management facility, being developed as part of a federal government program, becomes available. In the irradiated fuel bay, used fuel bundles are placed into 96-bundle storage modules. Modules with used fuel at least 10 years or older may be loaded into a DSC, which has the capacity to hold four storage modules. The DSC is loaded with the storage modules and the lid is secured while the DSC is submerged in water. The DSC is then removed from the water, drained, the exterior decontaminated, and then the DSC is prepared for on-site transfer to the DWMF for further processing and subsequent interim storage (OPG, 2013a).

2.2.2.1.2 Radioactive Solid Waste

Radioactive Solid Wastes include both low and intermediate level wastes. Low and intermediate level waste is packaged in the station and transported to OPG's WWMF for processing and storage.

Low Level Waste (LLW) is defined as waste with contact radiation fields of less than 10 mSv/h at 30 cm. LLW is made of maintenance wastes from day-to-day reactor operations including cleaning materials, personal protective equipment, contaminated metal parts, metal sweepings, and miscellaneous items. LLWs are categorized as incinerable, compactable, or as non-processible.

The majority of incinerable LLW is collected in plastic bags, packed into shipping containers and transportation packages, and shipped off-site for incineration at the WWMF at the Bruce site.

Compactable LLW, including light gauge metals, welding rods, metal cans, insulation, metallic air filters, air hoses, small cables, and other assorted wastes, is collected in plastic bags and temporarily stored in the solid radioactive waste handling area before being shipped to the WWMF where it is compacted and stored.

Non-processible LLW includes lathe turnings and metal filings, heavy gauge metal and components, floor sweepings, glass, and larger electrical cables. This waste is packaged and shipped to the WWMF.

Intermediate Level Waste (ILW) is defined as waste with dose rates greater than 10 mSv/h at 30 cm. Materials categorized as ILW include spent ion exchange resins, disposable filters, and other non-processible radioactive wastes. This waste is placed in appropriate transportation packages and shipped to the WWMF.

The Retube Waste Storage Building will provide storage for retube waste containers which will contain reactor components removed during refurbishment.

2.2.2.1.3 Radioactive Liquid Waste

The RLWMS receives, treats and disposes of all potentially RLW streams not containing appreciable amounts of heavy water; these are directed to the system via the active drainage system. The activity in the liquid waste originates from contamination by mixed fission products, process system corrosion and activation products, and may include tritium, carbon-14, alpha and beta-gamma emitters. Gross beta-gamma is a gross measure of radioactivity and is inclusive of all non-volatile radionuclides in effluent, including for example cesium-137, cesium-134, and cobalt-60. RLW from the DWMF is not expected or is minimal. A flow diagram of the RLWMS is shown in **Error! Reference source not found.**.

Active or potentially radioactive liquid wastes are segregated into different tanks depending on activity levels. Active liquid waste with chemical contaminants are subject to pH adjustments in the active chemical waste tank and chemical decontamination solution tanks. All active liquid waste is sent for treatment in order to reduce radioactive and non-radioactive impurities. Following treatment and confirmation of sample results, the waste is then directed to a dedicated clean tank(s) where it awaits discharge. The effluent is sampled for radiological and chemical parameters prior to release and is discharged only if required specifications are met. In addition to meeting all active and non-radioactive limits, all discharges from the RLWMS must be non-toxic as directed by the MISA regulations. Radioactivity monitors on the discharge piping automatically stop discharge flow if the detected activity is above specified limits. If limits are met, treated wastes are discharged with the CCW to Lake Ontario through the diffuser.

Certain types of organic radioactive liquids such as contaminated oils are put through an oil and water separator. Other fluids are solidified and transported to the WWMF for storage and/or incineration (OPG, 2013b).

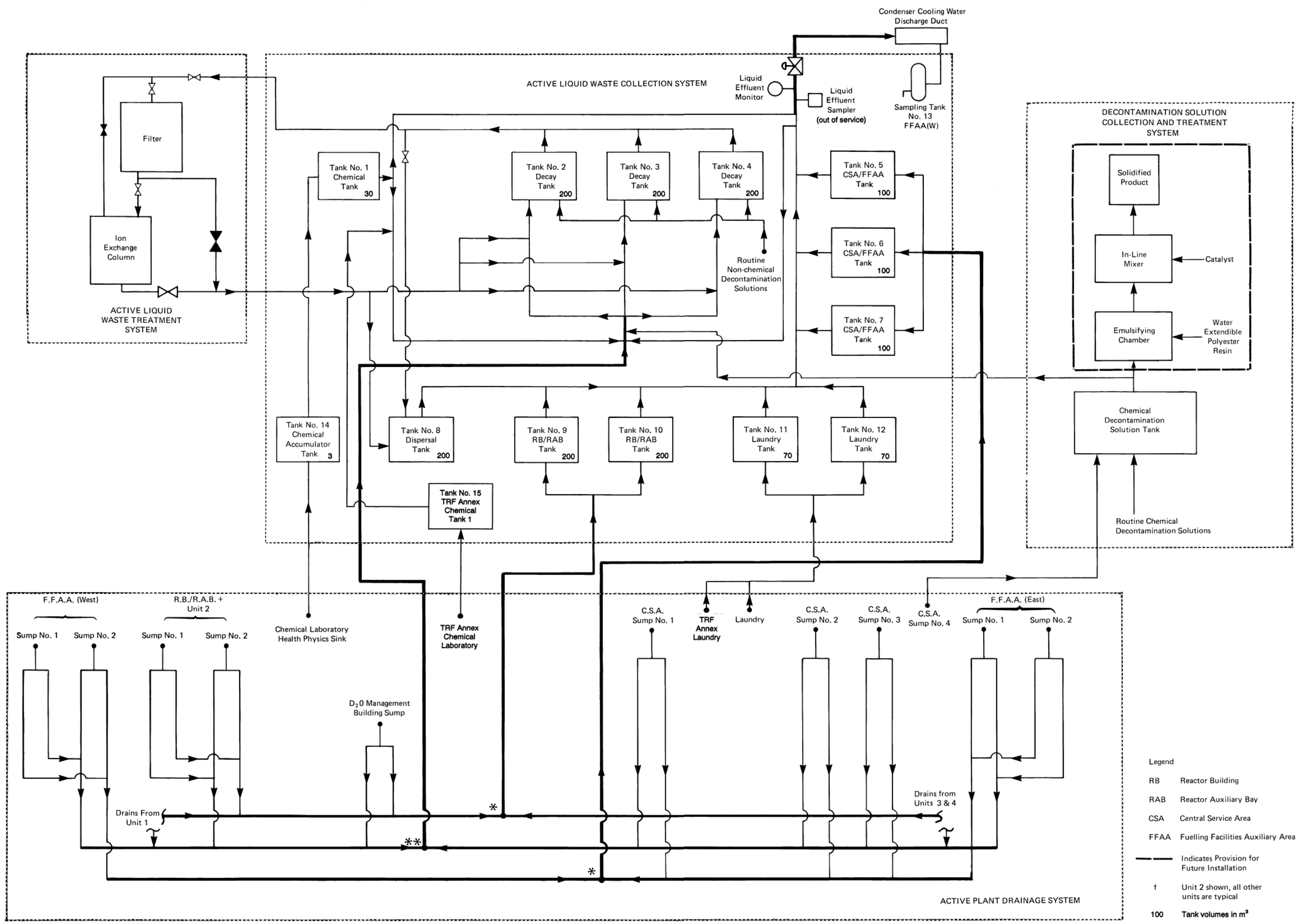


Figure 2-5: Radioactive Liquid Waste Management (OPG, 2013b)

2.2.2.1.4 Radioactive Gaseous Emissions

Tritium is produced in the reactor by the absorption of neutrons by the deuterium in the heavy water. Tritium is released in the form of tritiated water vapour with any leakage of heavy water from the moderator or heat transport system to the reactor building, although these facilities are extremely leak tight. The reactor vault, moderator auxiliary systems, and emission control rooms are also potential sources of tritium; however, ventilation systems with dryers are used to recover heavy water vapour. In addition to releasing tritiated water vapour, the TRF is the primary source for releases of small amounts of elemental tritium

The primary source of particulate emissions is the heat transport system where solid radionuclides originate from within the fuel bundles or from corrosion of system components. Additional radioactive particulate emissions include cesium-137 and cobalt-60 which primarily originate from the heat transport system where they are formed in the fuel bundles or from corrosion of the system components. Carbon-14 is released from the moderator cover gas system and the annulus gas system through the reactor building stack. The ventilation exhaust stacks are monitored for particulate and gaseous carbon-14 activity where necessary.

Radioactive iodine isotopes are formed by fission and can escape through defects in fuel bundles.

Gaseous wastes from potentially active areas are monitored for radioactivity before atmospheric release. When radioactive particulates and radioiodine may be present, gases from active ventilation stacks are filtered through absolute or charcoal filters prior to release.

Natural radioactive decay minimizes noble gas emissions. Noble gases from the annulus gas system, fueling machine head, and irradiated fuel discharge mechanism are processed in the Off-Gas Management System to delay release of radioactive noble gases by allowing natural radioactive decay (OPG, 2013a).

Radioactive gaseous emissions are modelled, for the purpose of public dose calculations, as one virtual source.

2.2.2.1.5 Non-Radioactive Solid Waste

Non-radioactive wastes are re-used or recycled where feasible. Hazardous wastes are handled in accordance with regulations and are shipped off site to licensed disposal facilities. Non-hazardous solid wastes are disposed in an off-site landfill if landfill requirements are satisfied.

2.2.2.1.6 Non-Radioactive Liquid Waste

Aqueous liquid effluent, except for domestic sewage and stormwater drainage, from DN is discharged directly to the CCW discharge duct or the intake forebay. Stormwater drainage is directed to Lake Ontario, and domestic sewage is pumped to the east or west SPS for subsequent treatment at the Courtice Water Pollution Control Plant.

Non-radioactive liquid emissions are controlled in accordance with the provincial Environmental Compliance Approval (ECA) requirements (formerly Certificate of Approval), and with the MISA program under O. Reg. 215/95 (Effluent Monitoring and Effluent Limits – Electric Power Generation Sector).

Under O. Reg 215/95 DN monitors the control points in use for MISA Compliance monitoring. The active control points and the parameters monitored at each point are presented in **Error! Reference source not found.** and include the RLWMS Tanks, the WTP Neutralization Sump and the Building Effluent Lagoon (OPG, 2016c). The locations and parameters monitored for ECA requirements are presented in **Error! Reference source not found.** and include the CCW duct and the boiler feedwater/blowdown (OPG, 2016d).

2.2.2.1.7 Non-Radioactive Gaseous Emissions

Non-radioactive gaseous emissions are controlled in accordance with ECA requirements. An Emissions Summary and Dispersion Modelling (ESDM) report is used to document and maintain compliance with O.Reg. 419/05 (Air Pollution – Local Air Quality) and forms the basis for the site's existing Environmental Compliance Approval (ECA LOF #8590-9GGMQ4).

The DN site is expected to have non-radioactive gaseous emissions including the products of fuel combustion, particulate matter, and volatiles. The ESDM lists maximum point of impingement (POI) concentrations for significant contaminants (OPG, 2015a). Contaminant concentrations on a ½ hour averaging period are determined based on the calculated emission rates and the output from the approved dispersion model in compliance with O.Reg. 419/05. The 2014 ESDM is the basis for the most current ESDM. In 2014, an additional assessment for hydrazine was completed using American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee's Dispersion Model (AERMOD) which changed the maximum POI concentration for hydrazine to an annual concentration (OPG, 2015a).

The locations of the air emissions sources used in the 2014 ESDM are presented in **Error! Reference source not found.**. In the ESDM report the facility was modelled with 21 virtual air emission sources and 4 point sources.

Table 2-3: MISA and ECA (Sewage Works) Monitoring Requirements

Control Point[1]	MISA Monitoring Requirements[2]	Monitoring Frequency	Daily Limit (mg/L)	Monthly Limit (mg/L)
Radioactive Liquid Waste Management Tanks (CP 0100)	Phosphorus[3]	Weekly	-	1.0
	Residual Solid Particulates[4]	Daily	73.0	21.0
	Zinc	Weekly	1.0	0.5
	Iron	Weekly	9.0	3.0
	Solvent Extractables	Weekly	36.0	13.0
	pH[4]	Daily	6.0-9.5	-
	Acute Lethality/Toxicity	Quarterly	-	Non-toxic
	Chronic Toxicity	Semi-Annually	-	Non-toxic
Water Treatment Plant Neutralization Sump (CP 2200)	Residual Solid Particulates	Daily	70.0	25.0
	Aluminum	Weekly	13.0	4.5
	Iron	Weekly	2.50	1.0
	pH	4 hours	6.0-9.5	-
	Acute Lethality/Toxicity	Quarterly	-	Non-toxic
	Chronic Lethality/Toxicity	Semi-Annually	-	Non-toxic
Building Effluent Lagoon (CP 5000, 5100 back-up)	Acute Lethality/Toxicity	Monthly	-	Non-toxic
	pH	Weekly	6.0-9.5	-
	Ammonia plus ammonium	Monthly	-	-
	Hydrazine	Monthly	-	-
	Total Organic Carbon	Monthly	-	-
	Phosphorus	Monthly	-	-
	Residual Solid Particulates	Monthly	-	-
	Copper	Monthly	-	-
	Oil and Grease	Monthly	-	-
	Total Residual Chlorine	Monthly	-	-
	Tritium	Monthly	-	-

Note:
[1] Only active control points are shown.
[2] **Error! Reference source not found.** is provided for reference purposes only. Current MISA monitoring requirements should always be verified against O.Reg 215/95.
[3] ECA requirement.
[4] ECA frequency is per discharge.

Table 2-4: ECA Monitoring Requirements

Location	ECA Monitoring Requirements	Monitoring Frequency	ECA Limit (mg/L)
Condenser Cooling Water Duct	Ammonia, unionized	Weekly	0.02
	Hydrazine	Weekly	0.1
	Morpholine	Weekly	0.02
	Total Residual Chlorine	Daily	0.01
	pH	Weekly	6.0-9.5
Boiler Feedwater/Blowdown	Total Ammonia	Monthly	20
	Hydrazine	Monthly	5
	Morpholine	Monthly	25
	pH	Monthly	-

Table is provided for reference purposes only. Current ECA monitoring requirements should always be verified.

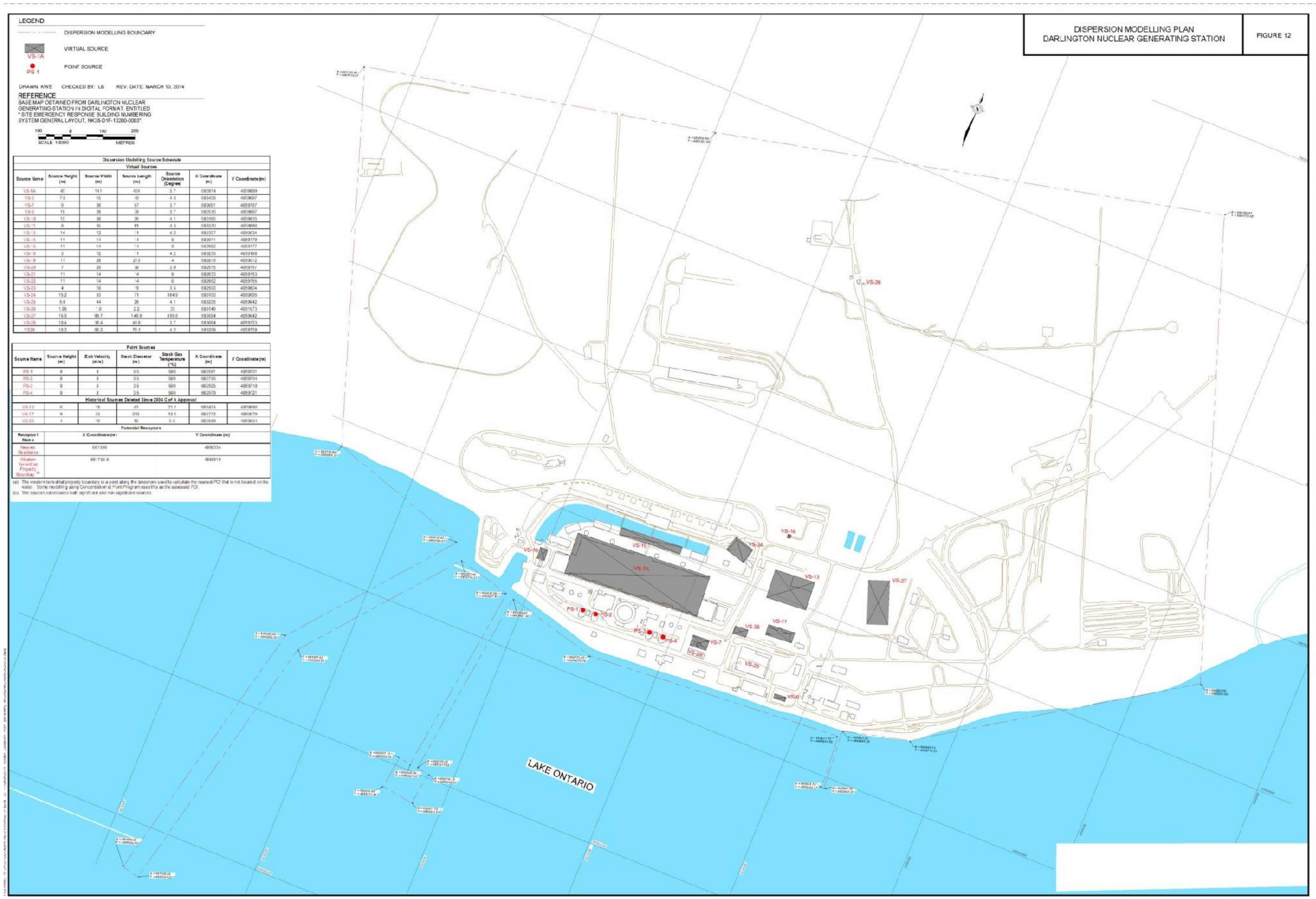


Figure 2-6: Non-radiological Air Emissions Sources (OPG, 2015a)

2.3 Description of the Natural and Physical Environment

This section will briefly describe meteorology and climate, site geology, hydrogeology, hydrology, vegetation communities, aquatic communities, human land use, and population distribution with a focus on DN site conditions. More detailed information can be obtained from the following TSDs for the Darlington Nuclear Generating Station RCO project EA (SENES and MMM, 2011) and for the New Nuclear – Darlington EA (SENES and MMM, 2009) with updates based on information from 2011 to 2015:

The following TSDs from the Darlington Nuclear Generating Station Refurbishment and Continued Operation Environmental Assessment were reviewed:

- Aquatic Environment Technical Support Document Darlington Nuclear Generating Station Refurbishment And Continued Operation Environmental Assessment NK38-REP-07730-10005-R000
- Terrestrial Environment Technical Support Document Darlington Nuclear Generating Station Refurbishment And Continued Operation Environmental Assessment NK38-REP-07730-10006-R000
- Non-Human Health (Ecological Risk Assessment) Technical Support Document Darlington Nuclear Generating Station Refurbishment And Continued Operation Environmental Assessment NK38-REP-07730-10010-R000
- Human Health Technical Support Document Darlington Nuclear Generating Station Refurbishment And Continued Operation Environmental Assessment NK38-REP-07730-10012-R000
- Radiation and Radioactivity Environment Technical Support Document Darlington Nuclear Generating Station Refurbishment And Continued Operation Environmental Assessment NK38-REP-07730-10014-R000
- Communication and Consultation Technical Support Document Darlington Nuclear Generating Station Refurbishment And Continued Operation Environmental Assessment NK38-REP-07730-10015-R000
- Atmospheric Environment Technical Support Document Darlington Nuclear Generating Station Refurbishment And Continued Operation Environmental Assessment NK38-REP-07730-10016-R000
- 2011 Thermal And Current Monitoring Program Darlington Nuclear Generation Station Refurbishment And Continued Operation Environmental Assessment NK38-REP-07730- 10019-R000

New Nuclear – Darlington EA

- Geological and Hydrogeological Environment NK054-REP-07730-00005
- Aquatic Environment Existing Conditions NK054-REP-07730-00003
- Terrestrial Environment Existing Environmental Conditions NK054-REP-07730-00004

- Terrestrial Environment Assessment of Environmental Effects NK054-REP-07730-00014

2.3.1 Meteorology and Climate

The DN site is located in southern Ontario on the north shore of Lake Ontario. It displays a humid continental climate with four distinct seasons. In Southern Ontario, the climate is highly modified by the influence of the Great Lakes which results in uniform precipitation amounts year-round, delayed spring and autumn, and moderated temperatures in winter and summer (Environment Canada, 1997, cited in SENES and MMM, 2011).

2.3.1.1 Temperature

Temperature data collected on-site during the period of 1996-2000 have been used to characterize site temperature patterns and are considered to be representative of regional temperatures (SENES and MMM, 2011). The mean daily temperatures during winter (December, January, February and March) are typically below 0°C, with the coldest mean daily temperatures, near -5.5°C, in January. During the summer, temperatures average 17.7°C, or higher. The highest daily mean temperature recorded during the 1996-2000 period was 20.0°C, and occurred in July. The mean daily temperature over this time was 8°C (SENES and MMM, 2011). Reliable temperature data from the DN meteorological tower is not available from 2011 to 2015, due to a high frequency of anomalous readings over this period; the problem was finally rectified in August 2016. For this report, temperature data from the PN meteorological tower 2011-2015 have been used.

Error! Reference source not found. summarizes the PN temperature data (at the 10m elevation), along with available data for two regional meteorological stations near the DN site: Pearson International Airport (TOR) (1981 to 2010) and Bowmanville Mostert (BOW) (1981 to 2010) (Government of Canada, 2016). The meteorological data collected from the PN meteorological station are generally consistent with the regional temperature normals, and are considered representative for DN.

Table 2-5: Temperature Normals near Darlington Nuclear

Month	Daily Mean (°C)			Mean Daily Maximum (°C)			Mean Daily Minimum (°C)		
	TOR[1]	BOW[2]	PN[3]	TOR[1]	BOW[2]	PN[3]	TOR[1]	BOW[2]	PN[3]
January	-5.49	-5.6	-4.63	-1.51	-1.4	-0.35	-9.44	-9.9	-7.62
February	-4.54	-4.4	-5.38	-0.35	0	0.16	-8.7	-8.8	-11.61
March	0.06	-0.2	0.12	4.62	4.3	5.61	-4.49	-4.6	-3.59
April	7.06	6.4	6.14	12.21	11.3	6.75	1.86	1.5	5.18
May	13.12	12.4	13.47	18.79	18	15.14	7.41	6.8	12.38
June	18.6	17.5	18.17	24.19	23.1	19.12	12.95	11.8	17.54
July	21.45	20	21.75	27.06	25.8	23.49	15.79	14.3	18.68

Month	Daily Mean (°C)			Mean Daily Maximum (°C)			Mean Daily Minimum (°C)		
	TOR[1]	BOW[2]	PN[3]	TOR[1]	BOW[2]	PN[3]	TOR[1]	BOW[2]	PN[3]
August	20.55	19.2	20.57	26.01	24.8	22.09	15.05	13.5	19.10
September	16.2	15	16.76	21.61	20.4	18.78	10.75	9.5	15.38
October	9.5	8.7	10.53	14.31	13.7	11.07	4.63	3.6	9.85
November	3.72	3.4	4.42	7.59	7.2	6.63	-0.17	-0.4	2.66
December	-2.18	-2.2	0.70	1.41	1.6	4.75	-5.76	-6	-3.93
Year	8.17	7.5	8.55	-	-	-	-	-	-

Notes:

[1] Toronto Pearson International Airport, 1981-2010 (Government of Canada, 2016).

[2] Bowmanville Mostert, 1981-2010 (Government of Canada, 2016).

[3] Pickering Nuclear, 2011-2015 PN Meteorological Station. Data from the DN Meteorological Station over this period are not considered reliable.

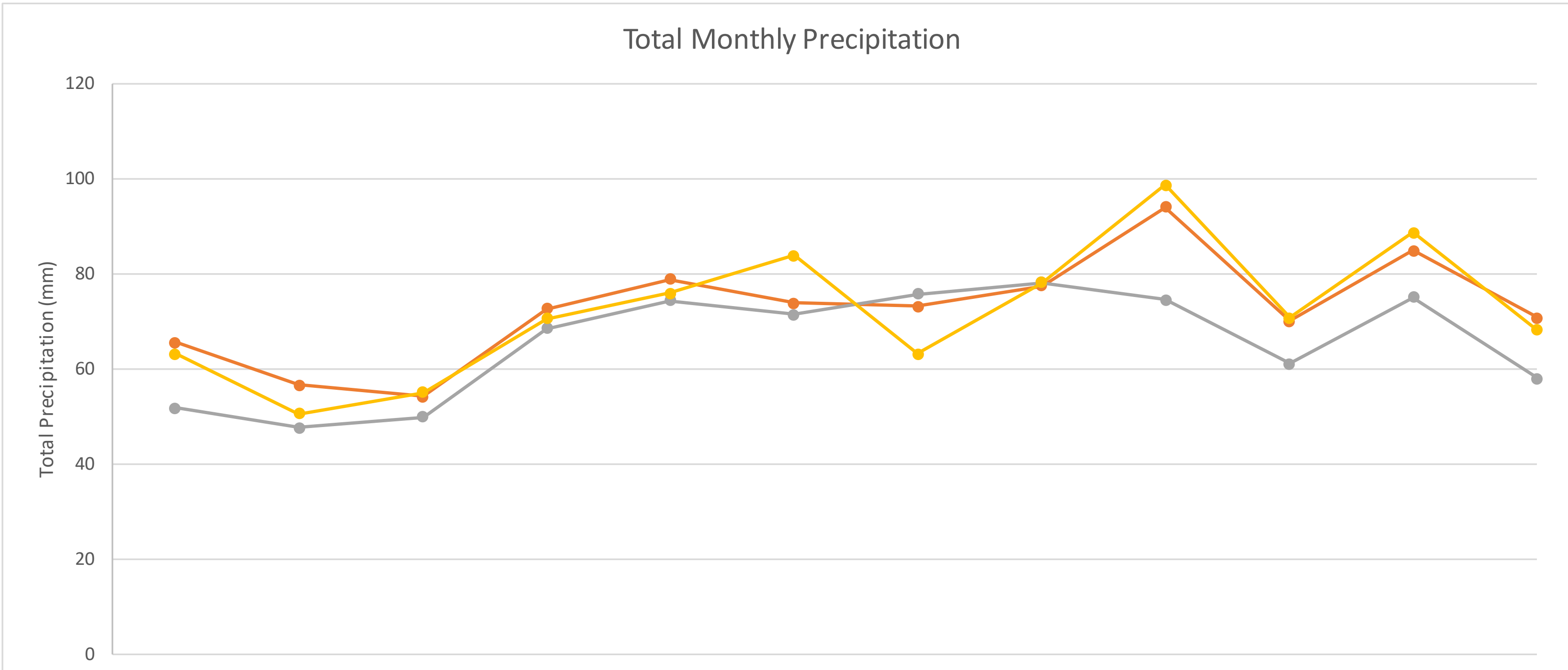
2.3.1.2 Precipitation

The Bowmanville climate station is the closest to the DN site. Precipitation data from the Bowmanville Mostert Station for the period from 1981-2010 has been used to characterize precipitation patterns for the DN site. During this time the Bowmanville station reported an average annual precipitation of approximately 866 mm. Snowfall represented less than 11% of total precipitation during the 1981-2010 period (Government of Canada, 2016). Total monthly precipitation averages range from approximately 50.5 mm in February to approximately 98.7 mm in September.

In comparison, other nearby climate stations reported annual total precipitation of approximately 800-900 mm during the same period, including: approximately 786 mm at Toronto's Pearson International Airport (1981 to 2010) and 872 mm at the Oshawa station (1981 to 2010) (Government of Canada, 2016). **Error! Reference source not found.** and **Error! Reference source not found.** show that monthly precipitation within the local study period tends to follow the regional monthly precipitation trends.

Table 2-6: Precipitation at Bowmanville Mostert Station (1981 – 2010)

Month	Monthly Averages			Daily Extremes		
	Precipitation (mm)	Rain (mm)	Snow (cm)	Precipitation (mm)	Rain (mm)	Snow (cm)
January	63.1	32.2	31	46.2	46.2	29
February	50.5	32.8	17.7	42.2	42.2	19.4
March	55	41	14.1	47.6	47.6	20.8
April	70.6	68	2.6	43.4	43.4	10.2
May	75.9	75.9	0	36.4	36.4	0
June	83.8	83.8	0	50.6	50.6	0
July	63.2	63.2	0	51.1	51.1	0
August	78.1	78.1	0	81.2	81.2	0
September	98.7	98.7	0	84	84	0
October	70.8	70.6	0.1	48.6	48.6	12.2
November	88.6	83.1	5.6	71.4	71.4	15.5
December	68.1	46.1	22	41.1	41.1	24
Annual Total	**866.4**	**773.5**	**93.1**	**-**	**-**	**-**



	January	February	March	April	May	June	July	August	September	October	November	December
OSH	65.6	56.6	54.2	72.7	78.9	73.9	73.1	77.4	94	70.1	84.8	70.7
TOR	51.8	47.7	49.8	68.5	74.3	71.5	75.7	78.1	74.5	61.1	75.1	57.9
BOW	63.1	50.5	55	70.6	75.9	83.8	63.2	78.1	98.7	70.8	88.6	68.1

OSH - Oshawa WPCP, 1981-2010 (Government of Canada, 2016)
TOR - Toronto Pearson International Airport, 1981-2010 (Government of Canada, 2016)
BOW - Bowmanville Mostert, 1981-2010 (Government of Canada, 2016)

Figure 2-7: Comparison of Monthly Precipitation Normals (1981-2010) for Local and Regional Meteorological Stations

2.3.1.3 Wind

Wind data for the DN site meteorological station for the period 2011 to 2015 are presented as a wind rose in **Error! Reference source not found.**. The 5-year average meteorological data from 2011 to 2015 are expected to be representative of current average meteorological conditions. During this period, calm winds less than 2 m/s were reported approximately 37% of the time. Prevailing winds were from the northwest and occurred 11% of the time. Winds from the north and from the west both occurred 10% of the time. The distribution of winds at the DN site is generally similar to that reported for the region based on wind patterns reported at Pearson International Airport, where the wind direction is primarily from the north and the west (SENES, 2009b).

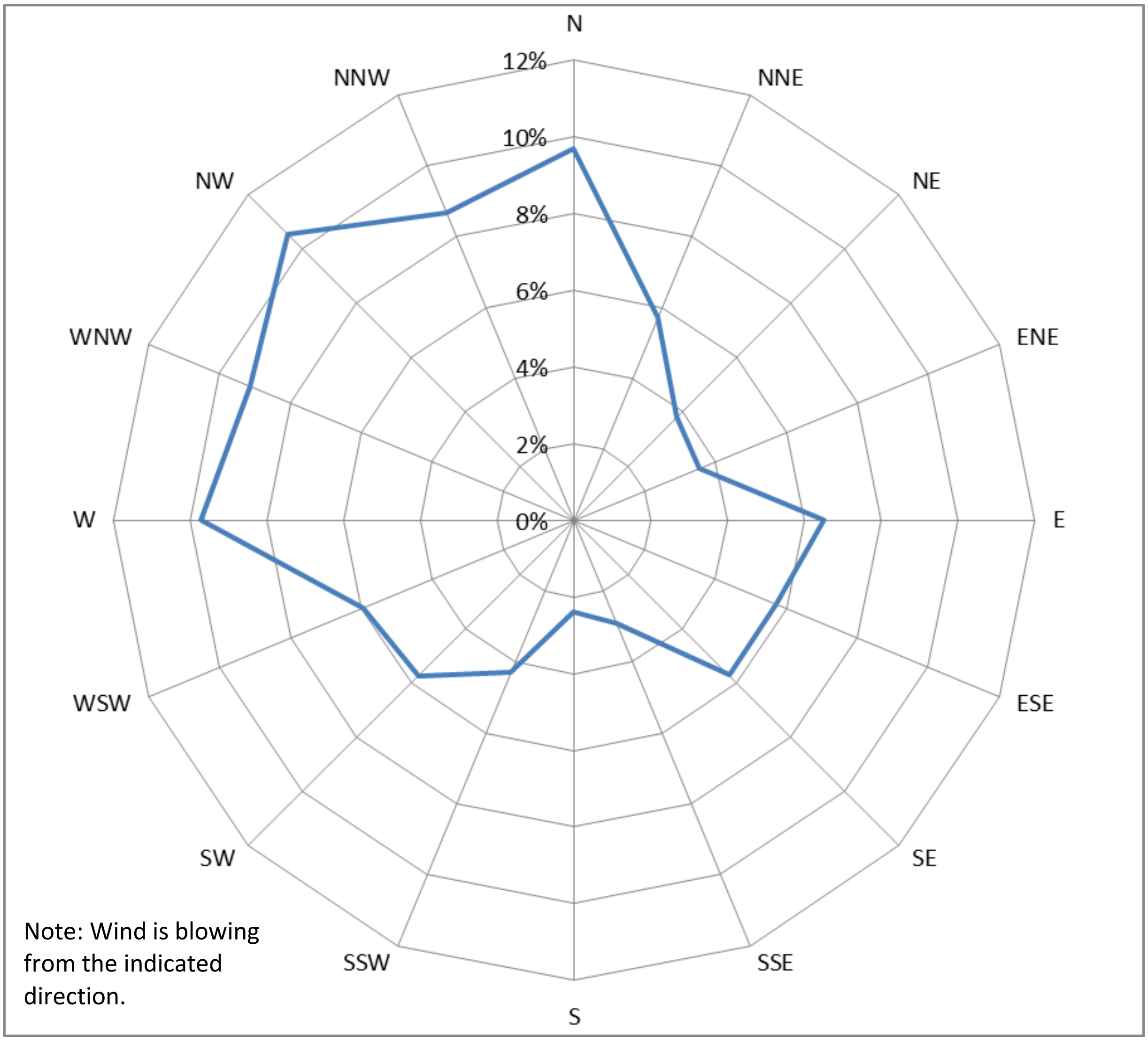


Figure 2-8: 2011 - 2015 Annual Average Windrose at 10-m Tower

2.3.2 Geology

On a regional level, the bedrock is completely covered by Quaternary deposits and bedrock outcrops are found only in local quarries and other man-made excavations. The Oak Ridges Moraine is a major geologic/hydrogeologic feature in Southern Ontario, running along an east-west trajectory north of the DN site. The Oak Ridges Moraine consists of interbedded layers of glacial till and sand and gravel, and is a major source of groundwater recharge and a large number of creeks and rivers in the region are derived from groundwater discharge from it. The Oak Ridges Moraine divides the flow of groundwater to the north to Lake Simcoe and to the south to Lake Ontario. The Iroquois Plain is situated south of the moraine and extends 8 to 12 km to Lake Ontario. Shoreline deposits and glaciolacustrine sediments overlay the glacial tills in this area. The shoreline deposits include sand and gravel bars and beach terraces as well as some deltas from former rivers and creeks flowing into Lake Iroquois, a prehistoric proglacial lake formed approximately 13,000 years ago. In the area of the DN site, the Iroquois Plain contains drumlins with a southeast orientation indicating the northwest glacial advance. Overburden thickness varies from over 200 m in the Oak Ridges Moraine to about 10 m at the Lake Ontario shoreline (SENES and MMM, 2009).

2.3.2.1 Bedrock

From surface to depth, the bedrock at the DN site consists of shale and limestone of the Blue Mountain Formation, Lindsay Formation, Verulam Formation, Bobcaygeon Formation and Gull River Formation, shown in **Error! Reference source not found.**. The Shadow Lake Formation, a sandstone and shale unit, lies nonconformably on the Precambrian Basement. Rock quality is noted to be good to excellent with few breaks or fractures. There is no evidence of karstic features in the local bedrock (SENES and MMM, 2009).

The limestone sequence has been found to extend to approximately 180 to 190 m in thickness. The Lindsay Formation is exposed at the surface in the St. Marys Cement quarry adjacent to the DN site which is a source of limestone for cement manufacture. The quarry has been developed in a series of four benches with the base of the quarry at an elevation of about 11 masl in 2009 (SENES and MMM, 2009).

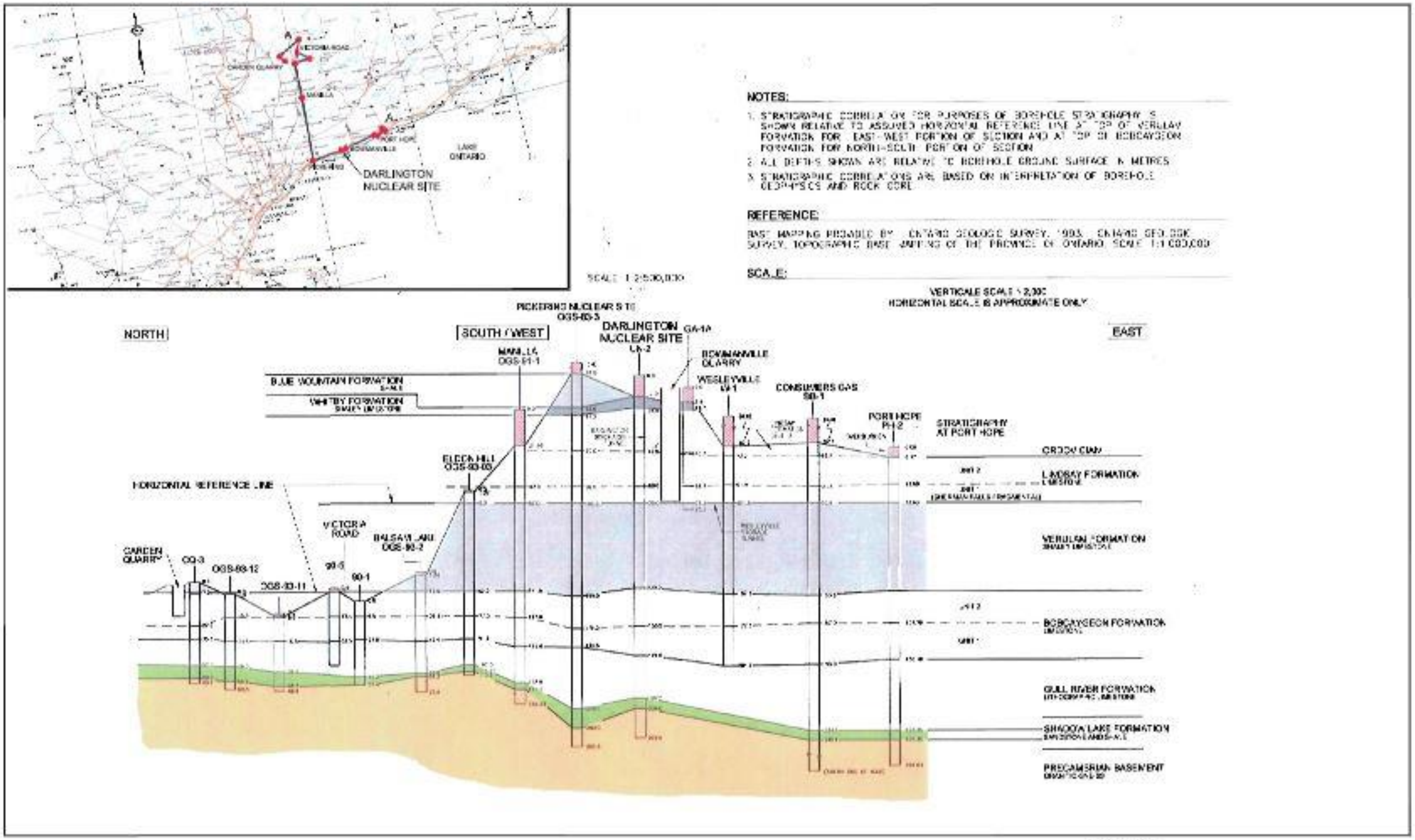


Figure 2-9: Regional Geology (CH2M Hill and Kinectrics, 2009)

2.3.2.2 Surficial Geology

Surficial geology at the DN site consists of fill materials in places at surface, underlain by upper and lower till units with interglacial deposits in between (SENES and MMM, 2009). The overburden overlies either shale or limestone bedrock. The fill materials are variable in thickness and composition.

The site topography is shown in **Error! Reference source not found.**. The Landfill located on the northwest portion of the DN site highest point of elevation at the DN site with an elevation of 133 metres above sea level (masl) at the top and 105 at the base. The Landfill was constructed mainly of native materials excavated from the Site construction with a small limited area where non-hazardous waste materials derived from the construction of DN Generating Station was deposited. The land generally slopes down to the southwest, to the south to Lake Ontario and to the east to Darlington Creek. The Canadian National Railway Company (CN) Railroad which cuts through the property from west to east is recessed into the ground through the central portion of the site with elevation differences of 5 to 10 m between the tracks and the adjacent ground.

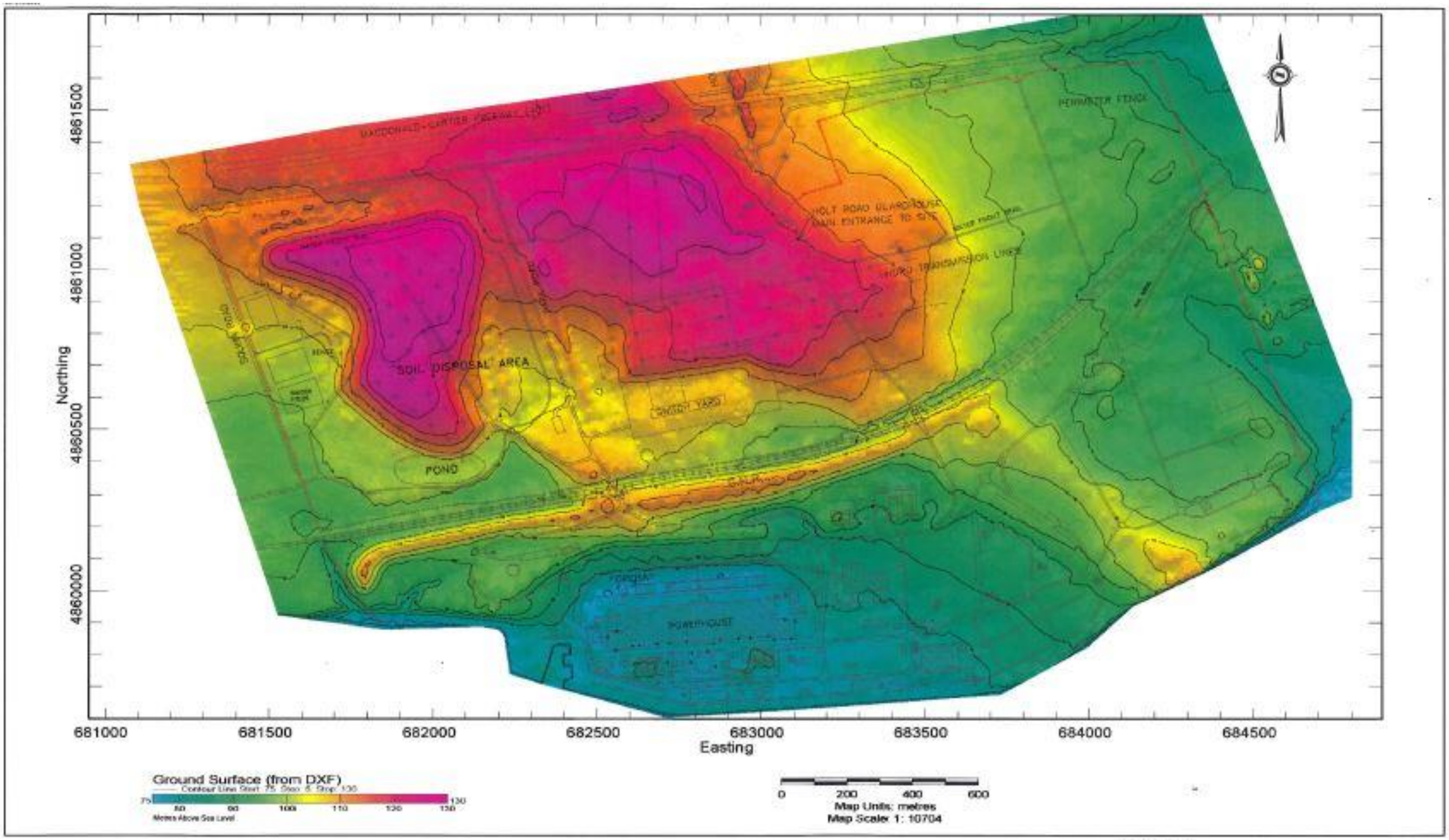


Figure 2-10: DN Site Topography (CH2M Hill and Kinectrics, 2009)

2.3.3 Hydrogeology

Groundwater in the region flows from the Oak Ridges Moraine to the south with discharge to local streams or to Lake Ontario. A number of creeks near the DN site, including Harmony, Bowmanville and Soper creeks, have their headwaters in the moraine. The intact bedrock is generally considered to be of low permeability and transmits very little water. Therefore regional bedrock does not generally yield appreciable amounts of groundwater for water supply. However, within areas where the upper fractured surface of the bedrock is in contact with more permeable overburden materials sufficient water for domestic water supplies may be available. South of the moraine, Interglacial Deposits lying between the till layers represent the primary source of water supply for rural areas north of the DN site which rely on groundwater for domestic water supply. Urban areas such as Bowmanville to the east and Courtice to the west rely on municipal water supply from a Lake Ontario-based source (SENES and MMM, 2009).

Groundwater flows in shallow/water table (overburden), interglacial deposit layers and shallow bedrock within the DN site area presented in **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**, respectively (OPG, 2015b). The general flow pattern within each layer is south toward Lake Ontario, except for the northwest portion of the site which flows toward Darlington Creek and then to Lake Ontario.

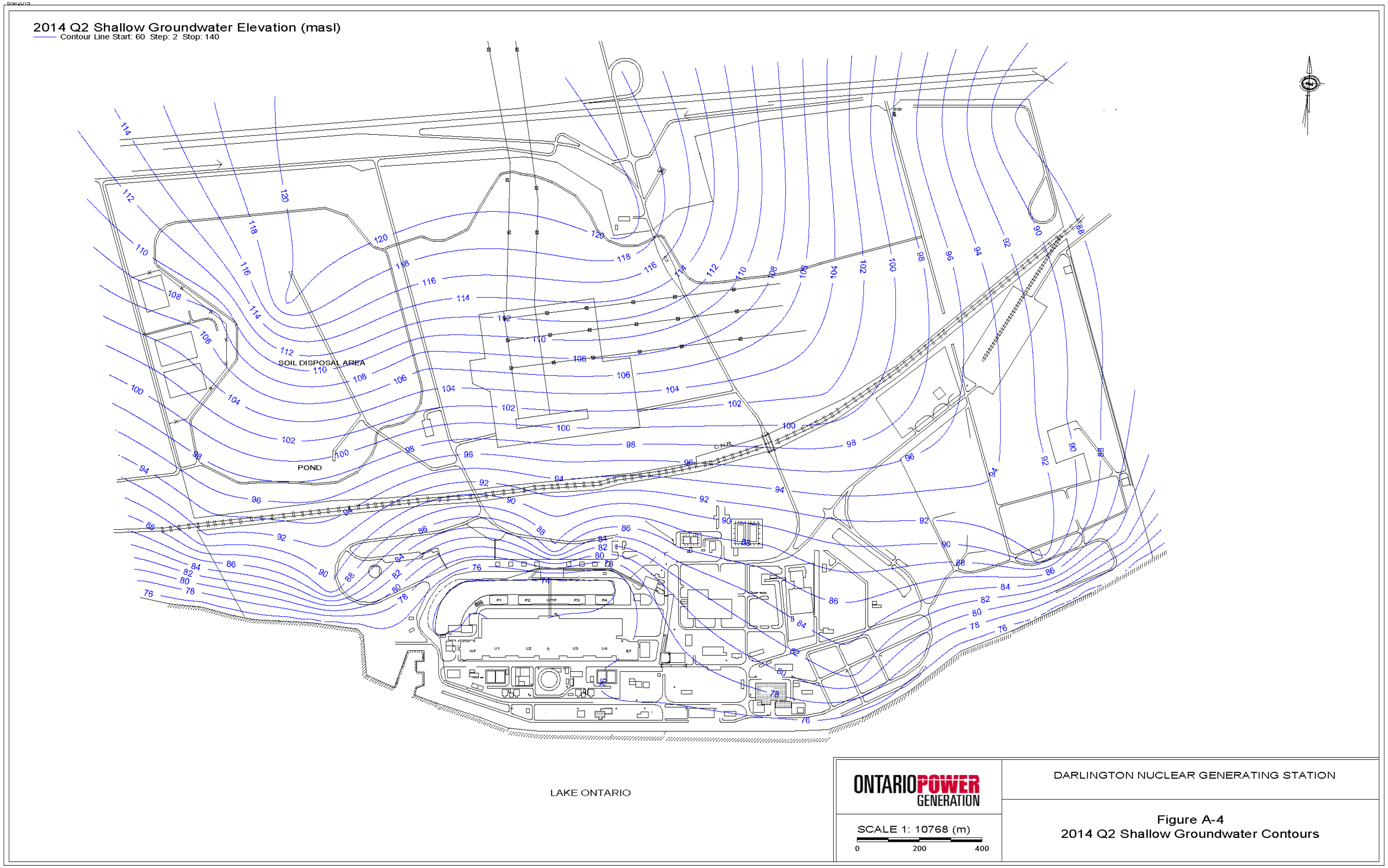


Figure 2-11: DN Site Groundwater Flows in Shallow Groundwater

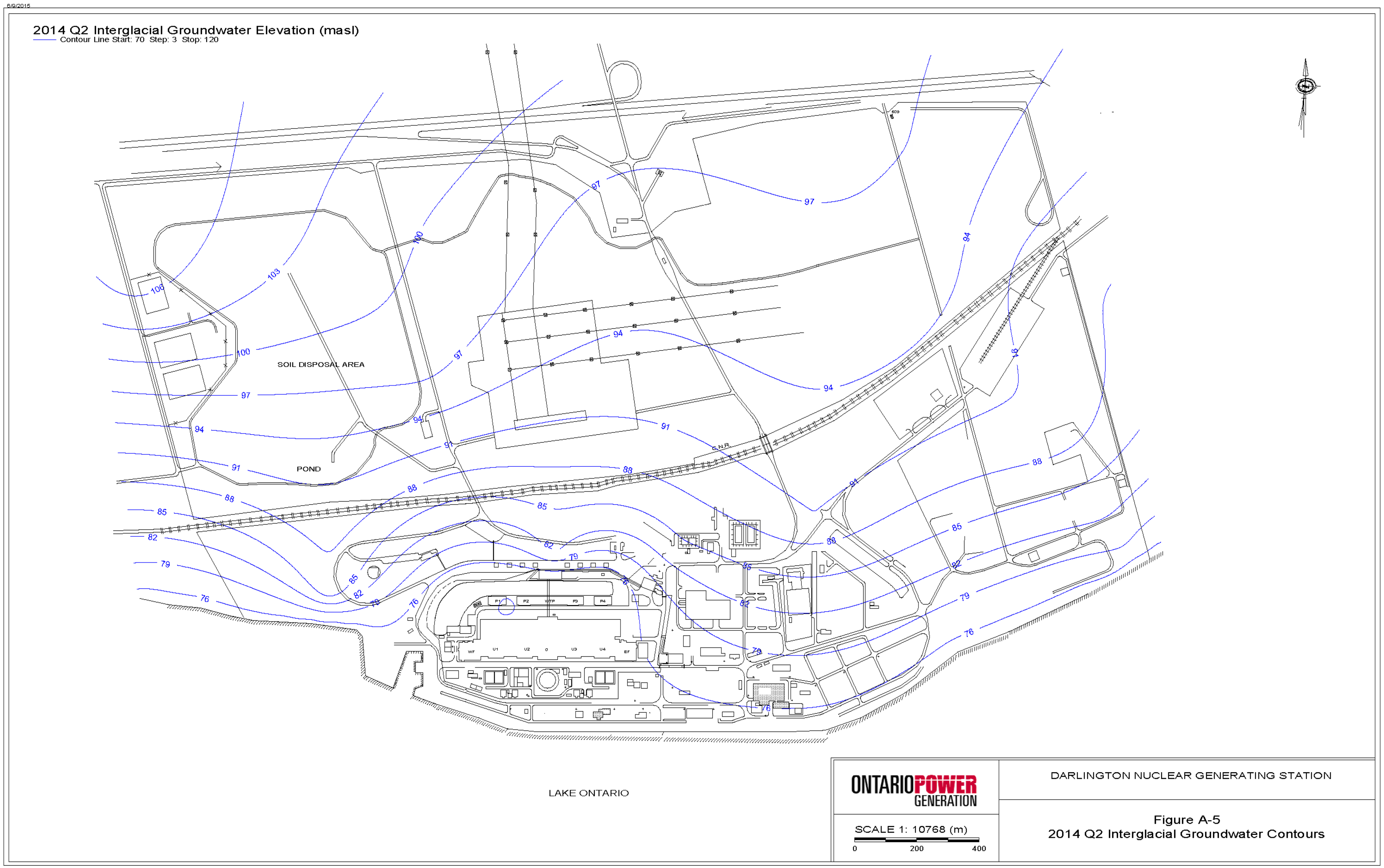


Figure 2-12: DN Site Groundwater Flows in Interglacial Deposit Layers

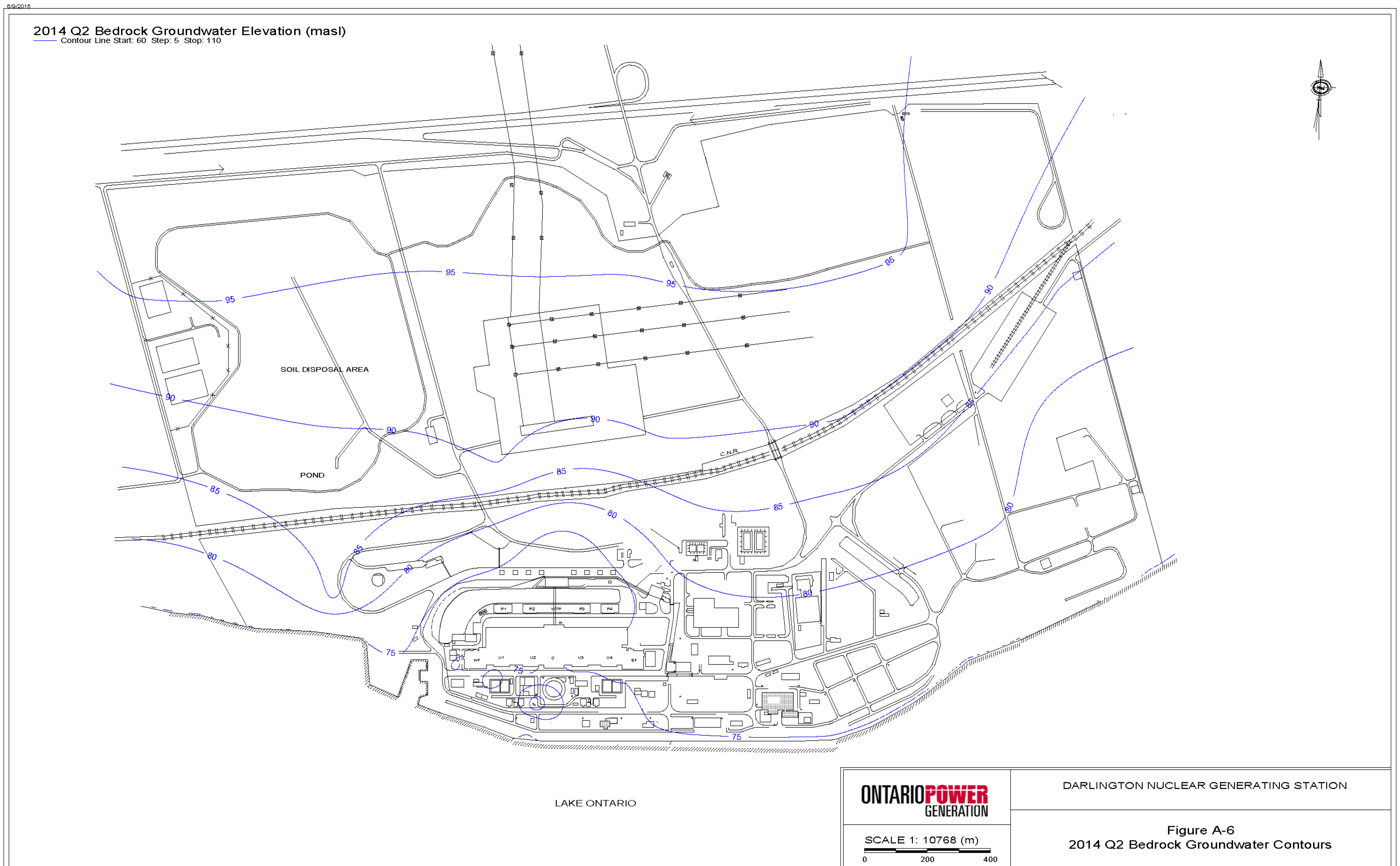


Figure 2-13: DN Site Groundwater Flows in Bedrock

Recharge of precipitation is expected to be low at the DN site in areas where till is encountered at surface. Within these areas most precipitation runs off to surface water ditches or yard drainage features (SENES and MMM, 2009). In the developed parts of DN, stormwater is collected in ditches and storm drains and directed to Lake Ontario. A stormwater pond is located to the south of the Engineering Support Services Building and another pond is associated with the DWMF. Another stormwater pond is located north of the lagoons which collected runoff from adjacent parking lots and from the railroad tracks (CH2M Hill and Kinectrics, 2009).

Within the DN site, till units with relatively lower hydraulic conductivities act as aquitards, or confining layers, and restrict groundwater movement. Groundwater flow in these units is expected to be primarily vertically downward. Alternately, Interglacial Deposits between till units have moderate hydraulic conductivities and act as aquifers and transmit groundwater (SENES and MMM, 2009).

Recharge to depth is restricted for the Interglacial Deposits by till or clay-rich layers which act as confining layers. Consequently, groundwater flow in the Interglacial Deposits is primarily horizontal. Where the Interglacial Deposits are exposed at surface, such as in the northeast of the DN site, a significant groundwater recharge is likely as a result. There may be an upward flow component from the bedrock into the lower till unit (SENES and MMM, 2009).

Seepage water and precipitation into the St. Marys quarry collects in a sump from where it is pumped to Darlington Creek (by permit). The low flows in the dry months of the year indicate that there is very little groundwater seepage to the quarry and most of the accumulation in the quarry is the result of precipitation (SENES and MMM, 2009).

2.3.4 Hydrology

2.3.4.1 Lake-wide Circulation

The DN site is situated on the north shore of Lake Ontario. The lake-wide circulation is generally eastward from the Niagara River to the discharge to the St. Lawrence River and is influenced by meteorological conditions, primarily wind and seasonal temperature effects (Golder, 2011a).

There is very little net flow along the northern shore of Lake Ontario. However, the current in the nearshore region is overall easterly and is influenced by brief patterns of strong winds exerting stress at the water surface (Golder, 2011a). Seasonal factors related to temperature and vertical mixing influence the strength and direction of the nearshore currents. Reversals of the nearshore current direction along the northern shore are common following brief patterns of strong winds exerting stress at the water surface (Golder, 2011a). Locally, the DN discharge can act as a barrier to longshore water movement during low energy periods although this effect is reduced as current speeds increase (Golder, 2011a).

Error! Reference source not found. and **Error! Reference source not found.** summarize available Lake Ontario current data for 2011 to 2015. **Error! Reference source not found.** shows the frequency of lake current flowing towards each direction and the maximum speed that occurred in each direction. **Error! Reference source not found.** shows the depth averaged lake current direction and speeds. Average lake current data are summarized for easterly, NE, ENE, E, and ESE, and westerly, SW, WSW, W, and WNW, lake currents. The average easterly and westerly current speeds for 2011 to 2015 were 8.5 cm/s and 8.2 cm/s respectively. Current speeds for all directions typically ranged from about 6 to 10 cm/s and were typically slower in spring and early summer, April through July, than during the late summer, fall and winter seasons, August through March.

Table 2-7: Summary of Lake Ontario Current Data from 2011 to 2015

Direction "To"	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Easterly	Westerly
Total Number of Measured Hours	6198	12143	25978	61260	42101	13903	8788	8244	8352	10448	18437	52217	59408	21611	11097	8400	143242	151673
Percent of Total Measured Hours	1.7%	3.3%	7.0%	16.6%	11.4%	3.8%	2.4%	2.2%	2.3%	2.8%	5.0%	14.2%	16.1%	5.9%	3.0%	2.3%	38.86%	41.15%
Average Speed (cm/s)	6.1	6.5	8.3	8.6	7.7	7.4	10.9	14.3	13.7	11.8	9.1	8.6	8.5	8.0	6.0	5.5	8.2	8.5
Maximum Speed (cm/s)	141.44	182.9	204.7	149.1	204.8	132.3	197.7	174.0	177.8	200.2	191.6	186.0	163.6	127.6	207.9	121.1	204.8	191.6

Notes:
Easterly includes NE, ENE, E, and ESE
Westerly includes SW, WSW, W, and WNW

Table 2-8: Summary of Lake Ontario Depth Averaged Current Speed and Direction from 2011 to 2015

Month	Direction	Speed – All Directions	Speed - Easterly	Speed - Westerly
	Degree from North	cm/s	cm/s	cm/s
January	145	9.1	8.4	8.3
February	143	9.2	8.6	9.0
March	161	7.8	6.8	8.3
April	163	7.8	7.4	8.1
May	196	5.9	5.5	6.5
June	172	5.9	6.0	7.0
July	185	6.6	6.2	7.6
August	202	9.8	8.8	10.6
September	193	9.9	10.2	10.0
October	175	9.8	9.4	9.3
November	162	9.1	9.2	7.4
December	172	8.9	8.1	8.1
Average of Monthly Averages		8.3	7.9	8.4

Notes:
Easterly includes NE, ENE, E, and ESE
Westerly includes SW, WSW, W, and WNW

2.3.4.2 Lake Water Temperature

Lake Ontario is generally classified as a dimictic lake because it undergoes a complete cycle of isothermal and vertically stratified conditions in a year. The thermal structure generally depends on the season because of large annual variation in surface heat fluxes. In spring and early summer, heating of the lake surface gradually results in potential formation of thermal stratification conditions, with warmer water at the surface layer and cooler water in the bottom layer. The depth of the summer thermocline generally ranges from 5 m to 10 m. Since nearshore water is heated up more rapidly than offshore water in spring, the depth of the thermocline in shallow water near the shore is greater than the depth of the thermocline in deep water offshore. The lake water is isothermal in fall and winter, or sometimes very weakly stratified in winter.

The division between the warmer nearshore waters and the cooler offshore waters is referred to as a thermal bar (i.e., the temperature gradients on the same horizontal plane). The thermal bar generally forms close to, within a kilometer of, the shoreline in April. As deeper water becomes stratified, the thermal bar moves progressively farther offshore, and it disappears when most of the lake is stratified sometime in June (Golder, 2011a).

Lake-wide surface temperatures typically range from freezing in the winter to approximately 20ºC in the summer (Beak, 1990 cited in Golder, 2011a). Ice formation in the winter is typically limited to the nearshore areas at the eastern end of the lake within the Kingston Basin (Golder, 2011a).

Ambient water temperature data were collected during 2010 to 2012 as part of the DN Generating Station RCO project EA from 10 historical locations and 21 additional locations (Golder, 2012a). Locations are shown on **Error! Reference source not found.**. **Error! Reference source not found.** presents a comparison of historical ambient water temperatures to water temperatures observed during winter 2010 to 2011 and winter 2011 to 2012.

Average monthly ambient water temperatures during the winter of 2010-2011 are similar to the average monthly ambient water temperatures recorded during the historical period. While the average temperature in November 2011 was comparable to the historical maximum average November temperature (period of 1984 to 1996), the average monthly ambient water temperatures recorded during the winter of 2011-2012 are consistently higher than the maximum mean monthly ambient water temperature recorded during the historical period. On average, the water temperatures recorded from December 2011 to March 2012 in the Darlington Nuclear study area (average of 3.8ºC) were 2.2ºC and 1.7ºC warmer than the historical average and the historical maximum monthly temperatures, respectively. On average, the water temperatures recorded from December 2011 to April 2012 in the Darlington Nuclear study area (average of 4.4ºC) were 2.1ºC and 1.6ºC warmer than the historical average and the historical maximum monthly temperatures, respectively.

Considering the period of available ambient water temperature data (i.e., 1984 to 1996 and 2011 to 2012), the ambient water temperatures observed during the winter of 2011-2012 were the warmest recorded near the Darlington Nuclear study area while the ambient water temperatures observed during the winter of 2010-2011 can be considered similar to the historical average (measured between 1984 and 1996).

Table 2-9: Statistical Summary of Ambient Water Temperatures near Darlington Nuclear

Month	Historical (1984 to 1996)			Winter (2010-2011)	Winter (2011-2012)
	Minimum	Average	Maximum	Average	Average
November	4.9ºC (1988)	6.0ºC	7.7ºC (1985)	na[1]	7.7ºC
December	1.7ºC (1995)	2.7ºC	3.4ºC (1993)	na[1]	4.5ºC
January	0.4ºC (1993)	1.1ºC	1.5ºC (1990)	0.5ºC[1]	2.3ºC
February	0.3ºC (1993)	1.0ºC	1.8ºC (1991)	1.0ºC	2.9ºC
March	0.9ºC (1992)	1.9ºC	2.7ºC (1995)	2.2ºC	5.4ºC
April	3.6ºC (1992)	4.8ºC	5.9ºC (1987)	5.4ºC	6.9ºC
Jan-Feb[2]	0.4ºC (1993)	1.1ºC	1.4ºC (1991)	0.8ºC[1]	2.6ºC
Dec-Mar[3]	1.2ºC (1994-1996)	1.6ºC	2.1ºC (1994-1995)	1.5ºC[1]	3.8ºC
Dec-Apr[4,5]	1.9ºC (1992-1993)	2.3ºC	2.8ºC (1991-1992)	2.7ºC[1]	4.4ºC

Notes:

1. No data collected before January 23, 2011.
2. Average ambient water temperature from January 1st to February 28th.
3. Average ambient water temperature from December 1st to March 31st.
4. Average ambient water temperature from December 1st to April 30th.
5. Historical data for November 1984 to April 1995 only. No data past March 1996

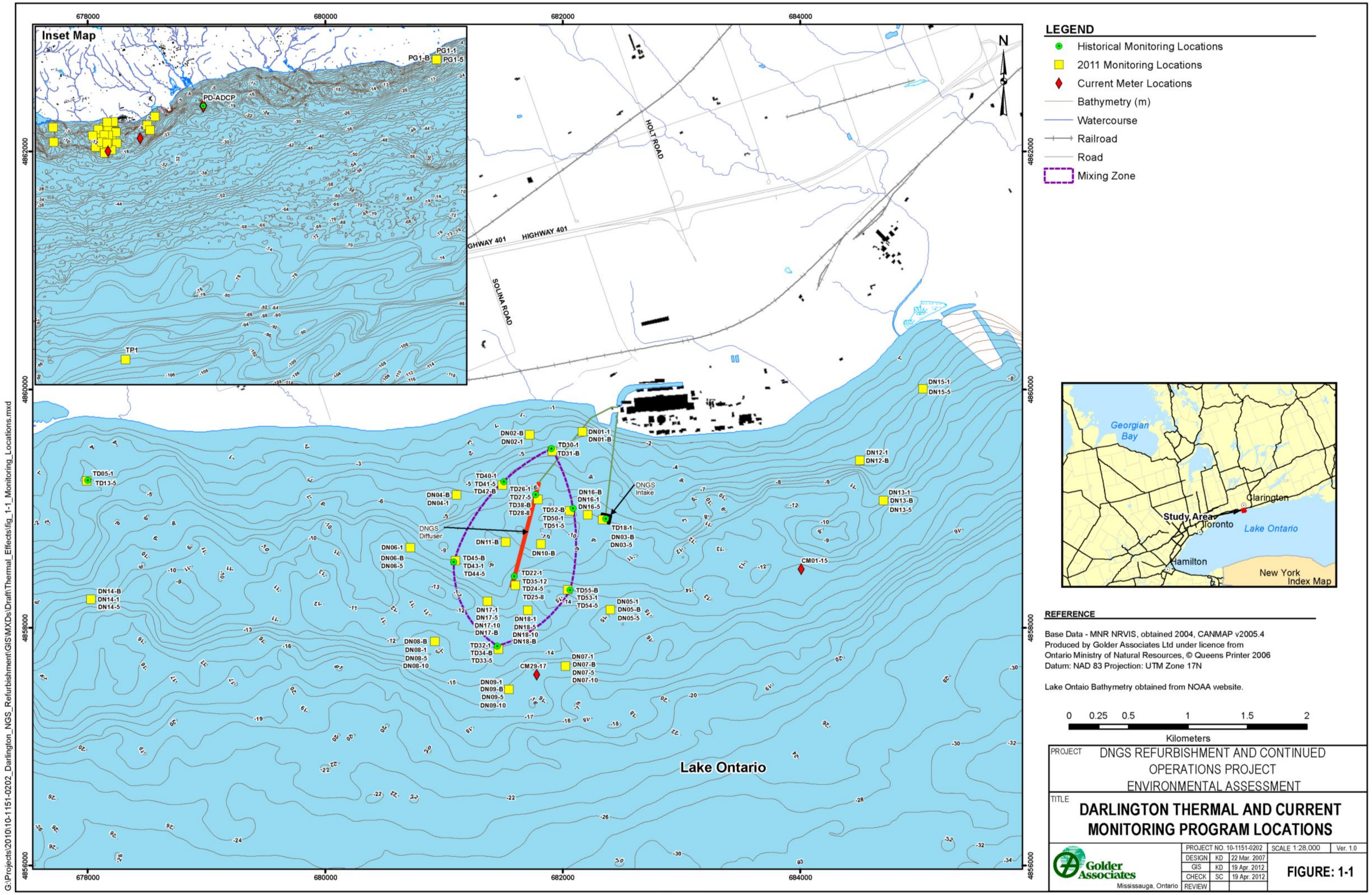


Figure 2-14: Thermal Monitoring Locations for Darlington Nuclear (Golder, 2012a)

2.3.4.3 Water Intake Drawdown

Water is drawn from the lake by DN via an 80-m diameter, porous bottom, submerged intake structure located at a distance of 700 m from the shoreline at a depth of 10 m. The intake is primarily designed to mitigate fish entrainment and impingement by reducing the intake velocity. Drawdown effects of the intake are limited to 5 m above the intake. Disruptions in the thermal regime are limited to a distance of approximately 250 m from the intake (Golder, 2011a).

2.3.4.4 Thermal Plume Horizontal Characterization

Cooling water is returned to Lake Ontario from DN via a 900-m long submerged diffuser extending approximately 1,600 m from the shoreline. The diffuser is equipped with 90 individual 0.6-m diameter discharge ports that extend from 700 m to 1600 m that protrude through the lake bottom. The water depth along the diffuser ranges from 10 to 12 m (Ontario Hydro, 1997 cited in Golder, 2011a).

The discharges cooling water produces either a warm or a cold thermal plume upon release to the bottom of the lake. A warm plume is produced when the discharge temperature is higher than the ambient surface water temperature while a cold plume is produced when the discharge temperature at the bottom of the lake is less than the ambient surface water temperature. Warm plumes are more frequent at DN. Cold plumes are only possible when the plant intake is drawing water that is below the thermal stratification layer. Warm plumes tend to be positively buoyant and spread on the surface while cold plumes tend to rise to the surface due to discharge velocity or to buoyancy effects if the discharge temperature is less than 4ºC. Cold plumes either mix vertically in the water column or form a diving plume.

Historical thermal plumes produced by DN were characterization by Burchat and Romanchuk (1997, cited in Golder, 2011a) using data from 33 synoptic plume surveys carried out between 1990 and 1995 by Ontario Hydro.

Updated surface water temperature data were collected in 2011/2012 for the Darlington Nuclear Thermal and Current Monitoring Program. One of the objectives of the program was to assess the potential thermal effects on aquatic species. Water temperatures were measured at several bottom locations where spawning of round whitefish potentially occurs. The results are presented and discussed in Section 4.4.3.

2.3.4.5 Surface Drainage

2.3.4.5.1 Off-Site Drainage

Lake Ontario is the farthest downstream of the five Great Lakes. It is the smallest in surface area but is substantially larger in volume, 1,640 km^3, than Lake Erie, which is located immediately upstream and empties into Lake Ontario via the Niagara River. The land area draining directly to Lake Ontario is approximately 64,030 km^2. The Niagara River constitutes the single most significant inflow to Lake Ontario. The natural outlet from Lake Ontario is the St. Lawrence River.

The watersheds that discharge into Lake Ontario along the shoreline east and west of the DN site are shown in **Error! Reference source not found.**. These include the Bowmanville-Soper Creek, Westside Creek and Darlington Creek that discharge into the lake to the east of the DN site, and that Tooley Creek, Robinson Creek, Black/Harmony/Farewell Creek and Oshawa Creek flow into the lake on the west side of the DN site. The watersheds range in size from approximately 570 ha (Robinson Creek) to over 16,000 ha (Bowmanville/Soper Creek). The closest creeks east and west of the DN site are Darlington Creek and Tooley Creek, respectively (Golder, 2011a). The main streams and their respective drainage areas and flows are summarized in **Error! Reference source not found.**. The average annual volume of water flowing into Lake Ontario along the shoreline from Bowmanville/Soper Creek to Oshawa Creek is approximately 145 million m^3. The risk of flooding at the DN site from natural waterways such as Darlington Creek and Tooley Creek is considered negligible based on historical flooding records and information collected from the local conservation authority presented in **Error! Reference source not found.**.

Table 2-10: Area and Flows for Watersheds East and West of DN (Golder, 2011a)

Location	Bowmanville/ Soper Creek	Westside Creek	Darlington Creek	Oshawa Creek	Black Harmony/ Farewell Creek	Robinson Creek	Tooley Creek	Total
	East of DN	East of DN	East of DN	West of DN	West of DN	West of DN	West of DN	-
Drainage Area (ha)	16,590	573	1,636	12,048	10,720	570	1,050	43,187
Simulated Monthly Flows (m^3/s)(1)								
January	2.53	0.09	0.26	1.66	1.67	0.08	0.16	6.5
February	2.89	0.12	0.34	1.94	2.06	0.11	0.22	7.7
March	3.55	0.10	0.28	2.23	2.18	0.10	0.18	8.6
April	2.76	0.07	0.18	1.61	1.45	0.07	0.12	6.3
May	1.13	0.04	0.09	0.72	0.65	0.03	0.05	2.7
June	0.70	0.03	0.06	0.45	0.45	0.02	0.04	1.8
July	0.42	0.02	0.03	0.25	0.27	0.01	0.02	1.0
August	0.60	0.03	0.06	0.42	0.45	0.03	0.04	1.6
September	1.00	0.05	0.10	0.62	0.68	0.04	0.06	2.6
October	1.11	0.04	0.08	0.66	0.61	0.02	0.05	2.6
November	3.03	0.09	0.25	1.86	1.76	0.07	0.15	7.2
December	2.84	0.09	0.26	1.77	1.73	0.08	0.16	6.9
Annual Flows (m^3/s)	1.88	0.06	0.17	1.18	1.16	0.06	0.10	4.6
Annual (ha m)	5929	202	523	3729	3669	173	329	14554
Annual (mm)(2)	357	353	320	310	342	304	313	337
2-year(3)	55.5	NA(4)	24.5	43.5	59.7	9.2	12.7	-
5-year(3)	95.1	NA(4)	36.4	69.8	94.9	16.7	23.2	-
10-year(3)	126.3	NA(4)	44.5	91.0	121.8	23.4	29.1	-
25 year(3)	169.5	NA(4)	54.9	123.4	155.4	33.2	39.8	-
50-year(3)	203.1	NA(4)	63.8	147.3	181.3	40.8	48.1	-
100-year(3)	240.2	NA(4)	71.9	208.7	212.9	48.3	55.6	-
Regional Storm(3)	972.1	NA(4)	NA(4)	858.6	673.7	64.9	114.5	-

Notes:

(1) Simulated average monthly flows at the catchment outlets, based on the Precipitation-Runoff-Modeling-System (PRMS) hydrologic modelling carried out as part of the Source Water Protection Program (provided by Central Lake Ontario Conservation Authority (CLOCA)
(2) Average annual volume of water distributed on the total watershed area
(3) Watershed areas and design storm peak flows were obtained from CLOCA
(4) Not Available

Source: Golder (2011)

2.3.4.5.2 On-Site Drainage

The DN site consists of approximately 480 ha of land bounded by Lake Ontario to the south, Holt Road to the east, Solina Road to the west Highway 401 to the north (Golder, 2011a). The surface drainage at the DN site is essentially divided by a railway line which runs east to west across the site. The area south of the railway tracks generally slopes toward Lake Ontario while the area north of the railway tracks and east of Holt Road slopes toward the east.

The ground surface along the lakeshore in the vicinity of the station is slightly elevated (78 masl) compared to the average Lake Ontario water level of 74.7 masl (Golder, 2011a). The ground surface elevation increases to approximately 100 masl at the railway line and approximately 128 masl just south of Highway 401. A soil disposal mound covering approximately 37-ha, located in the northwest corner of the property, is the highest point on the DN site and has an approximate maximum elevation of 133 masl (36 m above the ground surface).

Error! Reference source not found. shows 12 sub-catchments located within the DN site and four that are partially located within the DN site. Storm runoff generated at the DN site is conveyed off-site to neighbouring land or directly to Lake Ontario via natural channels/swales and constructed outfalls.

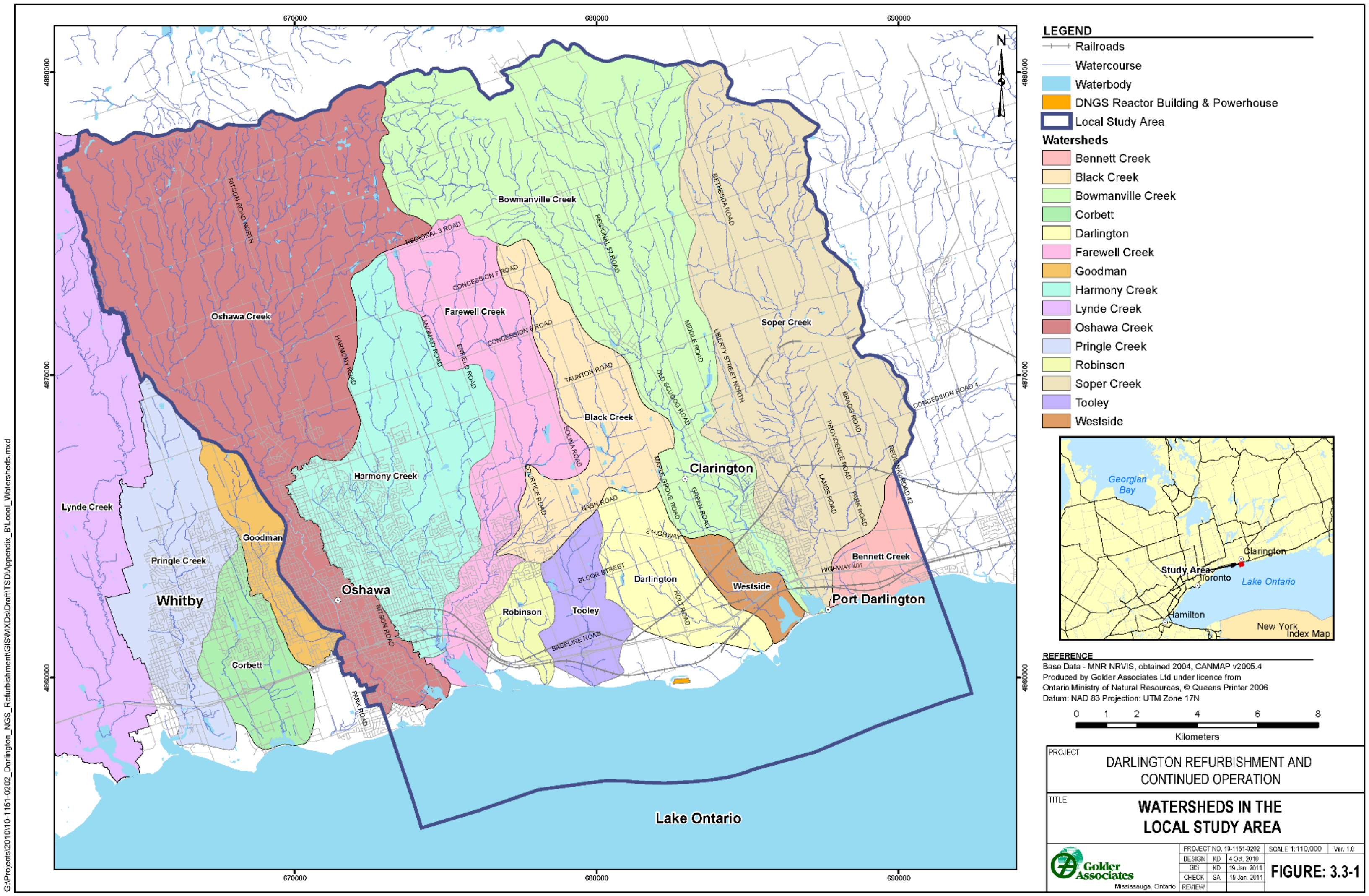


Figure 2-15: Regional Watersheds (Golder, 2011a)

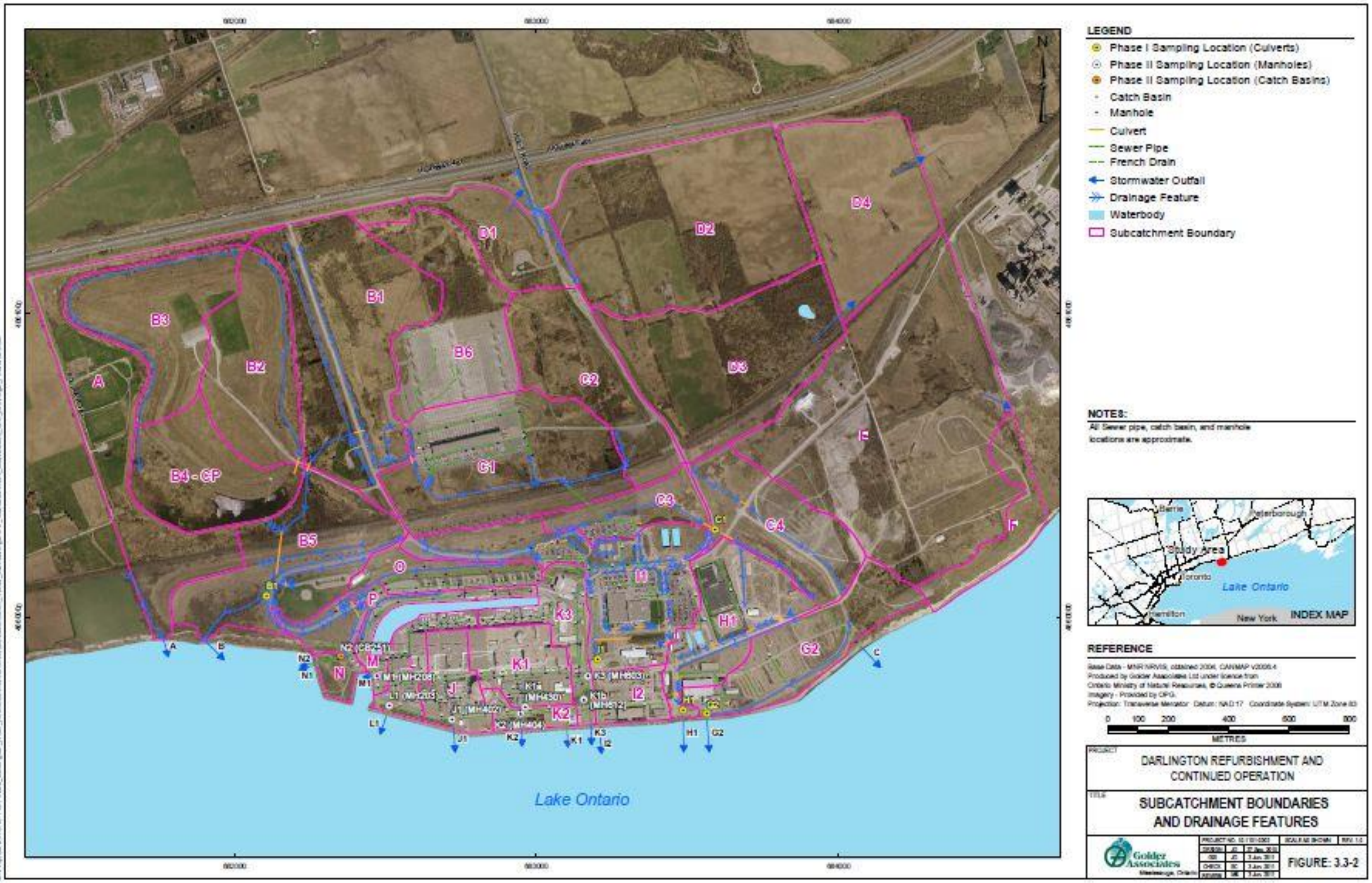


Figure 2-16: Site Surface Water Drainage Catchments (Golder, 2011a)

2.3.5 Vegetation Communities

This section provides a brief overview of regional vegetation communities and summarizes existing vegetation communities located in the DN site area. The regional, local and site vegetation communities and other components of the terrestrial environment are described in greater detail in Beacon Environmental (Beacon) (2009a and 2011).

Most vegetation communities at the DN site are developing from previous land uses and are not mature. The natural vegetation community classes at the DN site include bluffs, beaches, and forests. However much of the DN site vegetation communities are characterized as cultural communities such as plantations, cultural meadows and woodlands that generally resulted from or are maintained by cultural or anthropogenic disturbances (Beacon, 2009a). Due to the successional nature of many of the vegetation communities, measurable change can take place over just a few years. Annual reports for the DN Site Biodiversity program (Beacon, 2012, 2013, 2014, 2015, 2016a) and Species at Risk Summaries (Beacon, 2016b) were consulted for this ERA to consider recent changes to the DN site vegetation communities.

2.3.5.1 Terrestrial Vegetation Communities

The DN site is located within the Niagara portion of the Deciduous Forest Region (Rowe 1972), where the natural forest vegetation is dominated by broadleaved deciduous trees. However, on a regional basis, much of the area has been cultivated over the past century and land use change has resulted in the propagation of numerous anthropogenic vegetation communities. The dominant vegetation cover surrounding the DN site relates to agricultural use, including row crops and pasture land. Some anthropogenic vegetation communities, such as cultural woodland, plantations, thickets and meadow features are in isolated pockets or are located adjacent to natural vegetation communities and are undergoing ecological succession. These areas tend to enhance connectivity and contribute to the natural heritage system (Beacon, 2011).

Natural vegetation features in the region are associated with valley lowlands adjacent to rivers and creeks, and along the Lake Ontario shoreline environment (Beacon, 2011). Oshawa Second Marsh and Westside Marsh, two Provincially Significant Wetlands, and Harmony-Farewell Iroquois Beach Wetland Complex are located near the DN site.

Coastal wetlands are located between the permanent water of Lake Ontario and adjacent upland areas and provide important habitat for migratory birds during the spring and the fall migrations. The Lake Ontario shoreline supports a variety of features as well as east – west connectivity in the near shore aquatic environment for a variety of waterbirds. The shoreline environment east of Westside Marsh provides extensive areas of relatively undisturbed land that is still well-connected. However, the shoreline connectivity is partially fragmented by St. Marys Cement docks and by the DN site. The northern half of the DN site represents approximately 200 ha of more or less contiguous wildlife habitat adjacent to the Oshawa

Second Marsh-McLaughlin Bay Wildlife Reserve – Darlington Provincial Park complex to the west (Beacon, 2011).

Approximately 284 ha, or 58%, of the DN site area is covered by vegetation communities (Beacon, 2009a). Upland vegetation communities and wetland vegetation communities cover approximately 51% and 7% of the DN site area, respectively. Vegetation communities are shown on **Error! Reference source not found.** (Beacon, 2009b). These are discussed in more detail in the following sections.

2.3.5.2 Upland Vegetation Communities

Bluffs

Bluff communities are characterized by variable vegetation cover that can range from patchy and barren to herbaceous cover. Generally bluffs have no more than 10% tree cover because of erosion which results in steep, sometimes near vertical faces that are more than two metres in height. The bluffs are also subject to wave action, and in the case of the DN site, by the lateral movements of water within sand lenses, which are affected by freeze-thaw cycles (Beacon, 2009a). Bluff communities are present west and east of DN and cover a very small portion (1%) of the DN site. The bluff community on the west side of DN is dominated by shrubs, mostly willows with Red-Osier Dogwood and Nannyberry. Trees such as Eastern Cottonwood and Balsam Poplar compose a small part of the canopy cover (10%) while more than 60% groundcover is composed of rush, Canada Goldenrod, Grass of Parnassus, Flat-topped Goldenrod and various sedges, rushes and mosses. This bluff community on the east side of DN is characterized by open or sparsely vegetated land due to ongoing disturbance. The most abundant vegetation on these bluffs is Colt's Foot. Bluff communities are identified as BLO 1 on **Error! Reference source not found.**.

Beaches

The beach community is characterized by patchy vegetation cover that varies from sparse cover to areas with treed cover equal to or less than 60%. Beach areas are subject to active shoreline processes such as wave action, erosion, wind action, and deposition. These areas are located above the seasonal high water mark and are often exposed to extremes in moisture and temperature (Beacon, 2009a). The beach community covers a very small fraction (1%) of the DN site and much of the area is relatively exposed to the lake (Beacon, 2009a). The area of beach present at the DN site varies annually and seasonally depending on the water level of Lake Ontario. However, beach communities can support a variety of important Great Lakes shoreline plant species. This is more evident in the beach community adjacent to the St. Marys Cement shoreline rather than at the DN site shoreline. Beach communities are identified as BBO 1 on **Error! Reference source not found.**.

Forests

The forest community is characterized by a high level of tree cover (more than 60%) as well as variable substrate types and conditions (Beacon, 2009a) and is classified as a coniferous, deciduous, or mixed forest type. The DN site forest community consists of deciduous and mixed forest classes dominated by such indigenous species as Sugar Maple, White and Green Ash, Trembling Aspen, Balsam Poplar, White Birch and Eastern White Cedar. Forested areas cover about 16.3 ha (about 3%) at the DN site. Deciduous forest communities are identified as FOD 3-1, 4-2, 5-8 and 8-1, and mixed forest communities are identified as FOW 4-2 and 7-1 on **Error! Reference source not found.**.

Cultural Woodlands

Cultural woodlands are characterized by a relatively open canopy (less than 60% cover), and arise following anthropogenic disturbance. They cover approximately 9% of the DN site (Beacon, 2009a). They typically consist of a wide variety of indigenous and introduced tree species. At the DN site, groundcover within cultural woodlands consists mainly of grasses and forbs (Beacon, 2009a). Cultural woodlands are identified as CUW 1 on **Error! Reference source not found.**.

Cultural Meadows

Cultural meadows cover approximately 25% of the DN site (Beacon, 2009a). Dominant vegetation types in field meadows include a variety of grasses and forbs. Field meadows are identifies as CUM 1-1 on **Error! Reference source not found.**.

Cultural Thickets

There are many types of cultural thickets on the DN site; they cover approximately 13% of the DN site (Beacon, 2009a). They are formed during early successional stages following anthropogenic disturbance. Shrubs generally comprise the bulk of the vegetation cover and can include a high proportion of non-native species. Young trees are generally found but usually represent a smaller proportion of cover than shrubs. The composition of ground cover species varies but is generally dominated by a variety of grasses and forbs. The DN site cultural thicket community includes mineral, sumac and chokecherry, identified as CUT 1, 1-1 and 1-3 on **Error! Reference source not found.**.

Plantations

Plantations have been deliberately planted with trees. Two types of plantations are on the DN site, including White Pine and Scots Pine, identified as CUP 3-2 and 3-3, respectively, on **Error! Reference source not found.**.

2.3.5.3 Wetland Communities

Marshes

Marsh communities are characterized by dominance by plant species, such as aquatic macrophytes, that are adapted to wet conditions and a small proportion of tree and shrub cover. Marshes typically have variable flooding regimes but the water depth does not exceed 2 m. Marsh areas were found over 13.5 ha on the DN site, or 3% of the total area (Beacon, 2009a). Marsh areas include some poorly drained former laydown areas in the eastern portion of the DN site which are now regenerating. The marsh vegetation communities found on the DN site include marshes dominated by horsetail, hanging fen, reed and canary grasses, cattail, phragmites and bur-reed. These are identified by MAM 2-7, 5 and 2-2, and MAS 2-1, 2 and 2-7, respectively, on **Error! Reference source not found.**.

Open Aquatic

Open aquatic areas at the DN site are identified by a lack of vegetation and a water depth in excess of 2 m. Excluding Lake Ontario, one area within the DN site, the centre of Coots Pond, is considered open aquatic area. It is less than 0.5 ha in extent.

Submerged Aquatic

Submerged aquatic communities have open water depths up to two metres and are characterized by the presence of submerged or floating-leaved wetland plants. Emergent aquatic plant species may also be present but are not dominant and tree and shrub cover is not present. The submerged aquatic community is very sparse on the DN site and occurs at Dragonfly Pond and Coots Pond. The vegetation communities in these areas include species such as Common Bladderwort and stonewort. Ephemeral marsh, dominated by rushes, spike rushes, mint, Water Plantain, and Narrow-leaved Cattail exists along the margins where there is no open water. The submerged aquatic vegetation community is identified by SAS 1-3 on **Error! Reference source not found.**.

Swamp

Swamps are characterized by the presence of wetland trees and shrubs and a low proportion of tree and shrub cover. Swamps have variable flooding regimes, some standing open water and water depth less than two metres. Swamp areas are the most dominant of the Wetland Community Classes at the DN site, covering approximately 19.4 ha or 3.9% of the total DN site. A number of different swamp community classes were identified on the DN site. Some had tree species such as willows, green ash and Manitoba maple present, or shrubs such as willows and Red-osier Dogwood. Swamps are identified by SWD 3-4, 4-1 and SWT 2-2 and 2-5 on **Error! Reference source not found.**.

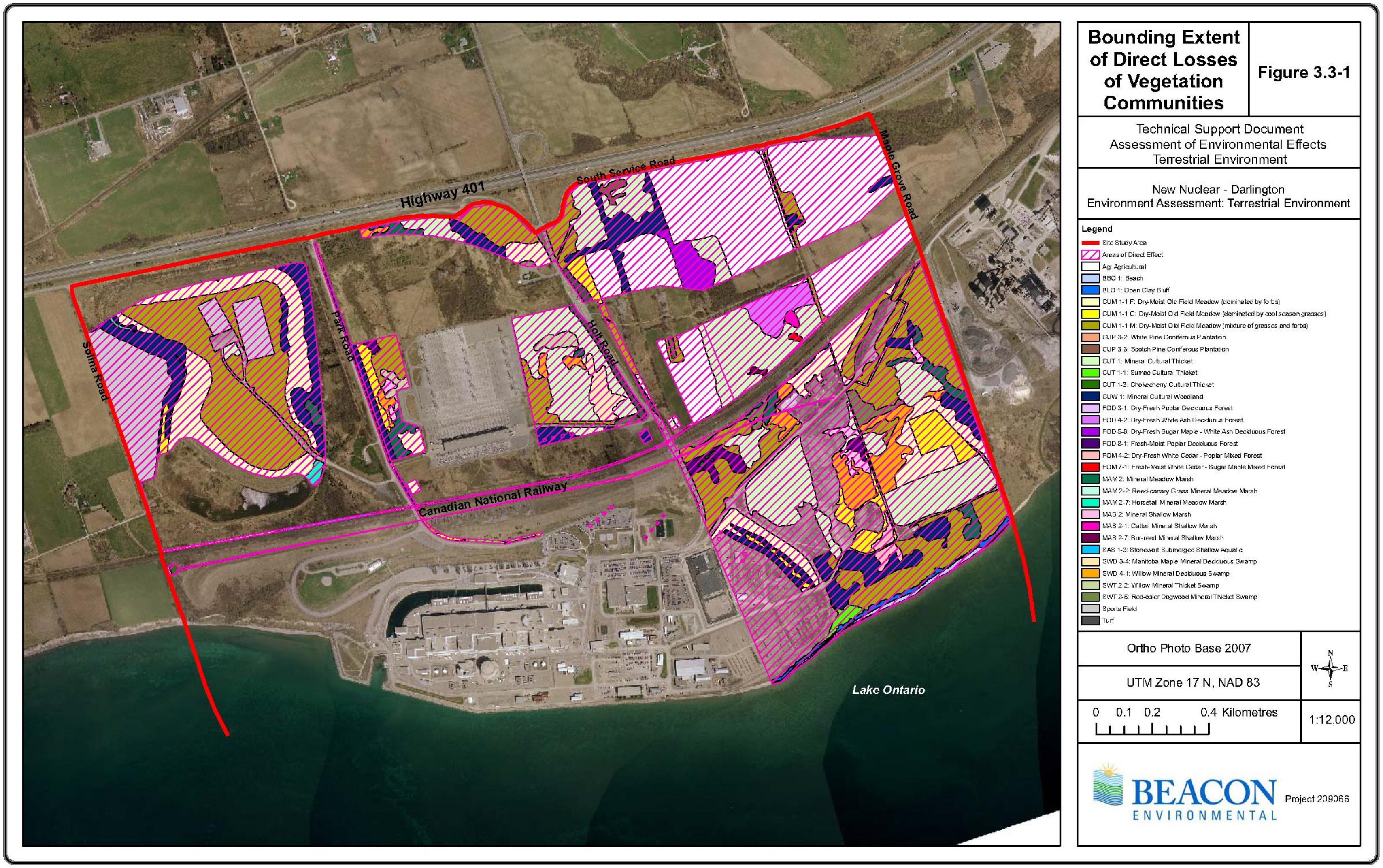


Figure 2-17: Vegetation Communities within the DN Site (Beacon, 2009b)

2.3.5.4 Vegetation Species at Risk

The federal Species at Risk Act [SARA], the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the provincial Endangered Species Act (2007) (ESA) protect designated species at risk and their habitat. The provincial act came into effect on June 30, 2008 and it applies to a species once it appears on the official list. The Committee on the Status of Species at Risk in Ontario (COSSARO is an independent body that classifies native plants or animals in 1 of 4 categories of at risk status under the ESA: endangered, threatened, special concern and extirpated. A list of the plant species that have a species at risk ranking of endangered, threatened or special concern in Ontario, and have been recorded at the DN site, is provided in **Error! Reference source not found.**, along with their regional federal status ranking under Schedule 1 of the federal Species at Risk Act (SARA), and COSEWIC.

The list provided in **Error! Reference source not found.**, includes observations from the 2011 to 2015 inventories. One plant species, Butternut, observed at the DN site during field investigations, is listed as a nationally endangered species provincially and federally (meaning it faces imminent extinction or extirpation). One individual Butternut tree has been inventoried at the DN site in the eastern part of the site. The most serious threat to the Butternut in Canada is a fungal disease known as Butternut Canker. The tree has canker but has persisted for more than nine years which suggests that it may benefit from some form of resistance.

Table 2-11: Plant Species at Risk Observed within the DN Site Area

Scientific Name	Common Name	Federal Species at Risk Status(1)	Provincial Ranking(2)	Most Recent Year Observed
Juglans cinerea	Butternut Tree	Endangered	Endangered	2015

Notes:
The Provincial Species at Risk in Ontario List and Federal List of Wildlife Species at Risk (Schedule 1 of the Species at Risk Act (SARA)) are frequently revised.
(1) SARA Schedule 1 ranks species at risk as Extirpated, Endangered, Threatened Species and Special Concern. Prohibitions of the Act do not apply to species of Special Concern. COSEWIC is also included.
(2) The provincial Endangered Species Act (2007) came into effect on June 30, 2008 and it applies to these species once they appear on the official list.
Source: adapted from Beacon (2016b)

2.3.5.5 Wildlife Habitat

Wildlife habitat is associated with the vegetation communities, and natural and developed areas found within the DN site. Regionally, over 350 bird species and 50 mammalian species have been inventoried, as well as a number of reptiles and amphibians and insect species of interest.

Within the DN site, most connectivity for wildlife currently exists north of the CN railway line (SENES and MMM, 2009). Ponds or other features on the site either directly on or somewhat removed from the CN corridor enhance this connectivity for some wildlife species. Raby Head Marsh located on the St. Marys Cement property, and the constructed ponds, including Treefrog, Dragonfly, and Polliwog ponds and associated natural features on the DN site, also provide potential local pathways for some species. However, the presence of Highway 401 compromises north – south connectivity between the DN site and other local areas to the north.

Wildlife habitat and species found at the DN site are discussed in the following sections.

2.3.5.5.1 Wildlife Habitat and Terrestrial Species

Birds

The DN site provides breeding habitat for many bird species as well as habitat for migrant songbirds. A total of 213 different species of birds has been observed at the DN site and almost all have occurred as migrants, even if they breed on the property (SENES and MMM, 2009). The total annual number of confirmed and probable breeding bird species at the DN site since 1997 has varied between 53 and 69, and was 65 in 2015 (Beacon, 2016a). Bank Swallows have been known to nest at and in the vicinity of the DN site for many years. The DN site also provides waterfowl staging areas and winter habitat at Coots Pond and along the Lake Ontario shoreline, as well as raptor feeding and roosting areas. The list of confirmed breeding birds for the DN site compiled for 2011 to 2015 is presented in **Error! Reference source not found.** for areas southwest and southeast of DN as well as within the DN Generating Station area itself.

Table 2-12: Breeding Bird Species Observed during 2011 to 2015 Biodiversity Surveys South of the Rail Line

Common Name	Scientific Name	Southwest Area	Station Area	Southeast Area
Green Heron	*Butorides virescens*			√
Black-crowned Night Heron	*Nycticorax nycticorax*	√		
Mute Swan	*Cygnus olor*	√	√	√
Canada Goose	*Branta Canadensis*		√	√
Mallard	*Anas platyrynchos*	√	√	√
Gadwall	*Anas strepera*	√	√	√
American Kestrel	*Falco sparverius*	√	√	√
Red-tailed Hawk	*Buteo jamaicensis*	√		
Killdeer	*Charadrius vociferous*	√	√	√
American Woodcock	*Scolopax minor*	√		
Rock Pigeon	*Columbia livia*	√	√	√
Mourning Dove	*Zenaida macroura*	√	√	√
Downy Woodpecker	*Picoides pubescens*	√		√
Northern Flicker	*Colaptes auratus*	√	√	√
Willow Flycatcher	*Empidonax traillii*	√		√
Alder Flycatcher	*Empidonaxalnorum*	√	√	√
Great Crested Flycatcher	*Myiarchus crinitus*	√	√	√

Common Name	Scientific Name	Southwest Area	Station Area	Southeast Area
Least Flycatcher	*Empidonax minimus*	√		√
Eastern Kingbird	*Tyrannus tyrannus*	√	√	√
N. Rough-winged Swallow	*Stelgidopteryx serripennis*	√	√	√
Cliff Swallow	*Petrochelidon pyrrhonota*		√	
Tree Swallow	*Tachycineta bicolor*	√		√
Barn Swallow	*Hirundo rustica*	√		√
Blue Jay	*Cyanocitta cristata*	√		√
American Crow	*Corvus brachyrhynchos*	√	√	√
Black-capped Chickadee	*Poecile atricapillus*	√	√	√
Blue-gray Gnatcatcher	*Polioptila caerula*	√	√	√
House Wren	*Troglodytes aedon*	√	√	√
American Robin	*Turdus migratorius*	√	√	√
Wood Thrush	*Hylocichla mustelina*			√
Northern Mockingbird	*Mimus polyglottus*	√	√	√
Gray Catbird	*Dumetella carolinensis*	√	√	√
Brown Thrasher	*Toxostoma rufum*	√	√	√
Cedar Waxwing	*Bombycilla cedrorum*	√	√	√
European Starling	*Sturnus vulgaris*	√	√	√
Northern Cardinal	*Cardinalis cardinalis*		√	√
Warbling Vireo	*Vireo gilvus*	√	√	√
Yellow Warbler	*Dendroica petechia*	√	√	√
American Redstart	*Setophaga ruticilla*	√		√
Chestnut-sided Warbler	*Setophaga pensylvanica*			√
Common Yellowthroat	*Geothlyphis trichas*	√	√	√
Field Sparrow	*Spizella pusilla*		√	√
Savannah Sparrow	*Passerculus*	√	√	√
Song Sparrow	*Melospiza melodia*	√	√	√
Clay-colored Sparrow	*Spizella pallida*			√
Swamp Sparrow	Melospiza georgiana		√	√
House Sparrow	*Passer domesticus*	√	√	√
American Robin	*Turdus migratorius*	√	√	√
Red-eyed Vireo	*Vireo olivaceus*	√	√	√
Red-winged Blackbird	*Agelaius phoeniceus*	√	√	√
Eastern Meadowlark	*Sturnella magna*	√		√
Common Grackle	*Quiscalus quiscula*	√	√	√
Brown-headed Cowbird	*Molothrus ater*	√	√	√
Orchard Oriole	*Icterus spurius*	√		√
Baltimore Oriole	*Icterus galbula*	√	√	√
House Finch	*Haemorhous mexicanus*	√	√	√
American Goldfinch	*Spinus tristis*	√	√	√
Turkey Vulture	*Cathartes aura*		√	√
Spotted Sandpiper	*Actitis macularius*	√	√	√
Black-billed Cookoo	*Coccyzus erythropthalmus*	√		√
Belted Kingfisher	*Megaceryle alcyon*	√		√
Wild Turkey	*Meleagris gallopavo*	√		√
Ruby-throated Hummingbird	*Archilochus colubris*			√
Eastern Wood Peewee	*Contopus virens*	√		√
Red-breasted Nuthatch	*Sitta canadensis*	√		√

Common Name	Scientific Name	Southwest Area	Station Area	Southeast Area
House Wren	*Troglodytes aedon*	√		√
Indigo Bunting	*Passerina cyanea*			√
Bobolink	*Dolichonyx oryzivorus*	√		√
Rose-breasted Grosbeak	*Pheucticus ludovicianus*			√

Source: Beacon (2012, 2013, 2014, 2015, 2016)

Coots Pond and other moist or wet thicket areas provide breeding habitats for the wetland bird community (SENES and MMM, 2009). The yellow warbler and red-winged blackbird are the most dominant breeding species in these DN areas. Nesting waterfowl are somewhat rare and numbers of nesting waterfowl can be influenced by the presence of aggressive resident species such as the Mute Swan (Beacon, 2016a). Coots Pond also provides waterfowl staging areas and winter habitat. On Lake Ontario, a wide-variety of bird species are associated with the outfall area and with the physical structures (e.g., docks) in the adjacent shoreline at St. Marys Cement (SENES and MMM, 2009).

A woody vegetation area known as Bunting Thicket, in the eastern portion of the site north of the CN railway, provides some of the higher quality migrant bird habitat at the DN site (SENES and MMM, 2009). This area also includes Treefrog, Polliwog and Dragonfly ponds. Bunting Thicket is the largest patch of woody vegetation on the site and the ponds offer additional forage and shelter potential making this thicket attractive to a wider range of bird species. Breeding birds associated with successional upland areas and woodlands have been increasing overtime at the DN site (SENES and MMM, 2009). The bird community associated with these areas is diverse.

The bluffs along the Lake Ontario shoreline provide nesting habitat for bank swallows. The species typically forages and gathers mud in various parts of the DN site. In 2014, the species was listed as provincially threatened (it was designated nationally threatened in 2013). The lakeshore colonies at the DN site were counted in 2015 by two groups of surveyors (HSLN 2015 and Burke 2015, cited in Beacon, 2016a). In 2015 approximately 61% of the existing nest burrows counted from the eastern-most third of the shoreline of the DN site were occupied, totaling approximately 1,800 occupied burrows, which is similar to the occupancy rate found in earlier surveys of this colony (Beacon, 2016a). The colony west of the DN site also presumably still supports nesting Bank Swallows.

<u>Mammals</u>

Thirty mammal species have been inventoried at the DN site as a result of incidental observations during field investigations conducted for other purposes since 1997 (SENES and MMM, 2009). Generally, species which frequent the DN site also frequent the St Marys Cement property. Some species are uncommon at the site, such as Black Bear, Pygmy Shrew and Long-tailed Weasel. Wintering habitat for a number of mammals appears to be poorly developed but present at the site, especially where some cover was present or slopes provided shelter, such as in the south-eastern area of the property. Mammals that winter at the site include White-tailed Deer, Coyote, Red Fox, Eastern Cottontail and Striped Skunk (SENES and MMM, 2009).

Amphibians and Reptiles

Three species of amphibians and four species of reptiles have been inventoried for the DN site during the breeding season from 2011 to 2015, including Green Frog, American Toad, Northern Leopard Frog, DeKay's Brownsnake, Common Gartersnake, Midland Painted Turtle, and Snapping Turtle (Beacon, 2012, 2013, 2014, 2015, 2016b). Green Frog, American Toad, and Northern Leopard Frog, have colonized Treefrog, Polliwog and Dragonfly ponds and are annual breeders. The Raby Head Marsh on the St. Marys Cement property appears to be a relatively productive area for breeding amphibians and may be the source for the amphibian species that have colonized the DN site.

Four species of reptiles were inventoried for Coots Pond in 2015, including the Snapping Turtle, Midland Painted Turtle, Red-eared Slider and Common Gartersnake. Some of these turtles may have been released to the DN site, particularly the non-native Red-eared Slider (Beacon, 2016a).

Insects and other invertebrates

To date 282 insect and other invertebrate species have been inventoried for the DN site (Beacon, 2016a). Moths represent the most diverse group (210 species) followed by dragonflies and damselflies (42 species) and butterflies (31 species). Other invertebrate groups that have been identified include tiger beetles (2 species), spiders (2 species) and other insects (5 species). Many of the moths recorded at the site are generalists, commonly associated with regenerating old field habitats, whereas forest and wetland species are rare (SENES and MMM, 2009). The presence of ponds at the DN site add considerably to the level of biodiversity at the DN site and provide habitat for a wide variety of wetland-associated insects such as dragonflies, butterflies, and other aquatic insects (Beacon, 2016a). Cultural meadows and thickets provide breeding habitat for Monarch Butterflies which require common milkweed as a caterpillar food and flowering asters and goldenrod which provide sources of nectar for adults migrating south in the fall (SENES and MMM, 2009).

2.3.5.5.2 Terrestrial Animal Species at Risk

One reptile species, seventeen breeding bird species, one mammal and one insect species at risk with a provincial ranking of threatened or special concern were recorded at the DN site over the period from 2006 to 2015. A list of the animal species that have a species at risk ranking of threatened or special concern in Ontario and have been recorded at the DN site is provided in **Error! Reference source not found.**, along with their regional federal status ranking under Schedule 1 of the federal SARA and COSEWIC.

Table 2-13: Wildlife Species at Risk Observed within the Vicinity of DN

Scientific Name	Common Name	Federal Species at Risk Status[1]	Provincial Ranking[2]	Most Recent Year Observed
Amphibians and Reptiles				
Chelydra serpentina	Snapping Turtle	Special Concern	Special Concern	2015
Birds				
Ixobrychus exilis	Least Bittern	Threatened	Threatened	2012
Haliaeetus leucocephalus	Bald Eagle	-	Special Concern (since 2008)	2006
Falco peregrinus	Peregrine Falcon	Special Concern	Special Concern (since 2007); previously Threatened	2015
Chlidonias niger	Black Tern	-	Special Concern	2008
Asio flammeus	Short-eared Owl	Special Concern	Special Concern	2007
Chordeiles minor	Common Nighthawk	Threatened	Special Concern (since 2009)	2010
Chaetura pelagica	Chimney Swift	Threatened	Threatened	2009
Contopus cooperi	Olive-sided Flycatcher	Threatened	Special Concern	2012
Contopus virens	Eastern Wood Peewee	Special Concern	Special Concern (since 2014)	2015
Riparia riparia	Bank Swallow	Threatened	Threatened (since 2014)	2015
Hirundo rustica	Barn Swallow	Threatened	Threatened (since 2011)	2015
Hylocichla mustelina	Wood Thrush	Threatened	Special Concern (since 2014)	2014
Cardellina canadensis	Canada Warbler	Threatened	Special Concern	2011
Icteria virens auricollis	Yellow-breasted Chat	Endangered (British Columbia only)	Special Concern	2009
Dolichonyx oryzivorus	Bobolink	Threatened	Threatened (since 2011)	2015
Sturnella magna	Eastern Meadowlark	Threatened	Threatened (since 2011)	2015
Euphagus carolinus	Rusty Blackbird	Special Concern	Special Concern	2010
Mammals				
Myotis lucifugus	Little Brown Myotis (bat)	Endangered	Endangered (since 2013)	2013
Insects				
Denaus plexippus	Monarch (butterfly)	Special Concern	Special Concern	2015

Notes:
The Provincial Species at Risk in Ontario List and Federal List of Wildlife Species at Risk (Schedule 1 of the Species at Risk Act (SARA)) are frequently revised.

Scientific Name	Common Name	Federal Species at Risk Status(1)	Provincial Ranking(2)	Most Recent Year Observed

(1) SARA Schedule 1 ranks species at risk as Extirpated, Endangered, Threatened Species and Special Concern. Prohibitions of the Act do not apply to species of Special Concern. COSEWIC is also included.
(2) The provincial Endangered Species Act (2007) came into effect on June 30, 2008 and it applies to species once they appear on the official list.
Source: adapted from Beacon (2016b)

2.3.6 Aquatic Communities

Aquatic Habitat at the DN site includes tributary watercourses and ponds on the DN site, and the adjacent areas of Lake Ontario. Aquatic habitats support a variety of aquatic plant and animal communities. Depending on the habitat, aquatic biota may include: periphyton, phytoplankton, benthic invertebrates, zooplankton and fishes. Aquatic macrophytes were included as part of vegetation communities discussed in Section 2.3.5.3.

The key aquatic features on the DN site are shown in **Error! Reference source not found.** and include:

- The main branch of Darlington Creek and the intermittent upper portions of tributaries to Darlington Creek: Darlington Creek is a Lake Ontario tributary that has been considerably affected by realignment and channelization over much of its length near the DN site to accommodate road and rail corridors and operations at St. Marys Cement;
- The artificially constructed Dragonfly, Treefrog and Pollywog Ponds;
- The intermittent upper portion of a tributary to Lake Ontario at the eastern toe of the Northwest Landfill Area slope; and
- Coots Pond is a stormwater runoff and settling pond that lies south of the construction waste landfill. Over time, management of the pond according to the DN site biodiversity program has resulted in extensive open water near the eastern end, and emergent vegetation on the margins and dominating the western end of this pond.

The artificially constructed ponds (Dragonfly, Treefrog and Pollywog Ponds) and the intermittent tributaries to Darlington Creek and Lake Ontario do not support fish and are not considered direct fish habitat. Since they are intermittent along most of their reaches aquatic communities in these features are limited. More detail on aquatic habitat in these watercourses and ponds is provided in the following subsections.

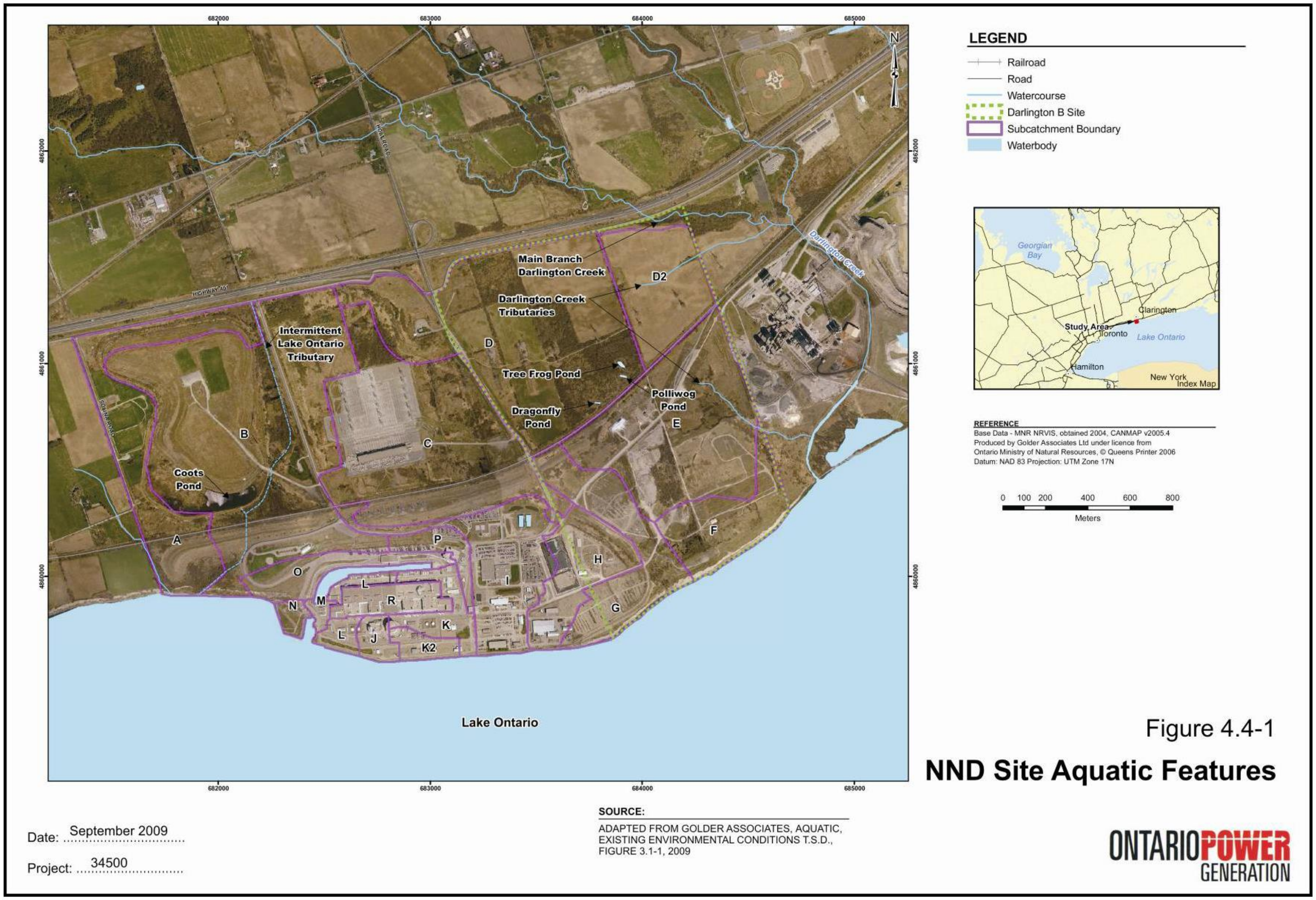


Figure 2-18: Darlington Nuclear Site Aquatic Features (SENES and MMM, 2009)

2.3.6.1 Periphyton, Phytoplankton and Zooplankton Communities

2.3.6.1.1 Lake Ontario

The nearshore environment of Lake Ontario is dynamic, making it generally unfavourable for aquatic plants and algae. Plankton occupy the water column but are not resident near the DN site because they are carried by ambient lake currents.

2.3.6.1.2 Coots Pond

Coots Pond has emergent and submerged aquatic vegetation and possesses wetland and open-water pond habitats.

2.3.6.2 Benthic Invertebrates

2.3.6.2.1 Lake Ontario

The benthic community is limited to relatively few species that can persist in the harsh conditions. The nearshore environment of Lake Ontario is characterized by hard substrates, and is a high energy environment, supporting a limited density and diversity of benthic invertebrates, mainly in shallow areas (<35 m). Chironomids and amphipods are the major components of the nearshore benthic community. Entrainment studies conducted for DN list the most abundant susceptible invertebrate taxa as copepods/cladocerans, followed by spiny water fleas, rotifers and amphipods (SENES and MMM, 2009).

Zebra mussels, and now quagga mussels, have successfully colonized the nearshore area of Lake Ontario and influence local benthic habitat and productivity (Golder and SENES, 2009). The presence of these mussels has altered nutrient flow, food webs and productivity in Lake Ontario, which has in turn resulted in a proliferation of attached algae, such as *Cladophora* along the shoreline. Mussels provide a food source for round goby, another invasive species, which is now very common in the nearshore environment at DN (SENES and MMM, 2009). Mussels have also been linked to the collapse of *Diporeia*, a native amphipod that previously accounted for more than 80% of total benthic production in Lake Ontario and was a critical component of the diets most benthic fishes (GLFC 2007, cited in SENES and MMM, 2009).

2.3.6.2.2 Coots Pond

The Coots Pond habitat quality is sufficient to support a wide array of aquatic invertebrates (Golder and SENES, 2009).

2.3.6.3 Fisheries

2.3.6.3.1 Lake Ontario

More than 90 species of fish are known to inhabit Lake Ontario. Almost all of these species make use of nearshore waters of the lake for spawning, rearing, feeding, and migrations.

The fish community in the vicinity of the DN site is relatively diverse and seasonally dynamic due to the presence of species associated with pelagic, nearshore, tributary, coastal marsh and embayment habitats. Although the community is diverse, fish density tends to be low (Golder and SENES, 2009). The seasonal abundance of many of the fish species may be related to the relatively short periods associated with inshore spawning migrations or may extend throughout seasons when water temperature and weather conditions are favourable for generalized foraging in the nearshore (Golder and SENES, 2009).

Fish species within the nearshore fish community identified during fish impingement studies at DN between May 2010 and April 2011 include Round Goby, Alewife, Rainbow Smelt, Spoonhead Sculpin, Pumpkinseed, White Sucker, Smallmouth Bass, Emerald Shiner, American Eel, Slimy Sculpin, sunfish species, Threespine Stickleback, Brown Bullhead and Yellow Perch (SENES, 2011a). Round Goby and Alewife are the dominant fish species affected by impingement at DN. Effects related to impingement and entrainment are discussed in Section 4.4.4.

2.3.6.3.2 Darlington Creek

Darlington Creek near the DN site supports a warmwater fish community. A habitat assessment of Darlington Creek was conducted in the spring of 2009 and indicated that habitat quality varied considerably along the creek, with higher quality habitat found in the upper reaches and lower quality habitat in the lower reaches in the vicinity of St. Marys Cement near the entrance to Lake Ontario (Golder and SENES, 2009). The intermittent tributaries to Darlington Creek on the DN site lack permanent aquatic habitat and do not support fish. They are often dry, based on field visits and review of aerial photographs. Their primary habitat function is the conveyance of water and nutrients to downstream habitats (Golder and SENES, 2009). The E tributary had no fish when surveyed during a wet period with water flow. The D2 tributary was dry when surveyed, and overgrown with weeds in the upper swale and corn crops in lower swale. There was no stunting of the crop as would be expected if water was frequently flowing, and no refuge pools were observed.

2.3.6.3.3 Artificially Constructed Ponds

Treefrog, Polliwog and Dragonfly ponds are small wetland ponds that are poorly connected to on-site watercourses and do not support fish (Golder and SENES, 2009).

2.3.6.3.4 Tributary to Lake Ontario

The channelized intermittent tributary to Lake Ontario passes between the construction waste landfill and Park Road, skirts south of Coots Pond and crosses the CN rail line before reaching Lake Ontario. It receives occasional overflow from the Coots Pond outfall. Beaver ponds provide permanent aquatic habitat during periods when there is no flow in the tributary. Fisheries connection to Lake Ontario is limited due to the high gradient and presence of long culvert enclosures (Golder and SENES, 2009). However, the beaver ponds are likely to contain Northern Redbelly Dace, introduced via Coots Pond outfall.

2.3.6.3.5 Coots Pond

Habitat quality in Coots Pond is sufficient to support one small fish species, Northern Redbelly Dace (Golder and SENES, 2009). Coots Pond was intended to be fish-free to encourage amphibian production. However, Northern Redbelly Dace has become established and has historically been abundant in the pond, although no fish have been observed in biodiversity studies in recent years (Beacon, 2016). The presence of this minnow species is consistent with a habitat of this type, as Northern Redbelly Dace are common inhabitants of wetlands and beaver ponds.

2.3.6.4 Fish Species at Risk

One fish species at risk with a provincial ranking of endangered has been recorded at the DN site over the period from 2006 to 2015, the American Eel (*Anguilla rostrata*). Its provincial ranking is provided in **Error! Reference source not found.**, along with its regional federal status ranking under Schedule 1 of the federal Species at Risk Act (SARA) and COSEWIC.

Table 2-14: Fish Species at Risk Observed in the DN Area

Scientific Name	Common Name	Federal Species at Risk Status(1)	Provincial Ranking(2)	Most Recent Year Observed
Anguilla rostrata	American Eel	Threatened	Endangered	2016
Acipenser fulvescens	Lake Sturgeon	Threatened	Threatened	1998

Notes:
The Provincial Species at Risk in Ontario List and Federal List of Wildlife Species at Risk (Schedule 1 of the Species at Risk Act (SARA)) are frequently revised.
(1) SARA Schedule 1 ranks species at risk as Extirpated, Endangered, Threatened Species and Special Concern. Prohibitions of the Act do not apply to species of Special Concern. COSEWIC is also included.
(2) The provincial Endangered Species Act (2007) came into effect on June 30, 2008 and it applies to species once they appear on the official list.
Source: SENES (2009)

Observations of American eel at the DN site have been infrequent. An electrofishing study included observations of adult American eel in the nearshore at the DN site (Tarandus 1998, cited in SENES, 2009). More recently, one adult American eel was impinged at DN in February 2011 and four in 2016. OPG is a participant in an American eel program associated with the Saunders Generating Station at the east end of Lake Ontario. Additionally, OPG has obtained a permit from Ontario MNRF to collect any dead American eel found on the trash racks at DN and store until pick-up by the MNRF (MNRF, 2016)

Two large juvenile Lake Sturgeon (*Acipenser fulvescens*) were documented at Bond Head, 13.5 km east of the DN site, during a 1998 DN monitoring program thereby suggesting that general nearshore nursery/foraging habitat may be present within the region. The southern Hudson Bay/ James Bay population of Lake Sturgeon has a provincial ranking of Special Concern but the Lake Ontario population has no ranking. Although the DN site nearshore may be considered suitable habitat for large juvenile sturgeon, it is only a small part of widely available similar habitat along the north shore of Lake Ontario (SENES, 2009).

2.3.7 Human Land Use

Land use information includes existing land uses and land use patterns, and any policy framework that guides future growth and development in the Region of Durham. Information provided in the DN EA (2011) was supplemented with:

- Durham Region (2015) Durham Region Profile Demographic and Socio-economic Report. Planning and Economic Development Department. October 2015.
- Durham Region Health Department (DRHD). 2015. Population at a Glance.
- OPG (2013d) Review of the Darlington Nuclear Site Specific Survey. NK38-REP-03481-10002

2.3.7.1 Regional Land Use: Durham Region and the Municipality of Clarington

DN is located in the Region of Durham, Municipality of Clarington, on the north shore of Lake Ontario. It is approximately 6 km east of the city of Oshawa and approximately 70 km east of downtown Toronto.

Durham Region is one of the most populous and urbanized regions of Ontario. It is characterized by a variety of landscapes and communities including major lakeshore urban communities in the southern portion, and small rural towns, villages, hamlets and farm holdings in the northern portion of the Region. Urban land uses generally parallel the shoreline of Lake Ontario in the communities of Pickering, Ajax, Whitby, Oshawa and Clarington, while rural land uses are found in the communities of Brock, Scugog and Uxbridge in the northern portion of Region. The manufacturing sector within the Region is strong and is largely associated with the presence of General Motors whose head office and assembly plants are located within the City of Oshawa. Durham Region hosts ten operating nuclear reactors on the DN site and the Pickering Nuclear site. OPG alone was the second largest employer, next to General Motors in 2010, while in Clarington (the host community for DN) it was the largest employer. Agriculture remains an important component of Durham Region’s economy.

Urban land uses in the Municipality of Clarington, including residential, commercial and employment, are generally located in Courtice, located approximately 6.4 km northwest of the site, and Bowmanville, located approximately 4 km northeast of the site. Agriculture is a predominant land use in the Municipality of Clarington, and is less predominant in the City of Oshawa west of the site.

2.3.7.2 Agricultural Production

An inventory of Ontario agricultural data was completed for the 2012 DN Site-Specific Survey (OPG, 2013d) using data from the 2011 Census of Agriculture conducted by Statistics Canada. The total area of land used for fruits, vegetables and potatoes in Ontario was estimated at 80,444 ha (804 km^2). Of that, 24.6% is used for fruit production, 56.6% is used for vegetable production and 18.8% is used for potato production. Assuming that agricultural production is uniform across Ontario, the total land used for fruit, vegetable and potato production within a semi-circle of 30 km radius centered at DN was estimated to be 348 km^2, 800 km^2 and 266 km^2, respectively. Fruit, vegetable and potato production from within the semi-circle was estimated to be 4.1×10^8 kg, 2.1×10^9 kg and 5.1×10^8 kg, respectively.

2.3.7.3 Water Supply

Three municipal water supply plants are located in the vicinity of DN, which are Oshawa, Bowmanville, and Newcastle Water Supply Plants (WSPs). These plants obtain their water from Lake Ontario. The water supplies for Oshawa and Bowmanville areas are provided primarily from the Oshawa and Bowmanville WSPs, respectively. The more rural areas of Durham are supplied by individual water supply systems from either surface water intakes or ground water wells.

Error! Reference source not found. summarizes the offshore distance and depth of the WSP intakes, capacities, populations served and distance of the intakes from the DN site for each of the DN WSPs (OPG, 2013b).

Table 2-15: Water Supply Plant Information (OPG, 2013b)

Water Supply Plant		Distance of Intake from Shore (m)	Intake Depth (m)	Capacity (m^3/day)	Population Served	Estimated Distance of Intakes from DN (km)
Oshawa WSP	East Intake	920	10	134,000	175546	7.8 W

Water Supply Plant		Distance of Intake from Shore (m)	Intake Depth (m)	Capacity (m^3/day)	Population Served	Estimated Distance of Intakes from DN (km)
	West Intake	830	8.5			
Bowmanville WSP		1,260	11	36,368	35,803	6.8 ENE
Newcastle WSP		1,070	11	8,173	11,152	13 ENE

2.3.7.4 Recreational Fishing

Recreational fishing and boating are activities undertaken by some residents from the LSA and Durham region. Recreational fishing by local residents is largely on an occasional basis (AECOM, 2011). A number of fishing related activities are organized in the Durham Region, which generally attract tourists and occasional visitors to the region. These include the Great Salmon Hunt (June to August), the Northshore Fishing Derby (August) and the Port Darlington Annual Fish Derby. The Great Salmon Hunt is a lakewide event, and it is estimated that approximately 150 boats are launched from Port Darlington each year for this event. Between 40 and 50 boats are launched from Port Darlington as part of the Northshore Fishing Derby, and the Port Darlington Annual Fish Derby attracts 25 to 30 boats (AECOM, 2011).

A marine prohibited area exists around the intakes and diffusers for the DN site which covers a zone less than 3 km^2. The objectives of the prohibition are to protect the intake and diffuser structures from damage, and to protect boaters from danger that may arise from the presence of the structures and possibly from turbulence and/or changes in currents in the area. The existing prohibition zone represents a small fraction of the nearshore area that is available for recreational boating and fishing (AECOM, 2011).

2.3.8 Population Distribution

The population for the Durham region is expected to increase from 729,030 in 2016 to 960,000 in 2031 with the population density of urban areas increasing over this time period (Durham Region, 2015). Population growth from 2004 to that estimated for 2014 for the Durham Region was highest among seniors 85 years and older, while populations actually decreased among children ages 5 to 14 years and among adults 35 to 44 years (DRHD, 2015). Overall population growth in Durham Region between 2004 and 2014 was highest in Ajax (34%) and Whitby (23%), and smallest in Pickering, with an increase of 4% (DRHD, 2015). The DN Site is located within the regional municipality of Clarington. Population growth from 2004 to 2014 for Clarington was 16.4% with a total estimated population of 90,579 in 2014 (DRPD, 2015).

The majority of residents in Durham Region live in urban areas. Over 90% of the population in Pickering, Ajax, Oshawa and Whitby reside in urban areas, whereas, the townships of Brock, Scugog and Uxbridge represent the greatest percentage of the rural population in Durham. Urban/rural population trends for Durham indicate this trend will continue into 2031 (DRPD, 2015).

Children under the age of 15 comprised 18.6% of Durham's population in 2011, while young persons (aged 15-29), adults (aged 30-64) and older adults (aged 65+) comprised 19.9%, 49.4% and 12.1%, respectively (DRPD, 2015). Ontario Population Estimates for 2015 (DRHD, 2015) indicate that the 50 to 54 age group is the largest age group for both males and females in Ontario and in Durham Region.

The most recent census data for the region are for 2011. A population of approximately 0.5 million resides within a 30 km radius of the DN site, based on 2011 census data shown in **Error! Reference source not found.** (OPG, 2013d). The bulk of this population (approximately 89% or 439,168 individuals) resides west of the DN site, in the west-south-west to north-north-west sectors, while approximately 11% (55,872 individuals) reside east of the DN site in the north to east-north-east sectors. Areas south and east of the DN site (south-west to east) are occupied by Lake Ontario. Almost no residents (5) reside within a 0 to 2 km radius of the DN site and approximately 86,533 individuals reside within 10 kilometers of the DN site.

Table 2-16: Population Distribution Surrounding DN Based on 2011 Census Data

Direction	N	NNE	NE	ENE	E to SW	WSW	W	WNW	NW	NNW	Total
0-2 km	0	0	0	0	0	0	5	0	0	0	5
2-4 km	1,295	1,934	0	0	0	0	0	10	102	15	3,356
4-6 km	2,200	8,466	797	0	0	0	455	494	324	430	13,166
6-8 km	5,224	13,037	498	194	0	0	6,646	15,604	1,430	0	42,633
8-10 km	1,343	958	4,019	176	0	2,951	9,637	10,093	647	549	27,373
10-12 km	267	159	2,240	1,726	0	7,800	21,487	18,067	835	846	53,427
12-14 km	210	317	3,726	402	0	0	21,852	23,134	1,480	308	51,429
14-16 km	290	1,643	710	190	0	73	22,069	16,649	184	179	41,987
16-22 km	737	843	1,097	412	0	13,511	80,229	15,535	645	1,525	114,534
22-30 km	1,739	875	850	298	0	95,338	35,779	8,913	1,300	2,038	147,130
Total	13,305	28,232	10,937	3,398	0	119,673	198,159	108,499	6,947	5,890	495,040

Source: OPG, 2013d

In 2011, the ethnic origin for most Durham Region residents was European (70.6%), North American (29.4%), and Asian (12.8%) descent (DRPD, 2015). In 2011, 8,905 persons in Durham (1.5% of the population) identified with at least one Aboriginal group, which represents an increase of 2,304 over 2006, when only 6,565 persons (1.2%) identified with one or more Aboriginal groups (DRPD, 2015). Overall, the ethnicity of the Clarington population was also largely European and North American with very low proportions of ethnic Africans, Asians, Latin/South Americans, Aboriginals and Caribbean individuals

(DRPD, 2015). The nearest First Nations community outside of Durham Region, approximately 35 km from the DN site, is Mississaugas of Scugog Island First Nation (SENES, 2011d).

2.4 Uncertainty in Site Characterization

The DN Site is considered to be well-characterized. No residual uncertainties in the Site Characterization have been identified.

3.0 HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment (HHRA) is a process that evaluates potential health risks to humans exposed to chemical and radiological contaminants. The HHRA accounts for the concentrations and activities of the contaminants in different environmental media; the exposure pathways by which humans may be exposed to these contaminants, and the toxicity of these contaminants to humans through oral, dermal, and inhalation exposure. The HHRA was conducted according to the CSA N288.6-12 standard, with the following supporting documents used where necessary, as documented in this report:

- Health Canada (HC). 2010a. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0, Prepared by: Contaminated Sites Division, Safe Environments Directorate, September 2010 (Revised 2012).
- Health Canada (HC). 2010b. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals ($DQRA_{CHEM}$), Prepared by: Contaminated Sites Division, Safe Environments Directorate, September 2010.

The HHRA consists of the following steps:

- Problem Formulation;
- Exposure Assessment;
- Toxicity Assessment; and
- Risk Characterization.

3.1 Problem Formulation

The problem formulation provides the objectives, goals, framework and methodology for the risk assessment and consists of identifying the relevant components for the HHRA. These components include the identification of human receptors that may be potentially present in or around the DN Site; the identification of exposure pathways operating on or around the DN Site, based on the fate and transport of chemical and radiological contaminants in the environment; the identification of chemical, radiological, and other stressors; and a conceptual site model that illustrates all of these relationships.

3.1.1 Receptor Selection and Characterization

The receptors for the HHRA were selected to be appropriate for assessment of both chemical and radiological stressors on human health.

3.1.1.1 Receptor Selection

3.1.1.1.1 On-site Non-Nuclear Energy Workers

On-site workers, contractors, and visitors are potentially exposed to environmental contaminants, both chemical and radiological, but these exposures are considered and controlled through the Health and Safety Management System Programand the Radiation Protection Program, and are not considered in this HHRA, as discussed below.

OPG's Health and Safety Management System Programis designed to ensure the protection of employees, contractors and visiting members of the public. The program outlines a systems approach used to manage risks associated with activities, products and services of OPG Nuclear operations. Contractors are required to maintain a level of safety equivalent to OPG staff while working at an OPG workplace. Work at DN is subject to safe work planning requirements where safety hazards are identified and mitigating measures are communicated through Pre-Job Briefings. Routine or planned work is governed by approved procedures and operating instructions (OPG, OPG-PROG-0010).

The Radiation Protection Program is designed to ensure that doses for employees, contractors and visiting members of the public are below regulatory limits, and As Low As Reasonably Achievable (ALARA), social and economic factors being taken into account. Employee radiation doses are monitored to ensure they do not exceed exposure control levels that are below regulatory limits. Doses to visitors and contractors are also monitored. Only workers classified as Nuclear Energy Workers (NEWs) may perform radioactive work. Visitors are limited to non-radioactive work and escorted by a qualified NEW. Personal information is collected for the purposes of dose reporting (OPG, N-PROG-RA-0013 R007).

Because human exposures on the site are kept within safe levels through the Conventional Safety Program and Radiation Protection Program, on-site receptors are not addressed further in the HHRA.

3.1.1.1.2 Members of the Public

Off-site members of the public are potentially exposed to low levels of airborne or waterborne contaminants. The most-affected off-site members of the public are defined as the "critical group". Potential critical groups are defined through the site specific survey and their doses are calculated in the OPG Annual Environmental Monitoring Program (EMP) Reports. Current EMP designs are based on the 2006 site specific survey information (Schweinsberg, S., 2006). Site specific surveys were updated in 2012 (OPG, 2013d) and pathway analyses were updated in 2014, however these did not identify any significant changes with the potential to substantially alter the predictions of the ERAs or the implementation of the EMP. Any changes to human receptors incorporated in the 2016 update of the DN derived release limits (DRLs) will be implemented into the EMP and will be reflected in future EMP Reports. The focus of the HHRA is on potential risks to off-site members of the public in the critical groups through exposures to chemical and radiological stressors in air and water.

3.1.1.2 Receptor Characterization

The critical group receptors used for the risk assessment are considered appropriate for assessment of potential health effects due to chemical and radiological stressors. Their characteristics are described in Appendix E of the 2015 EMP Report (OPG, 2016b) and are presented below.

- The **Oshawa/Courtice** potential critical group consists of urban residents in Oshawa and in the community of Courtice within the Municipality of Clarington located to the W and WNW of the site starting at about 6 km from the site. These residents obtain drinking water from the Oshawa WSP, and grow a small percentage of their annual fruit and vegetable consumption in gardens.

- The **Bowmanville** potential critical group consists of urban residents located to the NE and NNE of the site at distances from 4 to 7 km from DN. These residents obtain drinking water from the Bowmanville WSP, and grow a small percentage of their annual fruit and vegetable consumption in gardens. They also purchase a small percentage of their annual meat, poultry and egg consumption from local farms.

- The **West/East Beach** potential critical group consists of urban residents located to the ENE of the site at distances from 3.5 km to 7 km. These residents obtain their drinking water from both wells and the Bowmanville WSP, and grow a small percentage of their annual fruit and vegetable consumption in gardens. They also purchase a small percentage of their annual poultry and egg consumption from local farms.

- The **Farm** potential critical group consists of agricultural farms (but not dairy farms) located in all landward wind sectors around the DN site at distances from 1.5 km to 10 km. The closest is in the WNW wind sector. Members of this group obtain their water supply mostly from wells and use it for drinking, bathing, irrigation and watering livestock. They also obtain a large fraction of their annual fruit, vegetable and animal product consumption from locally grown products.

- The **Dairy Farm** potential critical group consists of dairy farms located in all landward wind sectors around the DN site at distances from 3 km to over 10 km. The closest is in the N wind sector. Members of this group obtain their water supply from wells and use it for drinking, bathing, irrigation, and livestock watering. They also obtain a large fraction of their annual fruit, vegetable and animal product consumption, including fresh cow's milk, from locally grown products.

- The **Rural Resident** potential critical group consist of residents in rural areas in all landward wind sectors around the site at distances of about 2 km to 5 km. Members of this group obtain about half of their water supply from wells and half from the Bowmanville WSP, and use it for drinking, bathing, and irrigation. They obtain a moderate fraction of their annual fruits, vegetables, poultry and eggs from locally grown products.

- The **Industrial/Commercial** potential critical group consist of adult workers whose work location is close to the nuclear site. The closest location for this group is the St. Mary's cement plant about 1.8 km NE of the site, however, the most affected location due to updated meteorological data is the Courtice Water Pollution Control Plant about 2 km W of DN. Members of this group are typically at this location about 23% of the time. They consume water from the Bowmanville WSP.

- The **Sports Fisher** potential critical group is comprised of non-commercial individuals fishing near the DN site discharge, about 0.5 km S of the DN site. Members of this group were conservatively assumed to obtain their entire amount of fish for consumption from the vicinity of the DN site and spend 1% of their time at the discharge location where atmospheric exposure occurs.

- The **Camper** potential critical group consists of campers at the Darlington Provincial Park, located from 4 to 6 km W of the site at the lakeshore, and includes McLaughlin Bay, a shallow water body where some fishing takes place. The campers are assumed to be in the park no more than six months of the year. They consume drinking water from the Oshawa WSP, and purchase a small fraction of their annual fruits, vegetables, meat, poultry, and eggs from locally grown sources. (OPG, 2016b)

OPG calculates the annual public dose for the three DN potential critical groups which have yielded the highest dose estimates in recent years. These are the Dairy Farm, the Farm, and the Rural Resident. Estimates of risk for these critical groups are expected to exceed those for the other critical groups, and the assessments of the Dairy Farm, Farm, and Rural Resident critical groups are therefore expected to be protective of the other receptors.

Aboriginal groups were considered in the selection of receptors for the HHRA. Information from engagement with Aboriginal communities, councils and organizations gathered during preparation of the DN Refurbishment EA (SENES, 2011d) showed no evidence that indicated use of lands, water or resources for traditional purposes within the Local Study Area. It is possible that a few individuals may carry out these activities in a very limited fashion. However, these activities would be restricted by the urbanization, population density, and preponderance of private land in the area. Based on this, it was concluded that any influence from DN on the health of Aboriginal peoples was likely to be bounded by the assessment for non-Aboriginal groups located much closer to DN who consume foods local to DN as part of their diet. For example, the farm receptors obtain a large fraction of their fruits, vegetables and animal produce locally, with the nearest location at 1.5 km from DN. While there may be dietary differences, such as more wild game in the Aboriginal diet, and more farm produce in the farm diet, both groups will have high local fractions, and overall dietary intakes will be similar. However, the atmospheric dispersion factor for the farm receptor is roughly 220-fold higher than that for the Mississaugas of Scugog Island First Nation, located 35 km north of DN. Therefore, the nearest Aboriginal receptor location at 35 km is unlikely to receive a higher dose than the receptor groups currently assessed in the ERA.

3.1.2 Selection of Chemical, Radiological, and Other Stressors

The DN facility emits chemical and radiological contaminants to air and water in the normal course of operations. Measurements and modeled concentrations of chemical contaminants in air and water, from 2011 to the end of 2015, were screened against available screening benchmarks that are protective of human health to determine if any contaminants of potential concern (COPCs) required further study in the context of human health risk assessment. Where no data were available during the 2011 to 2015 period, older data were used. The selection of COPCs in other environmental media is also discussed below.

3.1.2.1 Selection of Chemical COPCs in Air

The main sources of atmospheric emissions result from boiler chemical emissions and fuel combustion. Boiler treatment chemicals including hydrazine, morpholine and degradation products are used within the feedwater system to prevent corrosion in the boilers. These chemicals are released to the atmosphere through controlled boiler venting. Combustion emissions result from the Standby Gas Turbines, Auxiliary Power System Combustion Turbine Units, Auxiliary Power System Diesel Generators and minor sources. These systems release carbon monoxide, nitrogen oxides, sulphur dioxide, suspended particulate matter, trace volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs).

The Air ECAs from 2011 to 2015 and the ESDM Reports from 2011 to 2014 were consulted to aid in chemical COPC selection for air.

The main body of each ESDM report presents the estimated atmospheric emissions of COPCs from the DN site (OPG, 2012a, 2013a, 2014a, 2015a). In accordance with Section 19 of Ontario Regulation (O. Reg) 419/15, the impact of contaminant emissions was assessed by comparing modelled ½ hour point of impingement (POI) concentrations to the MOECC ½ hour POI limits and against the Ontario Ministry of the Environment and Climate Change’s (MOECC’s) Jurisdictional Screening Levels (JSLs) list, using O. Reg 346 dispersion models. The ESDM reports (2011-2014) also indicate that OPG conducted a preliminary screening for negligible sources and negligible chemicals using Section 7 criteria in the MOE’s Procedure for Preparing an ESDM Report (MOE, 2009, cited in OPG, 2012a, 2013a, 2014a, 2015a). Examples of methods used in the ESDM to screen out negligible contaminants include using emission thresholds or deminimus concentrations. Significant sources and contaminants are identified in Table 1 of the ESDM (OPG, 2015a) and are the focus of the secondary screening presented in this ERA and discussed below.

The emergency equipment assessment was outside of the main body of the ESDM Report, consistent with MOE guidance with respect to assessing nitrogen oxides emissions for emergency equipment. The air dispersion modelling results for nitrogen dioxide from the emergency generator assessment showed that under all scenarios in the assessment the maximum predicted concentration remained below the ½ hour POI limit of 500 µg/m³.

For the purposes of this human health risk assessment, ½ hour maximum predicted POI concentrations for each of the modeled parameters in the ESDM reports were compared to health-based screening benchmarks from the MOECC. No modelled exceedances of MOECC screening criteria occurred from 2011 to 2014, as shown in Appendix A (Table A.1). When no MOECC screening criteria were available for particular contaminants, MOECC's ambient air quality criteria (AAQCs) or the Texas Commission on Environmental Quality Effects Screening Levels (TCEQ, 2015) were used instead. Modelled ½ hour POI concentrations were adjusted to values for longer timeframes as needed to accomplish these comparisons, based on MOECC guidance. None of the maximum predicted POI concentrations exceeded either the TCEQ screening levels or the AAQCs.

Based on these results, no chemical COPCs in air have been carried forward into the human health risk assessment.

3.1.2.2 Selection of Chemical COPCs in Surface Water

The surface water screening is based primarily on measurements of chemical COPCs in lake water, to which human receptors may be exposed. In addition, concentrations of chemical parameters in the CCW discharges from 2011 to 2015, and concentrations of chemical parameters in storm water discharges to Lake Ontario from 2011 to 2015, were screened to ensure that the list of chemical COPCs was complete. If a COPC was identified in lake water, effluent or storm water, it was forwarded for further consideration in the human health risk assessment.

3.1.2.2.1 Lake Water Sampling

As documented in the Darlington Nuclear Refurbishment and Continued Operation Environmental Assessment Follow-Up Program – Effluent Characterization Sampling Plan (NK38-PLAN-03480-10003-R000), OPG identified a list of potential contaminants in liquid effluent that may be related to DN operations. This list of contaminants has been used as a basis for the screening of COPCs in Lake Ontario

The data set for lake water was based on two main sampling campaigns. The earliest portion of the lake water data set was based on the water quality sampling campaign conducted in November 2007 and May and September 2008 as part of the New Nuclear Darlington Environmental Assessment.

The next most recent portion of the data set was made up of 140 samples of Lake Ontario water collected in the study area of the ecological risk assessment for the New Nuclear Environmental Assessment (SENES, 2009a).

The lake water data set also included more recent data obtained from a supplementary study on chlorine and morpholine in Lake Ontario. In 2014, lake water sampling for Total Residual Chlorine (TRC) and morpholine was conducted near the DN diffuser discharge to determine if:

a) TRC concentrations remain below the Provincial Water Quality Objective (PWQO) of 2 µg/L, and less than the toxicity reference values for aquatic life.

b) Morpholine concentrations are less that the interim PWQO of 4 µg/L and the toxicity reference values for aquatic life.

The results of this supplementary study were included in the lake water data set for this ERA.

Maximum measured concentrations from these data were compared to the following criteria to determine potential COPCs, in order of preference:

- The more conservative of:
    - Health Canada Canadian Drinking Water Quality Guidelines (HC, 2012);
    - Ontario Drinking Water Standards for Potable Ground Water (MOE, 2011) and the related GW1 Component Values for protection of potable water that underlie the Site Condition Standards in Ontario Regulation 153/04; and,
    - United States Environmental Protection Agency (U.S. EPA) Human Health “Organism Only” Criteria (2016) for ingestion of freshwater fish
- Ontario Provincial Water Quality Objectives, which are assumed by MOECC to be protective of human health (MOEE, 1994);
- Ontario Interim Provincial Water Quality Objectives, which are assumed by MOECC to be protective of human health;
- Mean Background Concentrations (based on sampling station LWC-1 at Cobourg from the 2015 baseline environmental monitoring program to support the Pickering Safe Storage Project).

Chemicals with maximum concentrations exceeding the most conservative of these benchmarks were carried forward as chemical COPCs in this assessment. Note also that contaminants were not deemed to be COPCs if they exceeded mean background concentrations by less than 20% as differences of less than 20% are typically not statistically discernible or measurable in the field or laboratory (Suter et al., 1995, 1996). The results of this screening can be found in Table A.2 in Appendix A.

The maximum analyzed concentration of nitrate in Lake Ontario water by SENES (2009a) was 89.7 mg/L, compared to a Canadian Drinking Water Quality Guideline of 10 mg/L from Health Canada. As such, nitrate was carried forward as a COPC in the HHRA.

The maximum measured chemical analysis for total aluminum in Lake Ontario water was 3.5 mg/L, as compared to a Canadian Drinking Water Quality Guideline (CDWG) of 0.1 mg/L. However, the maximum measured concentration for dissolved aluminum (in a filtered sample) was 0.01 mg/L, which is an order of magnitude below the CDWG. The relatively high concentration of aluminum in the unfiltered samples is therefore considered to be indicative of the presence of suspended solids in the samples. Since the dissolved phase of aluminum is expected to be considerably more bioavailable than any aluminum in a suspended phase, which is likely to be in the oxide form, aluminum has not been carried forward as a chemical COPC for human health. In addition, the CDWG is an Operational Guideline (OG); according to HC (2012), no consistent and convincing evidence exists that adverse effects are caused by aluminum in drinking water.

As shown in Table A.2, the detection limit for phosphorus exceeds its screening PWQO benchmark, which is based on ecological health. Phosphorus is considered to be essentially non-toxic to humans, as it exists in the environment as phosphate, where it acts as a nutrient, and has not been associated with adverse effects in humans. As such, phosphorus has not been considered to be a COPC for human health.

Based on this analysis, and as shown in Table A.2 in Appendix A, only nitrate was carried forward as a chemical COPC in water for assessment of human health.

3.1.2.2.2 Liquid Effluent Sampling

Information from 2011 to 2015 on the concentration of COPCs discharged in liquid effluents into the environment was available from DN ECA reports, MISA reports, and National Pollution Release Inventory reports. This information was assessed to aid in COPC selection to ensure that the lake water chemical COPC selection was complete. DN liquid effluents originate from the following systems:

- Condenser Cooling Water (CCW) System;
- Service Water Systems;
- Steam and Feedwater System;
- Water Treatment Plant (WTP);
- Radioactive Liquid Waste Management System (RLWMS);

- Inactive Drainage System; and
- Storm Water Management (SWM)/Yard Drainage System.

As shown in **Error! Reference source not found.**, all liquid effluents from DN are discharged into the CCW (either via the Intake Forebay or directly to the CCW Discharge Duct), with the exceptions of stormwater drainage from the DN site. The DN Yard Drainage system discharges to Lake Ontario either directly through the storm sewers or through drainage swales/creeks via culverts which eventually discharge to Lake Ontario. Screening of this stream was undertaken for the HHRA, with results presented separately in Section 3.1.2.2.3. As such, only the final station discharge released from the CCW discharge duct was assessed as the exposure point for screening at this stage.

3.1.2.2.2.1 Monitoring for ECA Requirements

As part of the ECA requirements, the effluent from the CCW is sampled and analyzed for compliance with effluent limits for unionized ammonia, hydrazine, morpholine, pH, and TRC. For each of these chemicals, the maximum measured concentration in the CCW effluent from 2011 to 2015 was screened against the same benchmarks as the lake water samples. This approach is conservative because these CCW concentrations were measured before dilution in the lake, so risks to human health are not underestimated.

Hydrazine does not have a PWQO or a Canadian Council of Ministers of the Environment (CCME) water quality guideline, or a drinking water quality guideline from either Ontario or Canada. However, the U.S. EPA estimated that a hydrazine concentration of 0.01 µg/L would result in a cancer risk level of one in one million ($1x10^{-6}$; EC/HC 2011), based on a drinking water intake rate of 2 L/day and no exposure amortization. Because this value offers the same level of protection from cancer risk as MOECC's own calculated screening benchmarks, the value was used as a human health screening level for hydrazine in water. The maximum measured hydrazine concentration in CCW effluent was greater than this selected screening benchmark. Similarly, the maximum measured morpholine concentration was greater than its selected screening benchmark.

The MOE (1979) water quality objective for pH in freshwater is within the range from 6.5 to 8.5. The MOE considers the PWQO for pH to be the range within which waters are the most productive (MOE, 1979). Surface water with pH above the upper limit of the PWQO may be less productive. The Canadian water quality objective for pH for freshwater biota is within the range from 6.5 to 9.0 (CCME, 2008). This same pH range has been recommended by the International Joint Commission (1977) and the U.S. EPA (1986). The range from 6.5 to 9.0 is considered to be harmless to fish and benthic invertebrates, although the toxicity of other contaminants, such as ammonia, may be affected by pH changes within this range. Several guidelines for pH thus exist to protect ecological health, but no guidelines are available from regulatory agencies to protect human health, since humans are expected to be less sensitive to pH changes in natural waters than ecological receptors. The pH is therefore primarily an ecological concern, and is not considered relevant to human health. In addition, the maximum measured pH is less than the CCME upper bound, and the effluent will be diluted in Lake Ontario; therefore, pH has not been carried forward for assessment in the HHRA.

Although TRC exceeded the PWQO (0.002 mg/L) during the 2011 to 2015 period (maximum 0.008 mg/L), it does not exceed the HC drinking water range of 0.04 to 2.0 mg/L. Although HC has not set a drinking water limit, at these concentrations, taste and odour related to chlorine or its by-products are generally within the range of acceptability for most consumers (HC, 2009). The World Health Organization (WHO) reports that at a residual chlorine concentration of 0.6 mg/L some sensitive individuals could have an aversion to the taste. The WHO has set a drinking water limit for chlorine of 5 mg/L, based on a 1992 study by the U.S. National Toxicology Program on rodents; however, no adverse health effects were observed at this concentration (WHO, 2011). Based on the above discussion, TRC has not been carried forward for further quantitative assessment in the HHRA.

Based on these arguments, and as shown in Table A.3 in Appendix A, hydrazine and morpholine were identified as COPCs for the HHRA.

3.1.2.2.2.2 Monitoring for MISA Requirements

Effluent monitoring is required under the MISA program, as described in Section 2.2.2.1.6. As part of the MISA program, COPCs for monitoring are identified for the following Control Points:

- Radioactive liquid waste (RLW) management tanks, Control Point 01 on **Error! Reference source not found.**, given the designation 0100;
- Water treatment plant (WTP) neutralization sump, Control Point 04 on **Error! Reference source not found.**, given the designation 2200; and
- Building effluent treatment facility lagoon, Control Point 17 on **Error! Reference source not found.**, given the designation 5000 (note that this is the outlet for the inactive drainage mentioned in Section 3.1.2.2.2).

A New MISA Control Point has also been added at the Building Effluent Management System Effluent Unit (Control Point 19 on **Error! Reference source not found.**, given the designation 5100). The remaining MISA Control Points at DN are normally inactive because their corresponding effluent water streams are directed elsewhere in the plant.

For MISA monitoring parameters measured in the RLW and WTP (phosphorus, Total Suspended Solids (TSS), zinc, iron, oil and grease, and aluminum), Golder (2011a) conducted mixing calculations to obtain expected concentrations of COPCs in the CCW based on effluent discharge to the CCW from the RLW and the WTP. These calculations have been updated for this ERA. Golder (2011a) based their mixing calculations on a worst case scenario, assuming effluent was discharged at the MISA limits. This is conservative, since exceedances of MISA limits have not been observed for the majority of the COPCs over the past from 2005 to 2009 (Golder, 2011a). A similar approach was adopted for the updated calculations.

Since none of the MISA monitoring parameters (except for pH) for the RLW are measured in the CCW duct after mixing, mixing calculations for the RLW discharge to the CCW duct were based on the maximum concentrations of the RLW discharge allowed under MISA. The calculated CCW concentrations were compared against the human health COPC screening benchmarks and were found to be well below these limits. The concentration in the CCW was calculated according to the following equation:

$$\text{Conc. in CCW} = \frac{\text{Conc. in RLW} \bullet \text{RLW flow rate} + \text{Intake Conc.} \bullet \text{CCW flow rate}}{\text{CCW flow rate}}$$

The maximum RLW discharge flow rate was assumed to be 0.0126 m^3/s (C. Cheng, pers. comm., September 30, 2016) and the CCW flow rate was assumed to be 114.56 m^3/s, which is equivalent to the average of daily CCW flows from 2011 through 2015.

For the WTP discharge to the CCW, the concentration in the CCW was calculated according to the following equation:

$$\text{Conc. in CCW} = \frac{\text{Conc. in WTP effluent} \bullet \text{Effl. flow rate} + \text{Intake Conc.} \bullet \text{CCW flow rate}}{\text{CCW flow rate}}$$

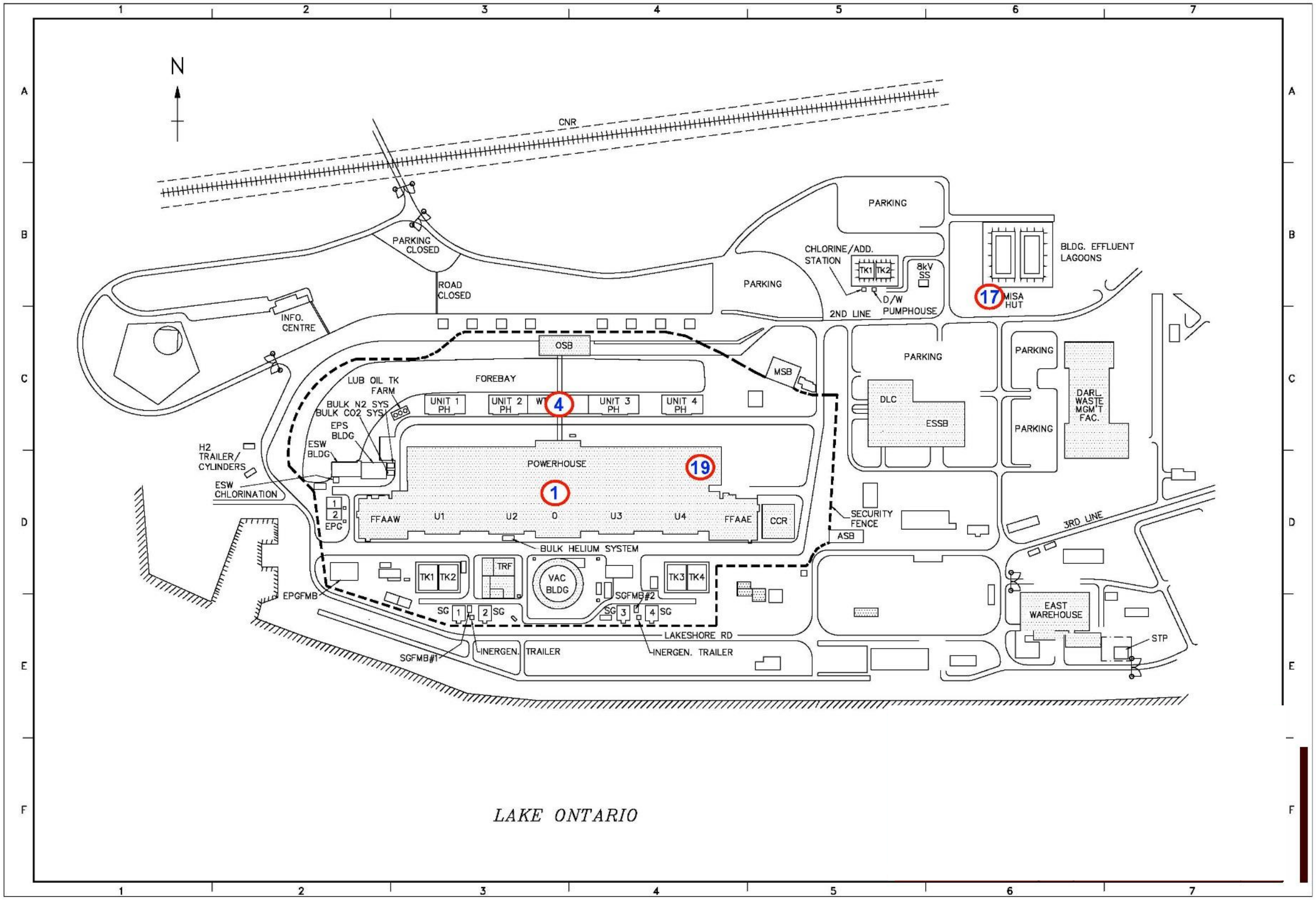


Figure 3-1: Darlington Station General Arrangement Active MISA Control Points

The maximum WTP discharge flow rate was assumed to be 0.04 m^3/s, following Golder (2011a), and the CCW flow rate was assumed to be 114.56 m^3/s, as above. The calculated CCW concentrations were compared against the human health screening benchmarks and were found to be well below these limits.

Based on historical MISA reports from 2011 to 2014, only one exceedance of MISA limits has been observed. The April, 2011 acute toxicity sample failed for rainbow trout with 80% mortality (the *Daphnia magna* result was 0%). As this was the first ever failure at the WTP neutralization sump (CP2200), the sample was retested at the same laboratory as well as at a second independent laboratory. Both samples passed and subsequent testing by University of Guelph experts confirmed that the fish used by the initial contract laboratory, despite the aggressive sterilization treatment, had an unusually resistant infection, which was hard to detect.

Based on this information and on the updated mixing calculations, no exceedances of screening benchmarks in the CCW are expected for the MISA parameters, as shown in Table A.4 in Appendix A. No additional chemical COPCs for water were identified through this screening.

3.1.2.2.2.3 2016 Effluent Characterization Study

In support of the review and update of the existing EcoRA and HHRA for DN, liquid effluent sampling and analysis was performed in 2016 to provide data for characterization of non-radiological parameters. This program is part of a follow-up monitoring program from the 2011 Refurbishment and Continued Operation (RCO) Environmental Assessment (EA) which includes broad spectrum characterization of DN liquid effluents to confirm EA predictions of no residual adverse effects on surface water. Under the program, five effluent streams were characterized through weekly sampling and chemical analysis for metals, glycols, morpholine, TRC, petroleum hydrocarbons (PHCs), phosphorus and phosphate, alkyl ethoxylates, alkylphenol ethoxylates, and linear alkylbenzene sulphonates. These streams included RLW, inactive drainage (building effluent treatment facility lagoon, as described in Section 3.1.2.2.2.2), Boiler Blowdown (BB), WTP, and the CCW.

Several parameters, including aluminum, copper, iron, molybdenum, and zinc, did not meet their respective Data Quality Objectives (DQOs) in field blank samples. However, discussions with Maxxam have indicated that the results in the field blanks were not abnormal, and that when dealing with trace metals with the low detection limits that are being used for the sampling program, exceedances of the detection limit by two to five times is not uncommon. Maxxam also indicated that the levels of these parameters in the field blanks relative to the levels in the samples should be considered when assessing the data. For example, in general, the measured concentrations of aluminum and zinc in effluent samples are five to ten times higher than in most field blanks and therefore the blanks' contributions are negligible and the data are useable. As such, the data from the

2016 effluent characterization study are considered acceptable for the purposes of conducting a human health risk assessment.

Because all liquid effluents from DN are discharged into the CCW (see **Error! Reference source not found.**), with the exceptions of stormwater drainage from the DN site, the CCW stream was the focus of this screening exercise. Parameter concentrations from CCW samples were screened against the same human health screening benchmarks used for the lake water screening.

Morpholine exceeded its screening benchmark in the RLW stream, as shown in Table A.5a, and it was not measured in the CCW stream during the 2016 Effluent Characterization Program. Since the RLW stream flows at 0.0126 m^3/s (Cheng, *pers. comm.*, September 30, 2016), and the average daily CCW flow rate from 2011 through 2015 was equivalent to 114.56 m^3/s, a multiplied dilution factor of roughly 1×10^{-4} (or, equivalently, a divided dilution factor of about 9,000) is expected to apply, and morpholine from the RLW stream is not expected to lead to an exceedance of morpholine in the CCW. Morpholine is therefore not considered a COPC based on the 2016 effluent characterization study results.

Similarly, TRC exceeded its screening benchmark in the WTP stream, as shown in Table A.5a, and it was not measured in the CCW stream during the 2016 Effluent Characterization Program. Since the WTP stream was assumed to flow at 0.04 m^3/s (Golder, 2011a), and the average daily CCW flow rate from 2011 through 2015 was equivalent to 114.56 m^3/s, a multiplied dilution factor of roughly 9×10^{-5} (or, equivalently, a divided dilution factor of about 10,000) is expected to apply, and TRC from the WTP stream is not expected to lead to an exceedance of TRC in the CCW. TRC is therefore not considered a COPC based on the 2016 effluent characterization study results.

The maximum analyzed concentration of aluminum in the CCW stream exceeded its selected human health screening benchmark. Because dissolved aluminum in the CCW is not measured as part of the effluent monitoring study, it is not possible to exclude the possibility that aluminum in this stream is bioavailable. However, we note that the selected screening benchmark is an Operational Guidance (OG) value that is not health based, and that according to HC (2012), no consistent and convincing evidence exists that adverse effects are caused by aluminum in drinking water. Therefore, aluminum has been excluded as a chemical COPC for this assessment.

The maximum analyzed concentration of lead in the RLW stream was 19.8 µg/L, which exceeded the selected human health screening benchmark of 10 µg/L. The maximum measured concentration of lead in the CCW stream, however, was 0.335 µg/L, which is almost two orders of magnitude less than the screening benchmark. As such, lead in the RLW stream is not expected to cause an exceedance of lead in the CCW, and as such, lead has not been carried forward as a chemical COPC in this assessment.

As shown in Table A.5a, the maximum measured concentration of phosphorus in the CCW stream exceeds its screening benchmark, which is based on ecological health, but it is considered to be essentially non-toxic to humans. It exists in the environment as phosphate, where it acts as a nutrient, and has not been associated with adverse effects in humans. As such, phosphorus has not been considered a COPC for human health.

A screening of alcohol ethoxylates (AEOs), nonylphenol ethoxyacetic acid (nonylphenol ethoxycarboxylate, or NP1EC), and linear alkylbenzene sulphonates (LASs) in surface water samples taken from the CCW is summarized in Table A.5b. Human health screening benchmarks were not available from regulatory sources for these substances, so a literature search was conducted for appropriate toxicity information.

For AEOs, following HERA (2009), the lowest available No Observed Adverse Effect Level (NOAEL) of 50 mg/kg/day for an individual AEO (C12-13 AE6.5) was assumed to apply to all AEOs, and a drinking water screening value of 512,500 µg/L for the most sensitive human life stage (an infant) was derived from this NOAEL assuming, also following HERA (2009), 75% bioavailability of AEOs in the human gastrointestinal tract. The maximum analyzed total AEO concentration from the study was 121 µg/L, which is over three orders of magnitude less than the derived screening value. As such, none of the individual AEO parameters, nor total AEOs, were carried forward as human health COPCs.

Similarly, a NOAEL of 85 mg/kg/day, as presented by HERA (2013), was assumed for LAS toxicity. With an assumed bioavailability of 80% (HERA, 2013), a drinking water screening value of 929,333 µg/L for the most sensitive life stage (an infant) was derived. The maximum analyzed total LAS concentration from the study was 15.3 µg/L, which is over four orders of magnitude less than the derived screening value. As such, none of the individual LAS parameters, nor total LASs, were carried forward as human health COPCs.

Lastly, NP1EC was not detected in any of the CCW samples from the study, so NP1EC has not been carried forward as a human health COPC.

3.1.2.2.3 Storm Water Sampling

The SWM System, or Yard Drainage System, collects storm runoff from the entire DN site and discharges to Lake Ontario either directly through the storm sewer drainage system or through drainage swales/creeks via culverts which eventually discharge to the Lake. Surface drainage around the DN site is comprised of 7 catchments and 12 sub-catchments, as shown in **Error! Reference source not found.**. A brief discussion of the drainage pattern is presented below:

- Sub-catchments A and B discharge to Lake Ontario via natural streams;
- Sub-catchment C discharges through a culvert and a storm sewer at the southeast quadrant of the property and ultimately into Lake Ontario;

- Sub-catchment D1 discharges to a Highway 401 roadside ditch;
- Sub-catchment E flows into a marshy area and ultimately to the eastern property limit, after which it discharges to Lake Ontario;
- Sub-catchment F discharges to Lake Ontario;
- Sub-catchments H1 and I1 discharge through culverts into Lake Ontario;
- Sub-catchments G2, I2, J, K1, K2, K3, L, M, and N discharge through storm sewers into Lake Ontario; and,
- Sub-catchments O and P connect via culverts and storm sewers to discharge out of Catchment N.

The quality of the storm runoff generated at the DN site has been reported in the following studies:

- DNGS Storm Water Control Study (Sharma 1997);
- DNGS Storm Water Remediation Report (Dunstall 2000);
- DNGS Storm Water Remediation Report 2001 (Dunstall 2001);
- Follow-Up Storm Water Control Study of Four Drainage Outfalls (Dunstall 2002);
- Follow-Up Stormwater Control Study for SW Outfalls - Phase I, Fall 2010 (Golder 2011b); and
- Follow-Up Stormwater Control Study: Phase II Monitoring Program, Spring 2011 (Golder 2011c).

As reported by SENES and MMM (2009), in 1995 and 1996, OPG (then Ontario Hydro) commissioned a Storm Water Control Study (Sharma 1997, cited in SENES and MMM, 2009) at the DN site under Ontario's MISA program. As part of this study, the DN site storm water drainage areas and flow pathways were identified and documented. Estimates of flow rates for each drainage area were derived and sources of potential environmental contaminants were identified.

Based on the results of the 1997 study, a two-phase Storm Water Control Plan (Dunstall 2000) was developed. Phase I of the plan recommended storm water management measures to improve the quality of storm water discharges and reduce TSS loadings to Lake Ontario. Phase II included a verification study to investigate the effectiveness of the management measures to reduce TSS concentrations in the storm water discharges and eliminate toxicity to aquatic organisms.

The 2000 Phase I Storm Water Remediation Program was then implemented for the potentially contaminated drainage areas. The remediation efforts consisted of regrading, slope stabilization, landscaping, plantation and placement of erosion control blankets at areas susceptible to erosion. The remediation work was reported in detail by Dunstall (2000 and 2001). The 2001 Phase 2 toxicity and TSS reduction evaluation study was documented in detail by Dunstall (2002). In this study, four locations corresponding to failed toxicity tests in 1996 were monitored. One *Daphnia magna* acute lethality test failure was observed at outfall G-2 in May 2001 as compared to a total of six toxicity test failures in 1996; however, there was no detectable change in the TSS and iron concentrations measured at these locations.

In 2010, data on storm water drainage on the DN site and surrounding areas was updated through the DN Storm Water Study (Golder 2011b, 2011c), which was conducted in two phases. There are no directly applicable criteria regulating allowable concentrations for the water quality parameters measured in storm water discharges from the DN site (with the exception of the DN ECA which limits the allowable oil and grease concentrations in storm/groundwater collected in the Emergency Power Generator Buildings, the Emergency Power Generator Fuel Management Building, the Standby Generator Buildings, the Standby Generator Fuel Management Buildings and the Standby Generator Fuel Oil Storage Tank Dykes and discharged to the Yard Drainage System). The water quality data collected during the Phase I and Phase II Program storm events were reviewed and, where possible, compared to observed/typical urban runoff water quality (as cited in the U.S.EPA Results of the Nationwide Urban Runoff Program (NURP) –Final Report Volume I (U.S.EPA 1983) and in the MOE Storm Water Management Planning and Design Manual (SWMP) (MOE 2003)) since the site consists mainly of buildings, parking lots, landscaped areas and ponds and is, therefore, comparable to a typical urban site as compared to a rural site which consists of mostly agricultural fields. The data were also compared to other criteria used as guidelines, i.e., PWQOs and the Durham Region Sewer Use By-law (Durham Region 2004).

The available storm water chemical analyses from 2010 and 2011 were compiled and maximum concentrations from this data set were converted to equivalent loadings to Lake Ontario using the maximum measured peak flow rates at the time of sampling (Golder 2011b, 2011c). These equivalent loadings were then converted to estimated Lake Ontario concentrations using the Golder (2011a) observation that Lake Ontario current speeds at Port Darlington were on average 0.09 m/s in both easterly and westerly directions. The wave zone in Lake Ontario extends to about 2 m depth, and this depth is achieved approximately 120 m from the shoreline. The storm water loading was assumed to be diluted in an alongshore flow, calculated as the current speed times the cross-sectional area of the wave zone. The calculation resulted in an estimated average Lake Ontario shoreline flow rate of 10800 L/s.

The estimated Lake Ontario concentrations were then screened against the same human health screening benchmarks used in the original lake water screening, as shown in Table

A.6 in Appendix A. None of the estimated Lake Ontario concentrations exceeded the selected human health screening benchmarks. Any chemicals for which no human health screening benchmarks were available, were not considered to be COPCs. These chemicals included the following: alkalinity, chloride, TDS, TSS, ammonia, nitrite + nitrate, total oil and grease, bismuth, calcium, lithium, magnesium, potassium, silicon, strontium, tellurium, thorium, tin, titanium, tungsten, individual xylene isomers, and individual polychlorinated biphenyl (PCB) congeners. Of this list, several are covered by other screened chemicals: nitrate + nitrite is covered by separate nitrate and nitrite screenings; total oil and grease is covered by other petroleum hydrocarbon screenings, including benzene, toluene, ethylbenzene, and xylene (collectively known as BTEX) and fractions F1 through F4 of petroleum hydrocarbons; individual xylene isomers are covered by the total xylenes screening; and individual PCB congeners are covered by the total PCB screening. In addition, several other parameters are known to not be human toxicants, such as alkalinity, chloride, TDS, TSS, calcium, lithium, magnesium, potassium, and silicon. No human toxicity information is available for the remaining contaminants. As such, none of the contaminants in storm water were assessed as chemical COPCs in the HHRA.

3.1.2.3 Selection of Chemical COPCs in Soil

For the human health risk assessment, potential risks from soil were determined to be of little concern. On-site workers, contractors, and visitors are potentially exposed to on-site soil; however, these exposures are considered and controlled through the Health and Safety Management System Program described in Section 3.1.1.1.1. For example, minimal soil exposure would be incurred by on-site workers using appropriate Personal Protective Equipment (PPE) and following safe work practices. Human exposure to contaminants in off-site soil is unlikely, since the results of the air screening presented in Section 3.1.2.1 show acceptable concentrations for contaminants that could deposit on soil. The DN site is not a source of dust. Any releases from DN and subsequent off-site deposition of non-radiological particulates (metals) will be lost against the background soil levels.

Soil has been considered in the ecological risk assessment; an EcoRA screening for non-radiological COPCs in soil is presented in Section 4.1.5.3.

3.1.2.4 Selection of Chemical COPCs in Groundwater

OPG initiated an annual groundwater monitoring program to understand the groundwater quality beneath the DN site. The groundwater monitoring program includes sampling groundwater monitoring wells for tritium, and certain locations for selected hazardous substances, such as petroleum hydrocarbons (PHCs), benzene, toluene, ethylbenzene and xylenes (BTEX), metals and chloride.

Specifically, the DN groundwater monitoring program is designed to meet the following objectives:

- Confirm predominant on-site groundwater flow characteristics of the DN;

- Monitor changes to groundwater quality to ensure timely detection of non-routine releases of nuclear and hazardous substances to groundwater; and;
- Demonstrate no adverse impacts from COPCs in groundwater to the receiving environment through tracking movement of existing elevated concentrations and monitoring of groundwater leaving the site.

In November 2012, EcoMetrix prepared a report for OPG on DN Groundwater Monitoring Program Design (EcoMetrix, 2012), and identified COPCs that should be the focus of the groundwater monitoring program. The selection of COPCs was based on analyzing groundwater data from 2008 to 2012 and comparing against appropriate screening concentrations as well as considering COPCs that were included in past assessments and studies. Groundwater data were screened against MOE (2011) Table 3 standards for groundwater wells located greater than 30 m from Lake Ontario, and Table 9 standards for groundwater wells located less than 30 m from Lake Ontario. For substances without MOE Table standards, data were compared against screening levels based on 10x the lowest of the Ontario PWQO and the CCME water quality guidelines. The 10x factor is consistent with the MOE (2011) derivation of the GW3 component values (groundwater to surface water pathway) which assumes at least 10-fold dilution of groundwater in surface water. Groundwater parameters were retained for monitoring if they exceeded applicable groundwater standards or screening levels, were identified as part of historical leakages, or were otherwise anticipated to be of potential concern.

Based on the screening assessment, EcoMetrix recommended that tritium, PAHs, PHCs, BTEX compounds, and inorganics be included in the groundwater monitoring program at specific locations such that any migration from source areas would be detectable.

The known source areas for chemical COPCs with potential for groundwater contact can be summarized as follows:

- Switchyard – Zinc and boron in soils south of the switchyard are believed to originate from galvanized steel structures in the yard. It is considered unlikely that these metals have reported to groundwater.

- Main Output Transformers (MOTs) – Past spills of insulating oil near the Unit 2 MOT resulted in soil contamination, which could not be completely remediated, due to the presence of underground utilities and structures. It is believed that the small quantity of residual petroleum hydrocarbon is sorbed to soil and is not likely to migrate.

- Pumphouses – A hydrocarbon odour was noticed while drilling a monitoring well in 2009. Investigations in 2010 found elevated concentrations of petroleum hydrocarbons in shallow bedrock in adjacent wells that have no connection to site infrastructure. The bedrock in the area is known to be naturally petroliferous.

Overall, groundwater on the DN site was found to generally flow toward Lake Ontario, while groundwater in the Protected Area is flowing toward the Forebay and into the cooling water system (EcoMetrix 2012, OPG 2012d, OPG 2013e, OPG 2014d, OPG 2015b). In general, groundwater monitoring results were not significantly different from 2011 to 2014. Results from over this time period do not show any evidence of any significant leaks occurring from the DN systems, although PHC and benzene concentrations are naturally elevated in the bedrock groundwater because of the naturally occurring hydrocarbons in the petroliferous rock formation.

There are no groundwater supply wells downgradient of potential source areas on-site. As water on the DN site is not used for human consumption, the only on-site pathway for human exposure to groundwater would be from ingestion of water from Lake Ontario after dilution of the groundwater in the Lake. Concentrations of potential chemical stressors in off-site drinking water wells are not influenced by DN. Groundwater has therefore not been used to select COPCs for the human health risk assessment.

There is potential for site groundwater to migrate to surface water (Lake Ontario); however, groundwater flux from the site into Lake Ontario is likely to be small based on the estimated groundwater velocity and influence of site infrastructure (CH2M Hill, 2011); therefore, any COPCs in groundwater that reach the lake are subject to considerable dilution before they can migrate with surface water to a point of water intake for human consumption. The nearest water intakes are at Bowmanville, 7 km ENE of DN, and at Oshawa, 8 km west. The surface water near DN is monitored and screened for classes of contaminants such as polycyclic aromatic hydrocarbons (PAHs), PHCs, and BTEX, so any groundwater migration to surface water would be observed through this monitoring.

Maximum concentrations from recent groundwater monitoring are screened in Appendix A against the MOE (2011) GW3 criteria for protection of surface water (Table A.16). In addition, a screening calculation of potential groundwater impact on surface water quality adjacent to the site shows that no chemicals in groundwater have potential for human health impact.

3.1.2.5 Selection of Chemical COPCs in Sediment

Sediment in Lake Ontario was characterized as part of the baseline data collection exercise for the ecological risk assessment in the New Nuclear Darlington EA (SENES 2009a). Except in embayments (St. Marys boat slip) the substrate is predominantly gravel and cobble on top of glacial till or bedrock. Any finer material, mostly sand, is patchy, thin and transient. No direct human health exposure pathways exist between potential chemical COPCs in sediments and the selected human receptors, so no screening of chemicals in sediment for potential human health effects is required.

Bioaccumulation of chemicals in fish is likely to be primarily driven by water exposures for the fish, since sediments in areas where human receptors catch fish, such as Lake Ontario, are transient. As such, the Lake water screening is considered sufficient to identify COPCs for human health due to potential fish ingestion.

3.1.2.6 Selection of Radiological COPCs Released to Air and Surface Water

Radiological emissions from DN from the five year period 2011 to 2015 are summarized in **Error! Reference source not found.** and **Error! Reference source not found.**. During this period, radiological emissions ranged from <0.01 to 0.46% of Derived Release Limits.

Table 3-1: Radioactive Emissions from DN (Bq)

Medium	Parameter	Year					
		2011	2012	2013	2014	2015	Average (2011-2015)
Air	Tritium Oxide	1.4E+14	1.3E+14	2.1E+14	2.7E+14	2.5E+14	2.00E+14
	Elemental Tritium	8.8E+13	2.6E+13	1.8E+13	5.2E+13	1.7E+13	4.02E+13
	Noble Gas	2.2E+13	1.9E+13	3.2E+13	4.6E+13	2.2E+13	2.82E+13
	Iodine	1.5E+08	1.4E+08	1.4E+08	1.6E+08	1.4E+08	1.46E+08
	Particulate	4.0E+07	3.4E+07	2.9E+07	3.1E+07	3.5E+07	3.38E+07
	Carbon 14	1.0E+12	1.0E+12	1.0E+12	1.3E+12	1.3E+12	1.12E+12
Water	Tritium Oxide	1.1E+14	1.3E+14	1.1E+14	1.7E+14	2.4E+14	1.32E+14
	Gross Beta/Gamma	3.1E+10	3.0E+10	2.8E+10	3.0E+10	4.9E+10	3.36E+10
	Carbon 14	1.9E+09	6.3E+08	3.2E+08	5.5E+09	7.3E+09	3.13E+09

Sources: OPG 2012e, 2013f, 2014e, 2015e, 2016e

Elemental tritium airborne emission levels have remained low and were lower in 2015 than the previous year due to elevated emissions resulting from 2014 TRF restart activities.

In 2013 and 2014, there was a small increase in DN tritium oxide (HTO) airborne emissions, which in 2013 was attributed to outage activities and dryer performance. The increase in 2014 was attributed to both dryer performance and TRF restart activities. Emissions during these years were also correlated to an increase in moderator tritium concentrations in the powerhouse at DN, which were increasing due to operational constraints in processing water at the TRF/HWMB. During 2015, workplans were executed to begin refurbishment of dryers throughout the station. Work was completed to replace motor bearings, valves, fan motors, and filters, in addition to other maintenance activities. Despite these results, emissions are consistent with the general performance over the past 10 years (OPG, 2013b).

A slight increase of DN HTO emissions to water was observed in 2014 and 2015. This was a result of the drainage and discharge activities of the vacuum building dousing water, which began in 2014 in preparation for the vacuum building outage in 2015. A vacuum building outage is scheduled to occur every 7 to 10 years to meet licensing requirements. Generally HTO water emissions have been stable since 2011.

Carbon-14 airborne emissions remained stable between 2011 and 2015. The DN waterborne gross beta-gamma emissions also remain low.

The Radiation and Radioactivity TSD (SENES, 2011e) indicated that although residual adverse effects on members of the public or workers are not anticipated, radiation doses should be carried forward for further consideration since radiation dose is of great public and regulatory interest. This approach is consistent with CSA N288.6 guidance (CSA, 2012).

Figure 3-2: Summary of DN Emissions Data from 2011 to 2015

OPG calculated Derived Release Limits (DRLs) for DN (OPG, 2011c) based on CSA N288.1-08. A DRL is the release rate for a radionuclide or a group of radionuclides that would result in the average member of the critical group (most exposed group of members of the public) receiving an annual dose of 1 mSv (regulatory limit, CNSC 2000). The list of parameters, for which DRLs were derived is as follows:

Table 3-2: Radionuclides Considered for Derivation of DRLs (OPG, 2011c)

^{3}H	^{95}Nb	^{83m}Kr
^{14}C	^{32}P	^{85}Kr
^{144}Ce (^{144}Pr)	^{106}Ru (^{106}Rh)	^{85m}Kr
^{60}Co	^{35}S	^{87}Kr
^{51}Cr	^{124}Sb	^{88}Kr (^{88}Rb)
^{134}Cs	^{125}Sb (^{125m}Te)	^{237}Np (^{233}Pa)
^{137}Cs (^{137m}Ba)	^{46}Sc	^{239}Np
^{154}Eu	^{113}Sn (^{113m}In)	^{234}U
^{55}Fe	^{89}Sr	^{235}U (^{231}Th)
^{59}Fe	^{90}Sr (^{90}Y)	^{236}U
^{159}Gd	^{160}Tb	^{238}U (^{234}Th)
^{153}Gd	^{234}Th (^{234m}Pa)	^{238}Pu
^{203}Hg	^{65}Zn	^{239}Pu
^{131}I	^{95}Zr (^{95}Nb)	^{240}Pu
^{132}I	^{41}Ar	^{241}Pu
^{133}I	^{131m}Xe	^{242}Pu
^{134}I	^{133}Xe	^{241}Am
^{135}I	^{133m}Xe	^{243}Am (^{239}Np)
^{140}Ba (^{140}La)	^{135}Xe	^{242}Cm
^{140}La	^{135m}Xe	^{244}Cm
^{54}Mn	^{138}Xe (^{138}Cs)	Noble Gases(1)

(1) A parameter representing a mixture of noble gases is used in modeling the dose from noble gas emissions.

Separate medium-specific DRLs were calculated for each radionuclide released to air and to water, but some of these radionuclides were grouped to allow easier screening. The airborne effluent release groups that were used for DN are as follows:

- Elemental tritium (HT),
- Tritium oxide as water vapour (HTO),
- Noble gas mixtures (Noble Gases),
- Radioiodine mixed fission products (Imfp),
- Carbon-14 as $^{14}CO_2$ (^{14}C),
- Mixed beta-gamma emitting radionuclides (Particulate), and
- Mixed alpha emitting radionuclides (Gross alpha).

The liquid effluent release groups that were used for DN are:

- Tritium oxide as water (HTO),
- Mixed beta-gamma emitting radionuclides (Gross beta-gamma),
- Carbon-14 as dissolved carbonate/bicarbonate (^{14}C), and
- Mixed alpha emitting radionuclides (Gross alpha).

The DRLs for the mixed radionuclide release groups were calculated based on selection of the radionuclide in each group with the most restrictive DRL, according to the process outlined in the CANDU Owners Group (COG) DRL Guidance document (COG, 2013). Radionuclides were selected to represent mixed beta-gamma based on meeting both of the following criteria for inclusion:

- Radionuclides are regularly present in the effluent; and
- Radionuclides represent no less than 1% of the total radioactivity present.

The very conservative criteria for "regularly present" is that radionuclides must be found more than once in the effluent. Additionally, radionuclides must make up more than 1% of the total radioactivity in the effluent based on long term analyses of representative samples.

The radionuclides selected to represent gross beta-gamma releases in DRL calculations are the beta-gamma emitters that result in the highest dose per unit release. These have also been used to represent gross beta-gamma releases in OPG's annual public dose assessments. These multi-media dose assessments form the basis of the radiological dose assessment in the HHRA. The 2011 DRL report (OPG, 2011c) indicated that Co-60 is the limiting radionuclide for gross beta/gamma releases to air, and Cs-137 is the limiting radionuclide for gross beta/gamma releases to water.

The 2011 gross alpha DRL for air emissions is 5.43×10^{-2} Ci/week (equivalent to 1.0×10^{11} Bq/year) based on Pu-239/240, and the 2010 gross alpha DRL for water emissions is 7.10×10^{2} Ci/month (3.2×10^{14} Bq/year) based on Am-241. The total annual gross alpha emissions to air and water and their respective fractions of these DRLs are presented in **Error! Reference source not found.**:

Table 3-3: Total Annual Gross Alpha Emissions to Air and Water

Year	Medium	Total Annual Emission	Unit	% of DRL
2011	Water	3.03×10^{-5}	Ci	3.41×10^{-6}
2012	Water	2.43×10^{-5}	Ci	2.85×10^{-7}
2013	Air	$<6.20 \times 10^{6}$	Bq	$<6 \times 10^{-3}$
	Water	8.54×10^{5}	Bq	2.74×10^{-7}
2014	Air	$<6.44 \times 10^{6}$	Bq	$<6.2 \times 10^{-3}$
	Water	1.81×10^{6}	Bq	5.8×10^{-7}
2015	Air	$<6.5 \times 10^{6}$	Bq	$<6.5 \times 10^{-3}$
	Water	$<2 \times 10^{6}$	Bq	$<6.25 \times 10^{-7}$

Note: Gross alpha was not monitored in air at DN prior to 2013.
Sources: OPG 2012e, 2013f, 2014e, 2015e

Since water emissions of gross alpha over this period are on the order of six to seven orders of magnitude smaller than the applicable water DRL, and air emissions over this period are four to five orders of magnitude smaller than the applicable air DRL, gross alpha and its constituent radionuclides were not considered to be COPCs for the HHRA.

As such, in accordance with the above, the following radiological stressors released to air and surface water were selected for the assessment of human health:

- Carbon-14 (C-14), which is released to both air and surface water by reactor operations at DN;
- Cobalt-60 (Co-60), which represents gross beta-gamma released to the atmosphere by DN;
- Cesium-137 and progeny (Cs-137+), which represent gross beta-gamma emissions released to surface water in liquid effluent from DN;
- Elemental tritium (HT), which is released to the atmosphere by the Tritium Removal Facility (TRF) and in very small amounts from the powerhouse at DN;
- Tritium oxide, also known as tritiated water (HTO), which is released to both air and water by the reactor operations at DN;
- Argon-41, xenon-133, and xenon-135 (collectively referred to as noble gases), which are released to the atmosphere by DN;
- Mixed fission product radioiodines, including iodine-131, iodine-132, iodine-133, iodine-134, and iodine-135 (collectively referred to as I(mfp)), which are released to the atmosphere by DN; and,
- Iodine-131 (I-131), which is the only iodine radioisotope released to the atmosphere with a long enough half-life to be present in other media.

These COPCs were identified through station pathway analyses and site-specific survey reviews (OPG, 2013d). Those released to air were considered to be COPCs in air, and those released to surface water were considered to be COPCs in surface water. Some may be COPCs in other media as well, according to their partitioning properties, as noted in the subsections below.

Organically Bound Tritium (OBT) may be created in living organisms as HTO produced by DN moves through the food chain, so the HHRA also assessed potential risks due to OBT, but this evaluation was considered part of the overall HTO risk.

3.1.2.6.1 Darlington Waste Management Facility

Waste management operations at DN are undertaken in three locations within the DN site, including in two Fueling Facilities Auxiliary Areas (FFAAs; East and West) and the DWMF. The DWMF is made up of two buildings, each able to hold up to 500 DSCs. The DWMF is located within its own fenced protected area. Radiological waterborne emissions from the

DWMF include yard drainage (runoff) and facility drainage. Weekly average values from yard drainage have been below the minimum detectable activity (OPG, 2012c). Facility drainage remains below approved limits. In 2011, a sump sample exceeded the action level for oil and grease and was therefore not discharged to the environment, but drummed and shipped off-site for disposal.

The DWMF Safety Report (OPG, 2011b) estimated that the dose rate at the DN site boundary (1,025 m from the DWMF) due to gamma radiation and skyshine from the DWMF is 3.8×10^{-6} µSv/h, equivalent to 3.3×10^{-2} µSv/a assuming full capacity.

OPG calculated dose rates for these facilities in 2012 and in 2015 as part of their As Low As Reasonably Achievable (ALARA) update reporting. As part of the 2015 ALARA update, OPG tabulated air kerma measurements from 12 locations around the DWMF perimeter fence from 2011 through 2014, during which time the average air kerma rate at the perimeter was 0.08 µSv/h. This average air kerma rate was found to be less than the regulatory dose rate limit of 0.5 µSv/h (which for 2000 hours would result in a dose to the public of 1 mSv). In addition, none of the annual average air kerma rates at individual locations exceeded this dose rate limit. The 2015 ALARA update also noted that all results from stack particulate samples from the DWMF for this period were below the minimum detectable activity.

In 2000, air kerma rates from the Pickering Waste Management Facility (PWMF) were measured at various locations over Lake Ontario. At a distance of 500 m from the PWMF, the measured air kerma rate was below the detection limit of 0.13 nGy/h. At a distance of 1 km from the PWMF, the air kerma rate was estimated to be negligible assuming an inverse square relationship with distance and a further reduction of a factor of 1,000 due to scattering in air. Based on the 2000 assessment, it was determined that air kerma rates from the PWMF are not significant for critical groups farther than 1 km from the source. For the DWMF, air kerma (skyshine) is not significant since all critical groups are farther than 1 km from the DWMF (OPG, 2015c).

As such, the contribution of the DWMF to dose for human receptors identified would be negligible. The dose contribution from the DWMF is not discussed further in the HHRA.

3.1.2.7 Selection of Radiological COPCs in Soil

The primary transport pathway of radiological COPCs to soil on-site and off-site is through deposition from air. However, two COPCs, HT and noble gases, are not expected to partition to soil. In addition, most of the radioiodines have short half-lives and would disappear quickly from soil, with the exception of I-131, which has a half-life of 8.03 days (CNSC 2016).

The beta-gamma release to air, represented conservatively by Co-60, will deposit to soil, and is considered to be a COPC in soil. In addition, gross beta-gamma release to surface water, represented conservatively by Cs-137+, can be transferred to soil by irrigation of gardens, and is considered as a COPC in soil for rural residents with gardens.

The final list of COPCs for soil was therefore as follows: C-14, Co-60 and Cs-137+, HTO, and I-131.

3.1.2.8 Selection of Radiological COPCs in Groundwater

Previous groundwater studies at DN have demonstrated that at many locations, tritium concentrations in groundwater have remained relatively constant or have decreased over time. However, tritium concentrations have fluctuated at some locations in recent years due to migration of a spill in 2009 from the Injection Water Storage Tank, located south of Unit 0. Tritium from the spill is migrating towards the westerly end of the Forebay. Since groundwater discharged into the Forebay channel is significantly diluted by the Forebay water, adverse impact on human health is not expected. This was confirmed by the measurement of low tritium concentrations in groundwater in both the Controlled Area (See **Error! Reference source not found.**) and the Site Perimeter.

Although the atmospheric release of tritium from DN influences tritium concentrations in groundwater on-site, the on-site groundwater is not considered potable. There are no groundwater supply wells downgradient of potential source areas on-site. Off-site drinking water wells are influenced by the atmospheric tritium plume, but this makes a negligible contribution to dose. In order to be consistent with the EMP, however, tritium has been identified as a radiological COPC in offsite groundwater for assessment as part of the HHRA. In addition, I-131 partitions to shallow groundwater, and is a COPC for farm and rural residents with shallow wells. I-131 cannot migrate to deep well screens.

3.1.2.9 Selection of Radiological COPCs in Sediment

Since the primary pathway for radionuclides to be transported to sediment is through partitioning from liquid effluents, the same COPCs were selected for sediment as were selected for surface water.

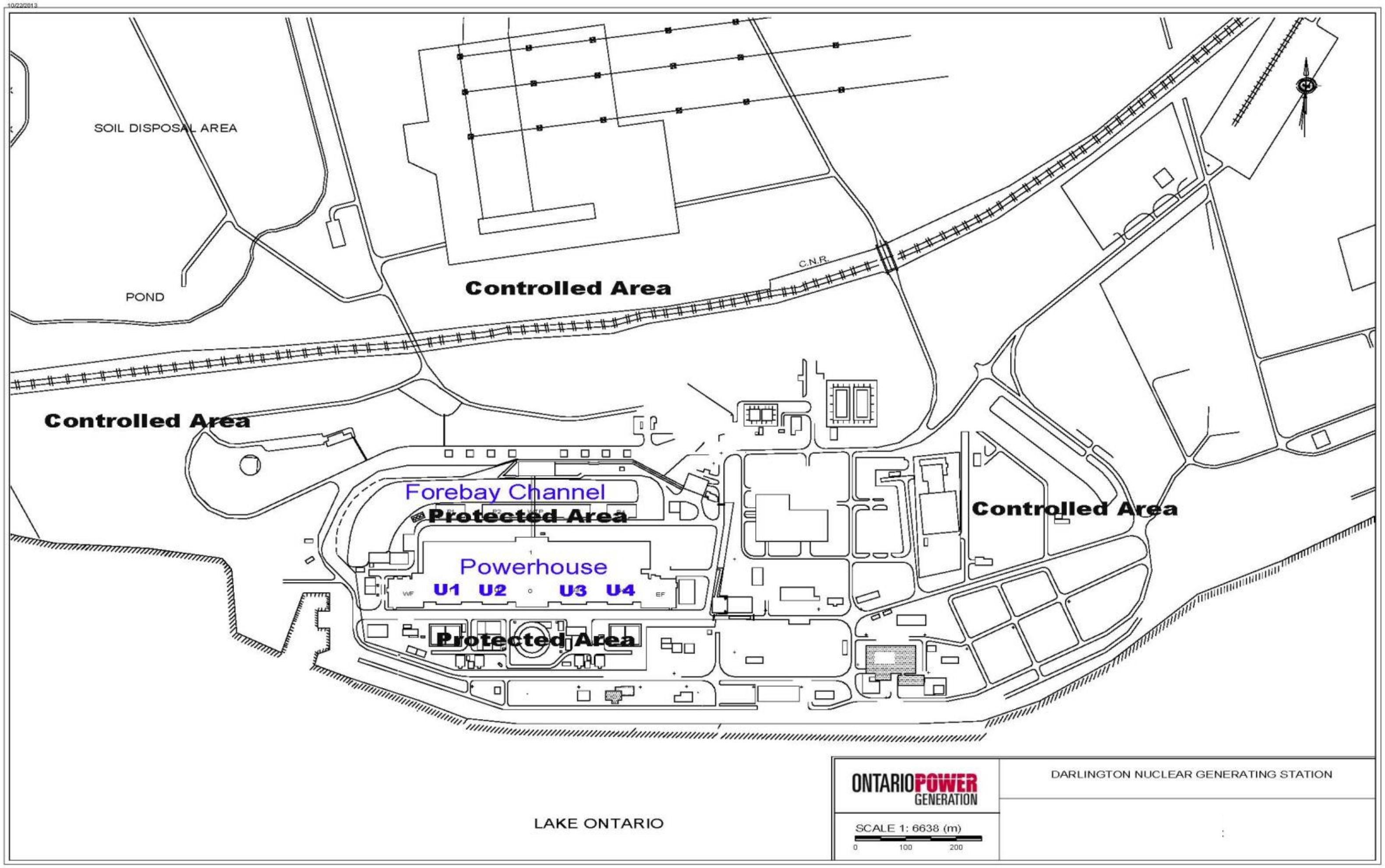


Figure 3-3: DN Site Plan Showing Controlled Areas

3.1.2.10 Selection of Other Stressors

Noise is the only physical stressor mentioned in N288.6 as a potential human stressor, and is the only physical stressor associated with DN that is of potential concern to humans.

3.1.2.10.1 Noise

The noise environment in the vicinity of DN site is typical of an urban setting and is influenced by several noise sources including DN Generating Station, traffic on Highway 401 and local roads, the CN rail line and the St. Mary's Cement plant.

The noise monitoring locations for humans, also known as Point(s) of Reception, located in the vicinity of OPG DN are in an area best described as Class 1 as per MOECC publication NPC 300 *"Environmental Noise Guideline, Stationary and Transportation Sources – Approval and Planning"* (NPC 300) (MOECC, 2013b). This designation is based on the presence of Highway 401 and its consistent contribution to background sound levels in the area.

The energy equivalent sound levels for stationary sources in Class 1 areas (L_{eq}) are summarized in **Error! Reference source not found.**, and used to assess compliance of a facility in accordance with NPC 300.

Table 3-4: Sound Level Limits for Class 1 Areas (SENES, 2009b)

Time Period	Class 1 MOECC Energy Equivalent Sound Level Limit (dBA)
Daytime (07:00 – 19:00)	50
Evening (19:00 – 23:00)	47
Night-time (23:00 – 07:00)	45

Continuous noise monitoring was conducted at two of the closest residential receptors to the DN (see **Error! Reference source not found.**) in order to establish background noise levels for the NND EA (SENES, 2009b). Both receptors were located approximately 1 km north and west of the DN Site. The results of this measuring campaign are presented in **Error! Reference source not found.**.

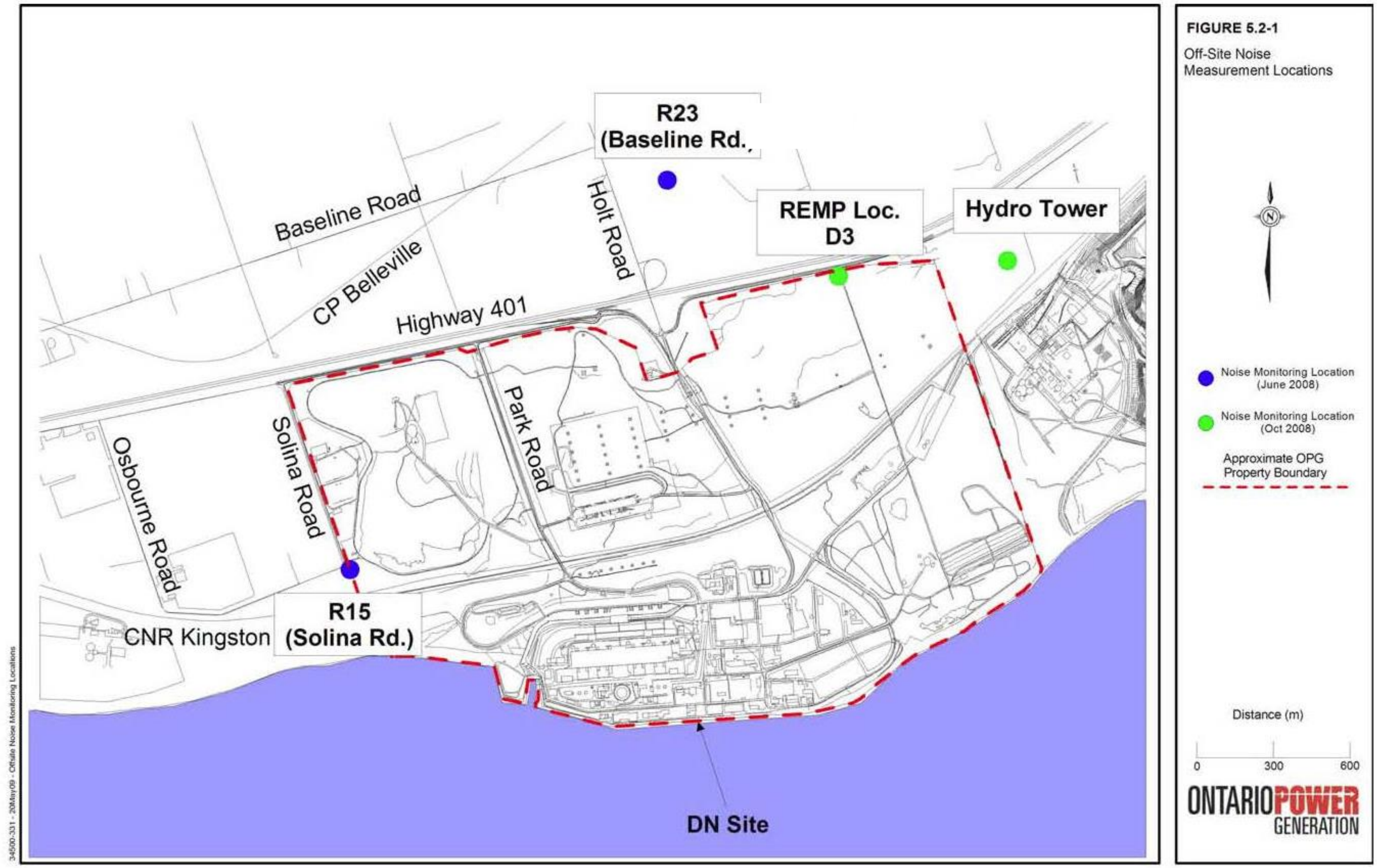


Figure 3-4: Offsite Noise Measurement Locations (SENES, 2009b)

Table 3-5: Measured Noise Levels at Residential Receptors (SENES, 2009b)

Location	Minimum Measured Background Energy Equivalent Sound Level Limit (dBA)	Maximum Measured Background Energy Equivalent Sound Level Limit (dBA)
R15	44.7	63.4
R23	46.2	62.3

SENES also carried out noise modeling with Cadna-A software to determine the sources of noise to these residential receptors. This model considered local terrain data, assumed perfectly reflective ground, and did not consider meteorology or railway sources of noise. Sources of noise in the modeling included DN, St. Mary's Cement, and road traffic on Highway 401, as well as other local roads. Overall, based on this modeling, SENES concluded that sound levels in the DN area were influenced by traffic, as well as DN and St. Mary's Cement operations. In particular, SENES noted that at location R15, the Solina Road location, the monitored day and night hour sound levels were roughly 3-5 dB higher than the modeled results, which suggested an influence of additional local sources of sound at this location, possibly including the nearby rail line, nature sounds, and Lake Ontario wave noise. SENES also noted that at location R23, at 2185 Baseline Road, which is closer to Highway 401, the monitored day and night sound levels were similar to the modeled sound levels. SENES concluded that overall, road traffic noise dominated other sources of noise at these locations.

The sound environment at both locations was dominated primarily by road traffic from Highway 401 and to a lesser degree from local roads. Noise from DN was not distinctly audible during the monitoring period which occurred between June 20 and June 23, 2008. Continuous noise monitoring results from the NND EA (SENES, 2009b) for the two monitoring locations are shown in **Error! Reference source not found.** and **Error! Reference source not found.**, respectively. Monitoring results show noise levels consistently above Sound Level Limits for Class 1 Areas, which are provided in **Error! Reference source not found.**.

Given that noise from DN was not distinguishable at these monitoring locations, and given the large contribution of noise at these receptors from roads in the area, in particular from Highway 401, noise was not carried forward as a COPC in the HHRA.

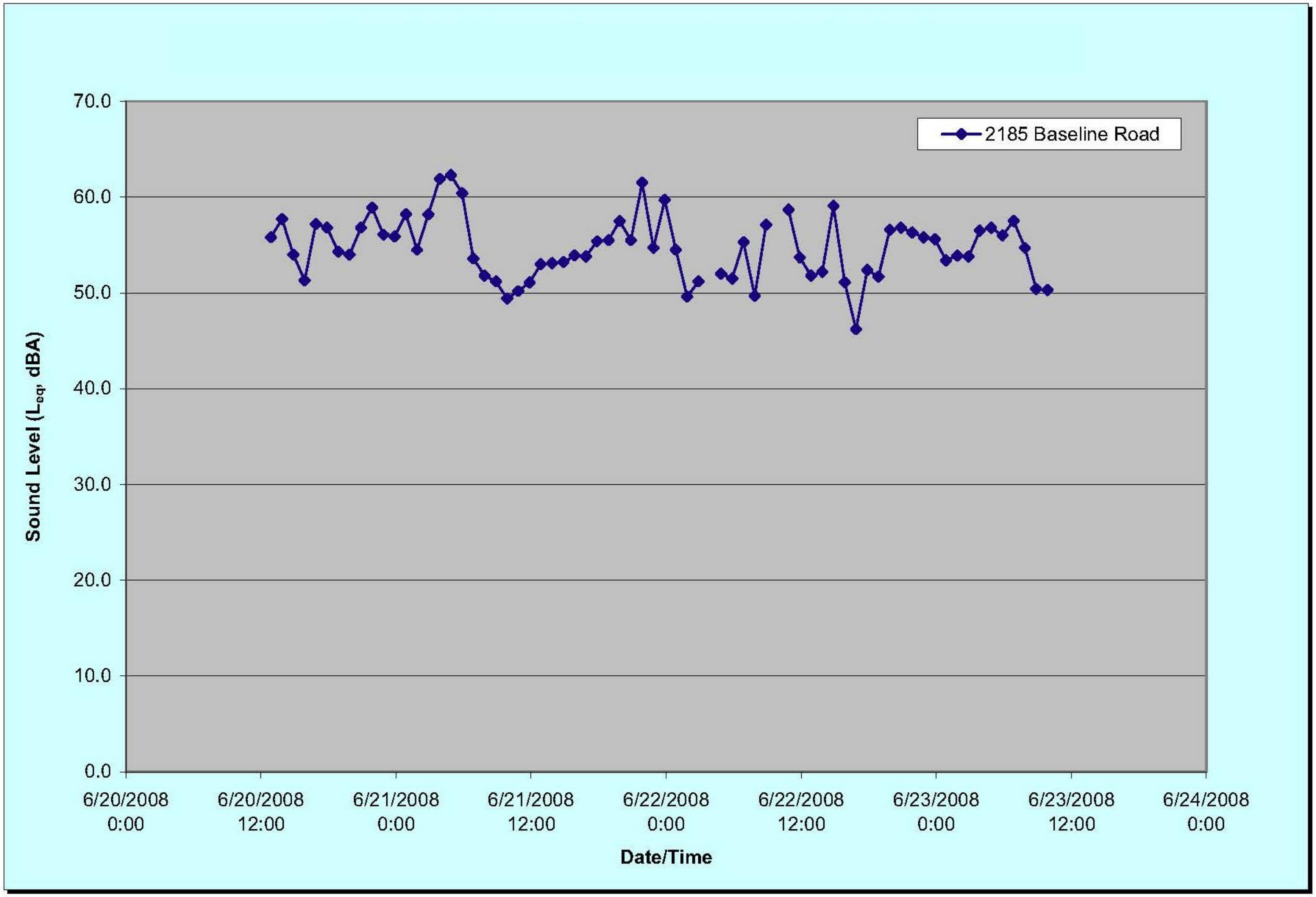


Figure 3-5: Measured Sound Levels at 2185 Baseline Road (SENES, 2009b)

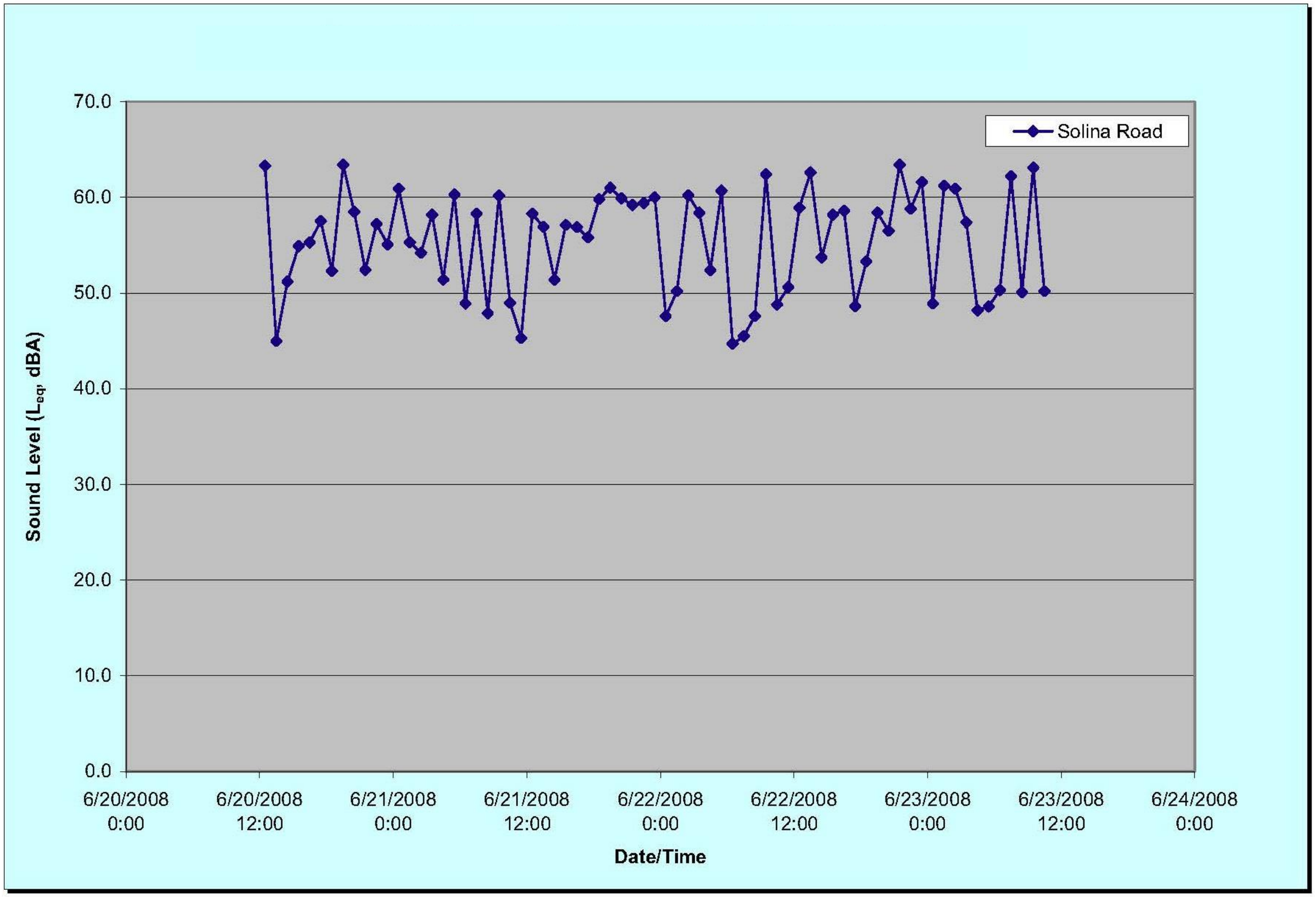


Figure 3-6: Measured Sound Levels at Solina Road Location (SENES 2009b)

3.1.2.11 Summary of COPC Selection

Error! Reference source not found. summarizes the radiological and non-radiological COPCs that are carried forward to the exposure assessment in the HHRA.

Table 3-6: Summary of COPCs Selected for the HHRA

Category	Radiological COPC	Chemical COPC
Air	C-14, Co-60, HT, HTO, noble gases, I(mfp)	None
Surface water	C-14, Cs-137+, HTO	nitrate, hydrazine, morpholine
Soil	C-14, Co-60, Cs-137+, HTO, I-131	None
Groundwater	HTO, Co-60, I-131	None
Sediment (beach sand)	C-14, Cs-137+, HTO	None
Other Stressors	None	

3.1.3 Selection of Exposure Pathways

For exposure of human receptors to radiological COPCs, the relevant exposure pathways include:

- Air inhalation and external exposure to air;
- Ingestion of water (WSP, wells) and external exposure to water (lakes, WSPs, wells)
- Soil and beach sand incidental ingestion
- Soil and beach sand external exposure;
- Ingestion of food.

The complete exposure pathways, as defined in OPG's EMP, for exposure of relevant receptors to radiological COPCs are summarized in **Error! Reference source not found.**. The exposure pathways for chemical COPCs were selected to be consistent with the radiological exposure pathways, but environmental media that were not expected to be affected by chemical COPCs (soil, ground water, terrestrial plants, and terrestrial animals) were not considered to have complete exposure pathways for human health. In addition, whereas immersion in water was considered to be a complete pathway for radiological COPCs, dermal absorption of chemical COPCs was considered to be minimal in comparison to drinking water ingestion, and was therefore not considered a complete exposure pathway for chemical COPCs. The final list of exposure pathways for chemical COPCs is presented in **Error! Reference source not found.**.

Table 3-7: Complete Exposure Pathways for Receptors for Exposure to Radiological COPCs

Receptor	Exposure Pathway	Environmental Media
Oshawa/Courtice Urban Resident	Inhalation	Air
	Ingestion	Water (Oshawa WSP) Soil and beach sand Aquatic animals (Lake Ontario) Terrestrial plants (homegrown)
	External	Air Water Soil and beach sand
Bowmanville Urban Resident	Inhalation	Air
	Ingestion	Water (Bowmanville WSP) Soil and beach sand Aquatic animals (Lake Ontario) Terrestrial plants (homegrown) Terrestrial animals (local)
	External	Air Water Soil and beach sand
West/East Beach Urban Resident	Inhalation	Air
	Ingestion	Water (ground water wells, Bowmanville WSP) Soil and beach sand Aquatic animals (Lake Ontario) Terrestrial plants (homegrown) Terrestrial animals (local)
	External	Air Water Soil and beach sand
Farm	Inhalation	Air
	Ingestion	Water (ground water wells) Soil and beach sand Aquatic animals (Lake Ontario) Terrestrial plants (homegrown) Terrestrial animals (home raised)
	External	Air Water Soil and beach sand

Receptor	Exposure Pathway	Environmental Media
Dairy Farm	Inhalation	Air
	Ingestion	Water (ground water wells) Soil and beach sand Aquatic animals (Lake Ontario) Terrestrial plants (homegrown) Terrestrial animals (home raised incl. milk)
	External	Air Water Soil and beach sand
Rural Resident	Inhalation	Air
	Ingestion	Water (ground water wells, Bowmanville WSP) Soil and beach sand Aquatic animals (Lake Ontario) Terrestrial plants (local) Terrestrial animals (local)
	External	Air Water Soil and beach sand
Industrial/ Commercial Worker	Inhalation	Air
	Ingestion	Water (Bowmanville WSP)
	External	Air Water Soil
Sport Fisher	Inhalation	Air
	Ingestion	Aquatic animals (Lake Ontario)
	External	Air Water
Camper	Inhalation	Air
	Ingestion	Water (Oshawa WSP) Soil and beach sand Aquatic animals (Lake Ontario) Terrestrial plants (local) Terrestrial animals (local)
	External	Air Water Soil and beach sand

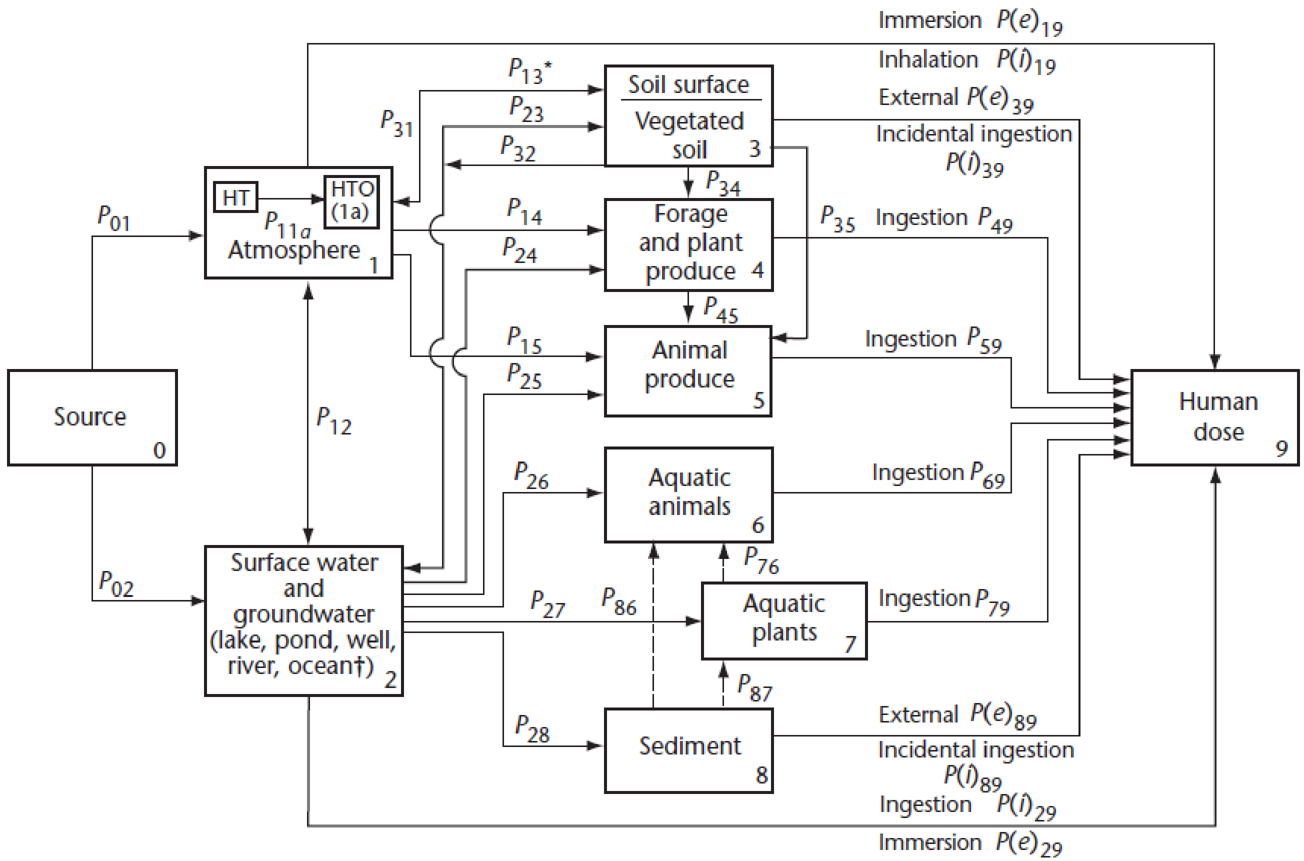
Table 3-8: Complete Exposure Pathways for Receptors for Exposure to Chemical COPCs

Receptor	Exposure Pathway	Environmental Media
Oshawa/Courtice Urban Resident	Ingestion	Water (Oshawa WSP) Aquatic animals (Lake Ontario)
Bowmanville Urban Resident	Ingestion	Water (Bowmanville WSP) Aquatic animals (Lake Ontario)
West/East Beach Urban Resident	Ingestion	Water (Bowmanville WSP) Aquatic animals (Lake Ontario)
Farm	Ingestion	Aquatic animals (Lake Ontario)
Dairy Farm	Ingestion	Aquatic animals (Lake Ontario)
Rural Resident	Ingestion	Water (Bowmanville WSP) Aquatic animals (Lake Ontario)
Industrial/ Commercial Worker	Ingestion	Water (Bowmanville WSP)
Sport Fisher	Ingestion	Aquatic animals (Lake Ontario)
Camper	Ingestion	Water (Oshawa WSP) Aquatic animals (Lake Ontario)

3.1.4 Human Health Conceptual Model

The conceptual model illustrates how receptors are exposed to COPCs. 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.

A generic conceptual model, taken from CSA N288.1 (2008) is shown in **Error! Reference source not found.**, and is applied to human receptors around DN. This represents the exposure pathways from source to receptor. It is appropriate for radiological and non-radiological COPCs, except that, for non-radionuclides, external and immersion pathways represent dermal exposure.



*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 3-7: Generic Conceptual Model for Human Receptors (CSA 2008)

3.1.5 Problem Formulation Checklist

The information required in Health Canada's (2010a) Problem Formulation Checklist has been provided in Sections 3.1.3 and 3.1.4, above.

3.1.6 Uncertainty in Problem Formulation

The data used in the HHRA problem formulation were concluded to be of adequate quality and quantity to support the objectives of the HHRA. Maximum measured concentrations were selected for COPC screening; this is considered conservative and is not reflective of typical human exposures. The human health screening benchmarks for water were generally the lower of applicable provincial and federal drinking water standards and guidelines, which is a conservative approach, ensuring that the list of COPCs would be as comprehensive as possible. The COPC screening also considered several media as sources of potential exposure, such as air, surface water (including Lake Ontario water, effluent, and storm water), soil, ground water, and sediment. As such, the COPC screening has resulted in a conservative list of COPCs.

More generally, the HHRA problem formulation has been conservative in its assumptions to accommodate uncertainties and meet the objective of protecting human health. The conceptual model for human health is considered to be complete for the majority of general public exposures in the vicinity of the DN site. The selected receptors are expected to lead to conservative estimates of health risks, and are expected to be protective of any shorter-term exposures to environmental media in the vicinity of the DN site. The selected exposure pathways are consistent with available guidance (for example, N288.1-08), and are expected to account for all significant exposure pathways for human receptors in the area.

There are uncertainties and conservative assumptions made in the emission estimates and operating conditions for the ESDM (OPG; 2015)

- 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.
- Incorporated 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.

3.2 Exposure Assessment

The exposure assessment describes the exposure scenarios (locations, receptors), the methods used in estimating exposure concentrations and doses at the receptor locations, and the results of the exposure and dose calculations for each human receptor.

3.2.1 Exposure Locations

An exposure location is the place where the receptor comes into contact with a COPC. For both the radiological and chemical exposure assessments, the relevant human receptors are the potential critical groups defined by the EMP, as discussed in Section 3.1.1.1. **Error! Reference source not found.** presents the locations of these receptors. The exposure assessment considered all nine receptors, as reported in the EMP, where appropriate. For the non-radiological exposure assessment, the farm and dairy farm critical groups were not assessed for water ingestion since they obtain the majority of their water intake from water wells, and not from a WSP.

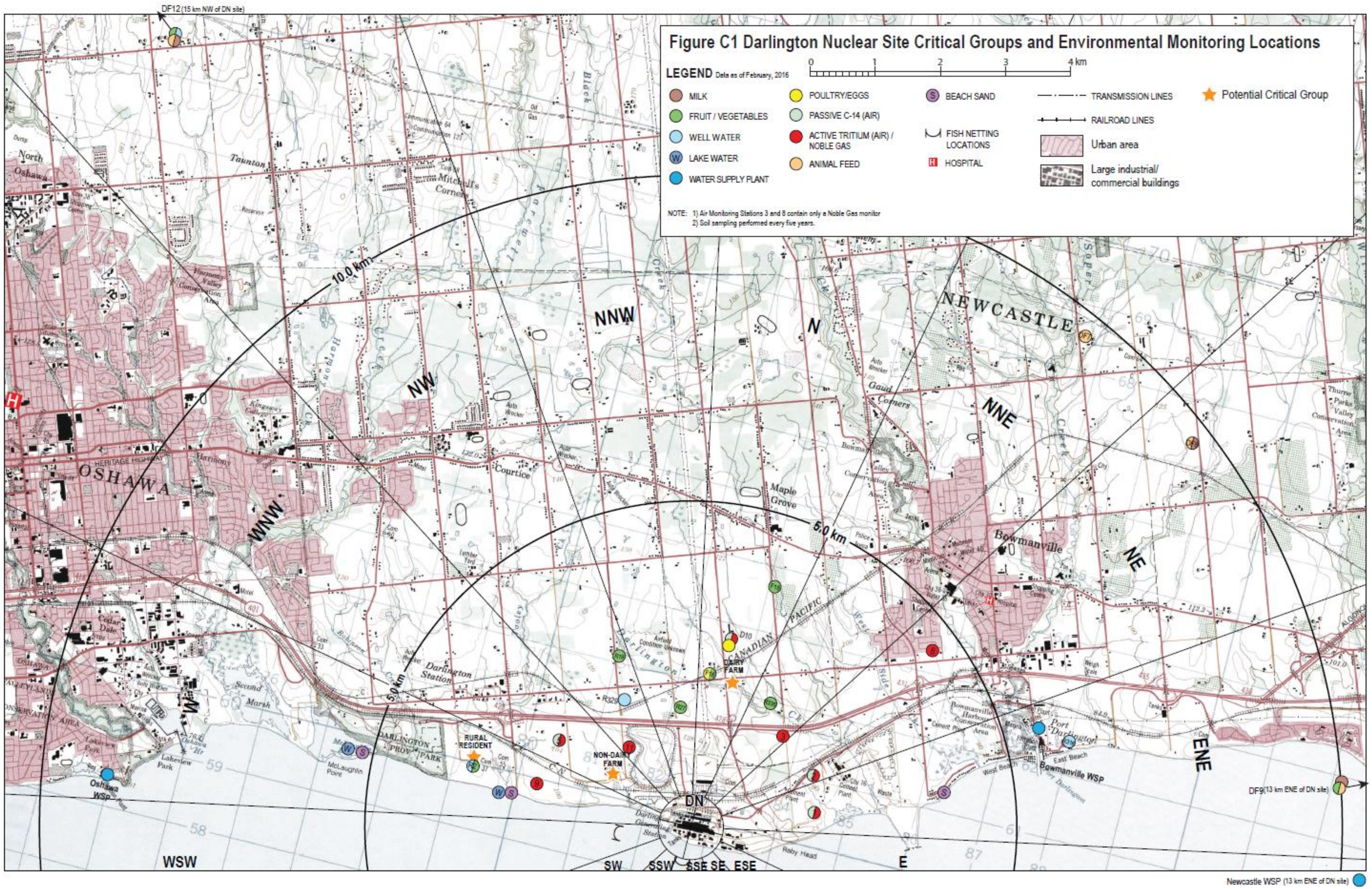


Figure 3-8: DN Critical Groups and Environmental Monitoring Locations (OPG, 2016b)

3.2.2 Exposure Duration and Frequency

The assumptions made for exposure duration and frequency are presented in Section 3.2.4.

3.2.3 Exposure and Dose Calculations

3.2.3.1 Radiological Dose Calculations

Radiological dose calculations follow the equations presented in CSA N288.1-08 (2008), which are not reproduced in this report.

3.2.3.2 Chemical Dose Calculations

The ingestion dose from exposure to nitrate, hydrazine, and morpholine in drinking water was calculated according to the following equation, consistent with CSA N288.6 (2012):

$$\text{Dose (mg/kg-d)} = C \bullet IR \bullet RAF_{GIT} \bullet D_2 \bullet D_3 \bullet D_4 / (BW \bullet LE)$$

where,

C	=	concentration of contaminant in drinking water (mg/L)
IR	=	receptor intake rate (L/d)
RAF_{GIT}	=	absorption factor from the gastrointestinal tract (unitless)
D_2	=	days per week exposed•(7 days)$^{-1}$ (d/d)
D_3	=	weeks per year exposed•(52 weeks)$^{-1}$ (wk/wk)
D_4	=	total years exposed to site (years) (for carcinogens only)
BW	=	body weight (kg)
LE	=	life expectancy (years) (for carcinogens only).

The ingestion dose from exposure to hydrazine and morpholine in fish was calculated according to the following equation, consistent with CSA N288.6 (2012):

$$\text{Dose (mg/kg-d)} = [\Sigma\ (C_{food\ i} \bullet IR_{food\ i} \bullet RAF_{GITi} \bullet D_i)] \bullet D_4 / (BW \bullet 365 \bullet LE)$$

where,

C_{foodi}	=	concentration of contaminant in food i (mg/kg)
IR_{foodi}	=	receptor ingestion rate for food i (kg/d)
RAF_{GITi}	=	relative absorption factor from the gastrointestinal tract for contaminant i (unitless)
D_i	=	days per year during which consumption of food i will occur (d/a)
D_4	=	total years exposed to site (years) (for carcinogens only)
BW	=	body weight (kg)

365 = total days per year (constant) (d/a)

LE = life expectancy (years) (for carcinogens only)

3.2.4 Exposure Factors

3.2.4.1 Radiological Exposure Factors

For the radiological dose calculations, the exposure factors (e.g., intake rates, occupancy and shielding factors, etc.) are generally those used in CSA N288.1-08. The intake rates for ingestion and inhalation are the central or mean intake rates provided in CSA N288.1-08 (2008) and 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 DN infant is assumed to drink only cow's milk (not water and infant formula) (OPG, 2010b). **Error! Reference source not found.** summarizes the exposure factors used in the 2011-2015 radiological dose calculations.

Table 3-9: Human Exposure Factors for Radiological Dose Calculations

Exposure Factor	Units[4]	Infant 1 year	Child 10 year	Adult
Inhalation rate	m^3/a	1830	5660	5950
Inhalation occupancy factor	NA	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[1] Aquatic animal intake rates[2] Terrestrial animal intake rates Terrestrial plant intake rates	L/a kg/a kg/a kg/a	0 0.58 249 120.5	262.8 1.97 234 275.1	511 4.6 256.6 465.9
Outdoor occupancy factor	NA	0.2	0.2	0.2
Indoor plume shielding factor (effective dose)	NA	0.5	0.5	0.5
Indoor plume shielding factor (skin dose and pure beta emitters)	NA	1.0	1.0	1.0
Indoor groundshine shielding factor (gamma emitters)[3]	NA	0.2	0.2	0.2
Groundshine shielding factor (uneven surface shielding)	NA	0.5	0.5	0.5
Beach swim occupancy factor	NA	0	0.014	0.014
Bathing occupancy factor	NA	0.014	0.014	0.014
Pool swim occupancy factor (WSP fill)	NA	0	0.028	0.028
Pool swim occupancy factor (Well water fill)	NA	0	0.014	0.014
Skin area	m^2	0.72	1.46	2.19
Dilution factor for shoreline sediments	NA	1.0	1.0	1.0
Shore Width factor (lake)	NA	0.3	0.3	0.3
Shoreline occupancy factor	NA	0.02	0.02	0.02
No. days/a soil ingested	d/a	135	135	135

Exposure Factor	Units(4)	Infant 1 year	Child 10 year	Adult
No. days/a sediment ingested	d/a	45	45	45

Notes:

(1) 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.

(2) Excludes shellfish due to fresh water environment at DN. Shellfish are a marine environment food product.

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

(4) dw used in specification of units indicates dry weight.

Sources: CSA (2008), Hart (2008), OPG (2010b)

3.2.4.2 Non-Radiological Exposure Factors

For non-radiological dose calculations, exposure factors are generally those from Health Canada Preliminary Quantitative Risk Assessment guidance (2004, 2010), as recommended by Clause 6.3.5 of CSA N288.6-12 (2012). **Error! Reference source not found.** summarizes the exposure factors used in the non-radiological dose calculations.

Based on the results of the screening, the human exposure assessment was performed for the drinking water and fish ingestion pathways for hydrazine and morpholine. Since nitrate is not expected to accumulate in fish because it is an oxyanion, only the drinking water ingestion pathway was evaluated for nitrate.

Each receptor was assumed to obtain only a portion of their drinking water or fish from the exposed media. The fractions of the total drinking water and total fish obtained from local WSPs and at the site, respectively, were based on the results of the site-specific survey (OPG 2012). These fractions are tabulated in **Error! Reference source not found.**.

3.2.5 Dispersion Models

OPG uses IMPACT™ version 5.4.0 (IMPACT) to calculate its annual public radiological doses using a mixture of environmental monitoring data and emissions data. IMPACT represents the method of dose calculation presented in CSA N288.1-08 (2008). Where environmental monitoring data were lacking, the concentration of radionuclides in air was determined from the sector-averaged Gaussian plume atmospheric dispersion model in IMPACT, based on the release rates from DN. **Error! Reference source not found.** shows a summary of which radionuclides and pathways were modelled and where measured data were used.

Dispersion models were not used for the assessment of chemical COPCs because no chemical COPCs were identified in air.

Table 3-10: Human Exposure Factors for Non-Radiological Dose Calculations

Parameter	Units	Urban Resident		Farm		Rural Resident		Industrial/ Commercial Worker	Sport Fisher		Camper		Reference
		Toddler	Adult	Toddler	Adult	Toddler	Adult	Adult	Toddler	Adult	Toddler	Adult	
Drinking Water Intake Rate	L/d	0.6	1.5	0.6	1.5	0.6	1.5	1.5	N/A	N/A	0.6	1.5	HC 2010
Fish Ingestion Rate	kg/d	0.056	0.111	0.056	0.111	0.056	0.111	N/A	0.056	0.111	0.056	0.111	HC 2004
Days per Week/7 (D2)	d/d	1	1	1	1	1	1	1	N/A	N/A	1	1	OPG 2012
Weeks per Year/52 (D3)	wk/wk	1	1	1	1	1	1	0.23	N/A	N/A	0.5	0.5	OPG 2012
Years Exposed (D4)	years	N/A	30	N/A	30	N/A	30	30	N/A	30	N/A	30	HC 2004
D_{fish}	d/a	365	365	365	365	365	365	N/A	365	365	182.5	182.5	OPG 2012
Body Weight	kg	16.5	70.7	16.5	70.7	16.5	70.7	70.7	16.5	70.7	16.5	70.7	HC 2010
Life Expectancy	years	N/A	70	N/A	70	N/A	70	70	N/A	70	N/A	70	HC 2010
$RAF_{GITnitrate}$		1	1	1	1	1	1	1	1	1	1	1	conservative assumption
$RAF_{GIThydrazine}$		1	1	1	1	1	1	1	1	1	1	1	conservative assumption
$RAF_{GITmorpholine}$		1	1	1	1	1	1	1	1	1	1	1	conservative assumption

Table 3-11: Assumed Fractions of Drinking Water from WSPs and Fish from DN Outfall (OPG, 2015c)

COPC	Urban Resident Oshawa/Courtice	Urban Resident Bowmanville	Urban Resident West/East Beach	Farm	Dairy Farm	Rural Resident	Industrial/ Commercial Worker	Sport Fisher	Camper
Water	0.835	0.785	0.142	0.05	0	0.158	1	0	1
Fish	0.0708	0.0038	0.0737	0.0322	0.0065	0.022	0	1	1

Table 3-12: Darlington Nuclear Critical Groups Data Use (OPG, 2015c)

Pathway	Radionuclide	Modeled (a)	Measured
Air Inhalation	HTO	√ (Fisher)	√(c)
	HT	√ (b)	
	C-14	√ (b)	√
	I(mfp)	√ (b)	
	Co-60	√ (b)	
Air External Exposure	Noble Gas		√ (c)
	C-14	√ (b)	√
	I(mfp)	√ (b)	
	Co-60	√ (b)	
Soil External Exposure	C-14	√	
	I-131	√	
	Cs-137+, Co-60	√	
Sand External Exposure	C-14	√	
	Cs-137+		√
Water External Exposure (Lakes, WSPs, Wells)	HTO	√ (wells)	√
	C-14	√	
	I-131	√	
	Cs-137+	√	
Terrestrial Animals Ingestion	HTO	√	√ (milk, eggs, poultry)
	C-14	√	√ (milk, eggs, poultry)
	I-131	√	
	Cs-137+, Co-60	√	
	OBT	√ (d)	
Terrestrial Plants Ingestion	HTO		√
	C-14		√
	I-131	√	
	Cs-137+, Co-60	√	
	OBT	√ (d)	
Aquatic Animals Ingestion	HTO		√
	C-14		√
	I-131	√	
	Cs-137+		√
	OBT	√ (d)	
Sand and Soil Incidental Ingestion	HTO	√	
	C-14	√	
	I-131	√	
	Cs-137+, Co-60	√	√ (sand)
Water Ingestion (WSPs, Wells)	HTO		√
	C-14	√	
	I-131	√	
	Cs-137+	√	

Notes:
"+" indicates that contributions from progeny are included.
(a) Modeling is based on emissions or from local air measurements where they are available.
(b) Concentrations are modeled from emissions and adjusted using empirical Ka determined for each critical group location.

(c) Doses are measured directly at the site boundary and adjusted to critical group locations using the ratio of modeled air dispersion factors for the boundary monitor and critical group.
(d) OBT dose is modeled from HTO concentration in terrestrial plants, terrestrial animals, or fish respectively.

3.2.6 Exposure Point Concentrations and Doses for Radiological COPCs

Since 2013, the annual Radiological Environmental Monitoring Program report was changed to the annual EMP report entitled "Results of Environmental Monitoring Programs". During this time, the EMP was redesigned to meet the requirements of CSA N288.4-10 (CSA, 2010) and expanded to include conventional contaminants, physical stressors and non-human biota in addition to the radiological contaminants and human exposure.

For the radiological exposure assessment, exposure point concentrations are either based on measured data from the annual EMP or modelled from emissions data, as described in **Error! Reference source not found.** and in OPG (2012). Additionally, when measurement averages or other calculations are performed, they are calculated using actual results obtained even if they are below the critical level (OPG, 2015c). As mentioned above, OPG uses IMPACT™ version 5.4.0 (IMPACT) to calculate its annual public doses using a mixture of environmental monitoring data and emissions data. **Error! Reference source not found.** presents a summary of the annual doses to the three most exposed critical groups from 2011 to 2015. These doses were calculated using annual average measured and modeled concentrations in environmental media.

The annual average dose to the three most exposed critical groups during the five year period of interest (2011 to 2015) ranged from 0.1 to 0.6 μSv and the most exposed critical groups were the farm and rural residents. The dominant pathways and radionuclides that contribute significantly to the total dose are inhalation and ingestion of HTO in air and in water, plants, and animal products; external exposure to noble gases; and ingestion of C-14 in plants and animal products.

The dose to the most exposed critical groups over the 2011 to 2015 time period remained relatively constant, and the doses have remained largely unchanged for the past ten years (OPG, 2016b).

Table 3-13: Summary of Doses to Most Exposed Critical Groups from 2011 to 2015

Year	Age Class	Radiological Dose (µSv/a)		
		Dairy Farm	Farm	Rural Resident
2011	Adult	0.5	0.6	0.3
	Child	0.4	0.5	0.3
	Infant	0.5	0.3	0.2
2012	Adult	0.5	0.3	0.3
	Child	0.4	0.3	0.2
	Infant	0.6	0.4	0.1
2013	Adult	0.3	0.6	0.3
	Child	0.3	0.5	0.2
	Infant	0.3	0.4	0.1
2014	Adult	0.3	0.6	0.3
	Child	0.3	0.5	0.2
	Infant	0.4	0.4	0.2
2015	Adult	0.3	0.5	0.2
	Child	0.3	0.4	0.2
	Infant	0.3	0.3	0.1

Sources: OPG, 2012b, 2013a, 2014b, 2015c, 2016b

3.2.6.1 Exposure Point Concentrations and Doses for Chemical COPCs

The exposure point concentrations are based on the screening conducted during problem formulation. For the waterborne non-radiological COPCs, data were screened based on a number of data sources: CCW data from the ECA from 2011 to 2015 (hydrazine and morpholine) and monitoring data from the 2014 EMP supplementary study (morpholine), and Lake Ontario water samples collected at DN in 2008, 2009, and 2014 (nitrate). The overall maximum and mean concentration from all of these sources was used for the exposure assessment. The dose to all receptors due to ingestion of fish exposed to hydrazine and morpholine assumes a continuous release. A large portion of the dataset for hydrazine and morpholine were non-detects, and these concentrations were evaluated at the detection limit.

3.2.6.1.1 Exposure Point Concentrations in and Doses from Surface Water

Maximum and mean measured concentrations in Lake water and in CCW effluent were diluted using the estimated dilution factors from OPG (2016f) in order to estimate exposure point concentrations for the COPCs, as follows:

- A dilution factor of 7 was applied to the CCW effluent to estimate a concentration in Lake Ontario at the Outfall;
- A dilution factor of 34.7 was applied to the CCW effluent to estimate a concentration at the Bowmanville WSP; and,

- A dilution factor of 35.6 was applied to the CCW effluent to estimate a concentration at the Oshawa WSP.

These dilution factors were calculated using the CSA N288.1-14 aquatic dispersion model (CSA 2014), which is an approved method of estimating dilution factors, and recommended site-specific parameters described in the COG DRL Guidance (COG, 2013). Additional model parameter values used in the calculations are listed in **Error! Reference source not found.**.

Table 3-14: Parameter Values for CSA Model and Resulting Dilution Factors (OPG, 2016f)

Parameter	Units	Description	Outfall	Camper (Beach)	Bowmanville WSP	Oshawa WSP
X	m	distance from DN	0	1,688	6,770	7,800
β	na	recirculation factor	1.15	1.15	1.15	1.15
Q_v	L/s	discharge flow	1.231E+05	1.231E+05	1.231E+05	1.231E+05
κ	na	proportionality factor	7.1E-06	7.1E-06	7.1E-06	7.1E-06
D_0	na	initial dilution factor	7	7	7	7
U_C	m/s	current speed to the right (W)	0.085	0.085	0.085	0.085
U_C	m/s	current speed to the left (E)	0.082	0.082	0.082	0.082
α	na	fraction of year current flows toward receptor	1.0	1.0	1.0	1.0
d	m	average plume depth	12	7	12	10.6
D_F	**na**	**calculated overall dilution factor**	**7.0**	10.9	**34.7**	**35.6**

In order to estimate nitrate concentrations in surface water at the WSPs, the maximum and mean nitrate concentrations measured in Lake Ontario were first concentrated by a factor of 7 to estimate an equivalent concentration in the CCW, assuming that the nitrate originated from the CCW. There is uncertainty whether nitrate should be concentrated by a factor greater than 7; however, this is the best information available. The dilution factor of 34.7 or 35.6 was then applied to this equivalent concentration to estimate the nitrate concentrations at Bowmanville and Oshawa WSPs, respectively.

The resulting exposure point concentrations in surface water are presented in **Error! Reference source not found.**. Based on these exposure point concentrations, and using the equations presented in Section 3.2.3.2 and the receptor characteristics presented in Section 3.2.4.2, surface water doses were estimated for each receptor. These doses are presented in **Error! Reference source not found.** (non-carcinogenic doses using maximum concentrations), **Error! Reference source not found.** (non-carcinogenic concentrations using mean concentrations), **Error! Reference source not found.** (carcinogenic doses using maximum concentrations), and **Error! Reference source not found.** (carcinogenic doses using mean concentrations).

Table 3-15: Summary of Exposure Point Concentrations of Non-Radiological COPCs in Surface Water

COPC	Lake Water (mg/L)		Effluent (ECA) (mg/L)		Dilution Factors *		
	Maximum Concentration	Mean Concentration	Maximum Concentration	Mean Concentration	Outfall	Bowmanville WSP	Oshawa WSP
Nitrate	89.7	2.8	-	-	7	34.7	35.6
Hydrazine	-	-	0.008	0.0032	7	34.7	35.6
Morpholine	-	-	0.008	0.0014	7	34.7	35.6

Notes:
* See Table 3.14 for parameters used in the derivation of these dilution factors.

COPC	Estimated at Outfall (mg/L)		Estimated at Bowmanville WSP (mg/L)		Estimated at Oshawa WSP (mg/L)	
	Maximum Concentration	Mean Concentration	Maximum Concentration	Mean Concentration	Maximum Concentration	Mean Concentration
Nitrate	89.7	2.8	18	0.56	18	0.55
Hydrazine	0.0011	4.6E-04	2.3E-04	9.2E-05	2.2E-04	9.0E-05
Morpholine	0.0011	2.0E-04	2.3E-04	4.0E-05	2.2E-04	3.9E-05

Table 3-16: Summary of Estimated Non-Carcinogenic Doses Due to Ingestion of Maximum COPC Concentrations in Surface Water

COPC	Urban Resident Oshawa/Courtice (mg/kg/d)		Urban Resident Bowmanville (mg/kg/d)		Urban Resident West/East Beach (mg/kg/d)	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Nitrate	5.36E-01	3.12E-01	5.17E-01	3.01E-01	9.34E-02	5.45E-02
Morpholine	6.82E-06	3.98E-06	6.58E-06	3.84E-06	1.19E-06	6.95E-07

COPC	Farm (mg/kg/d)		Dairy Farm (mg/kg/d)		Rural Resident (mg/kg/d)	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Nitrate	3.29E-02	1.92E-02	Does Not Drink Lake Water		1.04E-01	6.07E-02
Morpholine	4.19E-07	2.45E-07			1.32E-06	7.73E-07

COPC	Industrial/ Commercial Worker (mg/kg/d)	Sport Fisher (mg/kg/d)		Camper (mg/kg/d)	
	Adult	Toddler	Adult	Toddler	Adult
Nitrate	8.83E-02	Does Not Drink Lake Water		3.21E-01	1.87E-01
Morpholine	1.13E-06			4.09E-06	2.38E-06

Table 3-17: Summary of Estimated Non-Carcinogenic Doses Due to Ingestion of Mean COPC Concentrations in Surface Water

COPC	Urban Resident Oshawa/Courtice (mg/kg/d)		Urban Resident Bowmanville (mg/kg/d)		Urban Resident West/East Beach (mg/kg/d)	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Nitrate	1.67E-02	9.75E-03	1.61E-02	9.41E-03	2.92E-03	1.70E-03
Morpholine	1.19E-06	6.97E-07	1.15E-06	6.72E-07	2.08E-07	1.22E-07

COPC	Farm (mg/kg/d)		Dairy Farm (mg/kg/d)		Rural Resident (mg/kg/d)	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Nitrate	1.03E-03	5.99E-04	Does Not Drink Lake Water		3.25E-03	1.89E-03
Morpholine	7.34E-08	4.28E-08			2.32E-07	1.35E-07

COPC	Industrial/ Commercial Worker (mg/kg/d)	Sport Fisher (mg/kg/d)		Camper (mg/kg/d)	
	Adult	Toddler	Adult	Toddler	Adult
Nitrate	2.76E-03	Does Not Drink Lake Water		1.00E-02	5.84E-03
Morpholine	1.97E-07			7.15E-07	4.17E-07

Table 3-18: Summary of Estimated Carcinogenic Doses Due to Ingestion of Maximum COPC Concentrations in Surface Water

COPC	Urban Resident Oshawa/ Courtice (mg/kg/d)	Urban Resident Bowmanville (mg/kg/d)	Urban Resident West/East Beach (mg/kg/d)	Farm (mg/kg/d)	Dairy Farm (mg/kg/d)	Rural Resident (mg/kg/d)	Industrial/ Commercial Worker (mg/kg/d)	Sport Fisher (mg/kg/d)	Camper (mg/kg/d)
	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Hydrazine	1.71E-06	1.65E-06	2.98E-07	1.05E-07	Does Not Drink Lake Water	3.31E-07	4.82E-07	Does Not Drink Lake Water	1.02E-06

Table 3-19: Summary of Estimated Carcinogenic Doses Due to Ingestion of Mean COPC Concentrations in Surface Water

COPC	Urban Resident Oshawa/ Courtice (mg/kg/d)	Urban Resident Bowmanville (mg/kg/d)	Urban Resident West/East Beach (mg/kg/d)	Farm (mg/kg/d)	Dairy Farm (mg/kg/d)	Rural Resident (mg/kg/d)	Industrial/ Commercial Worker (mg/kg/d)	Sport Fisher (mg/kg/d)	Camper (mg/kg/d)
	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Hydrazine	6.82E-07	6.58E-07	1.19E-07	4.19E-08	Does Not Drink Lake Water	1.32E-07	1.93E-07	Does Not Drink Lake Water	4.09E-07

3.2.6.1.2 Exposure Point Concentrations in and Doses from Fish

Hydrazine is released into the atmosphere through boiler steam releases and venting. Hydrazine and morpholine are discharged into the aquatic environment through boiler blowdown and flushing to the intake forebay. Hydrazine is added to the feedwater for oxygen removal and morpholine is added to the feedwater for pH control. For this assessment, it was assumed that hydrazine and morpholine are released to the aquatic environment continuously.

Since several of the receptors are potentially exposed to chemical COPCs through fish ingestion, the fish tissue concentration for hydrazine and morpholine was estimated using bioaccumulation factors (BAFs), as discussed below.

Limited data exist on the bioaccumulation of hydrazine in aquatic organisms. Slonim and Gisclard (1976) derived a bioconcentration factor (BCF) of 288 L/kg based on a hydrazine concentration (144 mg/kg) estimated in guppies after four days exposure to hard water at a hydrazine concentration of 0.5 mg/L. According to Environment Canada and Health Canada (EC/HC, 2011) there are limitations and uncertainties associated with this study. Hydrazine was not measured in the fish, but was estimated from measurements in water, assuming that the slightly greater loss from water over 4 days, when fish were in the water, was due to uptake into the fish. Hydrazine bioaccumulation in fish was not directly measured. Since the same study showed higher rates of hydrazine degradation due to fish excretia in water, it is not clear that any hydrazine uptake into fish actually occurred. As well, a hydrazine concentration of 0.5 mg/L can generate ecotoxicity; therefore, there is uncertainty around the BCF of 288 L/kg. According to the *Persistence and Bioaccumulation Regulations* under the *Canadian Environmental Protection Act*, hydrazine would not be considered a substance that bioaccumulates since its BAF (or BCF) is less than 5000 and its $\log K_{ow}$ is less than 5 ($\log K_{ow}$ of -2.07, EC/HC, 2011).

Considering the large uncertainty surrounding the Slonim and Gisclard (1976) study, the published BCF from that study was not used for the quantitative evaluation of hydrazine. Quantitative Structure-Activity Relationship (QSAR) models are available to estimate bioconcentration factors for chemicals using correlations between BCFs and hydrophobicity ($\log K_{ow}$), where experimental data on bioaccumulation are lacking (European Commission, 2006). Meylan et al. 1999 (as cited in European Commission, 2006) recommends an improved model that suggests using a logBCF of 0.5 for all non-ionic compounds with $\log K_{ow} < 1$. Therefore, a logBCF of 0.5 was used to represent bioaccumulation of hydrazine in fish.

No data exist on the bioaccumulation of morpholine in aquatic organisms; however, bioaccumulation is not expected based on its low octanol-water partition coefficient ($\log K_{ow}$ of -2.55) (BUA, 1991 as cited in WHO, 1996). According to the *Persistence and Bioaccumulation Regulations* under the *Canadian Environmental Protection Act*, a substance is considered to bioaccumulate if its BAF$\geq$5000, or its BCF$\geq$5000, or if the

$\log K_{ow} \geq 5$ (if neither the BAF nor the BCF can be determined). Similar to hydrazine, a logBCF of 0.5 was used to represent bioaccumulation of morpholine in fish, based on the recommended QSAR models discussed above (Meylan et al. 1999; as cited in European Commission, 2006).

The resulting estimated exposure point concentrations for fish are presented in **Error! Reference source not found.**. Based on these exposure point concentrations, and using the equations presented in Section 3.2.3.2 and the receptor characteristics presented in Section 3.2.4.2, fish ingestion doses were estimated for each receptor. These doses are presented in **Error! Reference source not found.** (non-carcinogenic doses using maximum concentrations), **Error! Reference source not found.** (non-carcinogenic concentrations using mean concentrations), **Error! Reference source not found.** (carcinogenic doses using maximum concentrations), and **Error! Reference source not found.** (carcinogenic doses using mean concentrations).

Table 3-20: Summary of Exposure Point Concentrations of Non-Radiological COPCs in Fish

COPC	Estimated Water Concentrations – Estimated at Outfall (mg/L)		Bioconcentration Factor (BCF) (L/kg)	Estimated Fish Concentrations (All Receptors Except Camper) – Estimated at Outfall (mg/kg)	
	Maximum Concentration	Mean Concentration		Maximum Concentration	Mean Concentration
Hydrazine	0.0011	4.6E-04	3.2	0.0036	0.0014
Morpholine	0.0011	2.0E-04	3.2	0.0036	6.3E-04

COPC	Estimated Water Concentrations – Estimated at Beach (mg/L)		Bioconcentration Factor (BCF) (L/kg)	Estimated Fish Concentrations (Camper) – Estimated at Beach (mg/kg)	
	Maximum Concentration	Mean Concentration		Maximum Concentration	Mean Concentration
Hydrazine	6.2E-04	2.5E-04	3.2	0.0019	7.8E-04
Morpholine	6.2E-04	1.1E-04	3.2	0.0019	3.4E-04

Table 3-21: Summary of Estimated Non-Carcinogenic Doses Due to Ingestion of Maximum COPC Concentrations in Fish

COPC	Urban Resident Oshawa/Courtice		Urban Resident Bowmanville		Urban Resident West/East Beach	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Morpholine	8.68E-07	4.02E-07	4.66E-08	2.16E-08	9.04E-07	4.18E-07

COPC	Farm		Dairy Farm		Rural Resident	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Morpholine	3.95E-07	1.83E-07	7.97E-08	3.69E-08	2.70E-07	1.25E-07

COPC	Industrial/ Commercial Worker	Sport Fisher		Camper	
	Adult	Toddler	Adult	Toddler	Adult
Morpholine	Does Not Eat Local Fish	1.23E-05	5.67E-06	3.30E-06	1.53E-06

Table 3-22: Summary of Estimated Non-Carcinogenic Doses Due to Ingestion of Mean COPC Concentrations in Fish

COPC	Urban Resident Oshawa/Courtice		Urban Resident Bowmanville		Urban Resident West/East Beach	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Morpholine	1.52E-07	7.03E-08	8.16E-09	3.77E-09	1.58E-07	7.32E-08

COPC	Farm		Dairy Farm		Rural Resident	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Morpholine	6.91E-08	3.20E-08	1.40E-08	6.45E-09	4.72E-08	2.18E-08

COPC	Industrial/ Commercial Worker	Sport Fisher		Camper	
	Adult	Toddler	Adult	Toddler	Adult
Morpholine	Does Not Eat Local Fish	2.15E-06	9.93E-07	5.78E-07	2.67E-07

Table 3-23: Summary of Estimated Carcinogenic Doses Due to Ingestion of Maximum COPC Concentrations in Fish

COPC	Urban Resident Oshawa/ Courtice	Urban Resident Bowmanville	Urban Resident West/East Beach	Farm	Dairy Farm	Rural Resident	Industrial/ Commercial Worker	Sport Fisher	Camper
	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Hydrazine	1.72E-07	9.24E-09	1.79E-07	7.83E-08	1.58E-08	5.35E-08	Does Not Eat Local Fish	2.43E-06	6.55E-07

Table 3-24: Summary of Estimated Carcinogenic Doses Due to Ingestion of Mean COPC Concentrations in Fish

COPC	Urban Resident Oshawa/ Courtice	Urban Resident Bowmanville	Urban Resident West/East Beach	Farm	Dairy Farm	Rural Resident	Industrial/ Commercial Worker	Sport Fisher	Camper
	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Hydrazine	6.89E-08	3.70E-09	7.17E-08	3.13E-08	6.32E-09	2.14E-08	Does Not Eat Local Fish	9.73E-07	2.67E-07

3.2.7 Uncertainties in the Exposure Assessment

Error! Reference source not found. summarizes the major uncertainties in the exposure assessment.

Table 3-25: Summary of Major Uncertainties in the Exposure Assessment

Risk Assessment Assumption	Justification	Over/Under Estimate Risk?
Water concentration for nitrate, hydrazine, and morpholine at Bowmanville and Oshawa WSPs is pre-treatment, and is modeled from liquid releases, with no degradation.	Hydrazine degrades by oxidation in water, with rates depending on hardness and organic matter; it degrades rapidly under chlorinated conditions typically used for treatment/distribution of drinking water (EC/HC, 2011). No information on degradation of other COPCs post WSP treatment or from PN to WSPs.	Overestimate
Dilution factors based on CSA aquatic dispersion model, as specified in CSA (2014), were used to estimate water concentrations at the WSPs	These dilution factors form the basis for the DRL calculation, which are consistent with N288.1-14. They are expected to be conservative estimates of true dilution factors.	Overestimate
BAF for hydrazine is based on QSAR model and not measured bioaccumulation data.	Limited information exists on bioaccumulation of hydrazine, although it is expected to be low. Only one study (Slonim and Gisclard, 1976) exists on hydrazine bioaccumulation, and there is large uncertainty surrounding the methods and results.	Neither (value is best estimate)
BAF for morpholine is based on QSAR model and not measured bioaccumulation data.	No information in literature regarding morpholine BAF, although it is not expected to bioaccumulate.	Neither (value is best estimate)

3.3 Toxicity Assessment

3.3.1 Toxicological Reference Values (TRVs)

TRVs may include slope factors and unit risks for carcinogens, and reference doses, tolerable daily intake, or acceptable daily intake for non-carcinogens. TRVs are used in the risk characterization to determine Incremental Lifetime Cancer Risks (ILCRs) and Hazard Quotients (HQs), as discussed in Section 3.4.1.2. A summary of the TRVs selected for nitrate, hydrazine and morpholine is presented in **Error! Reference source not found.** and discussed below.

Nitrate is not known to be carcinogenic or teratogenic. It is reduced to nitrite by bacteria in the human gut, and nitrite oxidizes hemoglobin to methemoglobin, which can no longer bind oxygen. Exposure to nitrates may therefore deplete the ability of the blood to transport oxygen, potentially causing cyanosis and at elevated levels, weakness, rapid pulse, and tachypnea (US EPA 1991). The US EPA has derived a Reference Dose (RfD) of 1.6 mg/kg/d for nitrates based on early signs of methemoglobinemia in infants younger than 3 months. An uncertainty factor of 1 and a modifying factor of 1 were applied to the No Observed Adverse Effect Level (NOAEL) of 10 mg/L of nitrate as nitrogen in drinking water, corresponding to a RfD of 1.6 mg/kg/d.

Hydrazine is classified by the International Agency for Research on Cancer (IARC) and the US EPA as a Group 2B carcinogen – probable human carcinogen; and by the European Commission as Category 2 for carcinogenicity – should be regarded as if it is carcinogenic to man. Studies showed tumor induction in mice, rats and hamsters following administration of hydrazine orally or via inhalation (EC/HC, 2011). The US EPA (1991) has derived an oral slope factor of 3.0 $(mg/kg\text{-}day)^{-1}$ for ingestion of hydrazine based on a 1970 study by Biancifiori on liver cancer in mice exposed to hydrazine sulphate orally.

Morpholine is not carcinogenic or teratogenic; however, morpholine can be nitrosated to n-nitrosomorpholine which is carcinogenic. Health Canada (2002) has derived an acceptable daily intake of 0.48 mg/kg/d based on a No Observable Adverse Effect Level (NOAEL) from a chronic oral toxicity study conducted by Shibata et al. (1987) in rats and mice, with the inclusion of uncertainty factors (UFs). Specifically, a UF of 10 was used for the inter-species differences between mice and humans, and a second UF of 10 was used for the intra-species differences between humans. Additionally, a UF of 2 was included to reflect the deficiencies in the toxicological database (J. Rotstein, personal communication, December 27, 2013).

Table 3-26: Selected Human Toxicity Reference Values for Chemical COPCs

COPC	TRV Type	Value	Units	Reference
Nitrate	Reference Dose	1.6	mg/kg/d	IRIS US EPA, 1991
Hydrazine	Oral Slope Factor	3	$(mg/kg/d)^{-1}$	IRIS US EPA, 2001 (as cited in US EPA, 2009)
Morpholine	Acceptable Daily Intake	0.48	mg/kg/d	HC, 2002

3.3.2 Radiation Dose Limits and Targets

The public dose limit 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.

3.3.3 Uncertainties in the Toxicity Assessment

The RfD for nitrate that was used in this assessment is a NOAEL for infant nitrate exposures causing methemoglobinemia. No uncertainty or modifying factors were used in its derivation. Infants are the most sensitive life stage for this health effect, and because a NOAEL was used as the basis for the RfD, all life stages are expected to be protected through its use.

Oral slope factors, such as that for hydrazine, are developed as conservative upper-bound estimates of the increase in carcinogenic risks due to lifetime exposure to the COPC. Slope factors are used to estimate an upper bound probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The slope factor is based on the assumption of a linear low-dose response. This is considered conservative.

The acceptable daily intake for morpholine incorporates several UFs. Specifically, a UF of 10 was used for the inter-species differences between mice and humans, and a second UF of 10 was used for the intra-species differences between humans. Additionally, a UF of 2 was included to reflect the deficiencies in the toxicological database (J. Rotstein, personal communication, December 27, 2013). These factors are intended to provide a conservative toxicity reference value.

3.4 Risk Characterization

3.4.1 Risk Estimation

3.4.1.1 Risk Estimation for Radiological COPCs

For radionuclides, the total doses presented in **Error! Reference source not found.** are compared to the public dose limit of 1 mSv/a, as discussed in Section 3.3.2 above.

3.4.1.2 Risk Estimation for Chemical COPCs

In order to characterize potential risks due to chemical COPCs quantitatively, the results of the exposure and toxicity assessments were used to estimate HQs and ILCRs for each receptor. HQs were estimated for non-carcinogenic substances using a threshold TRV as follows:

Hazard Quotient = Estimated Exposure / Toxicity Reference Value

These HQs were compared to a target value of 0.2, as recommended by Clause 6.5.2.6 in CSA N288.6-12.

For carcinogenic substances, the estimated oral exposure was multiplied by a slope factor, to derive a conservative estimate of the potential ILCR, as follows:

ILCR = Estimated Oral Exposure x Cancer Slope Factor

The estimated ILCRs were compared to a target cancer risk of 1 in 1,000,000 or 10^{-6}, as recommended by Clause 6.5.2.4 in CSA N288.6-12. This level is consistent with the acceptable risk level used by the Ontario MOE (2011) and the US EPA (2005). At this risk level, health impacts are considered to be negligible. Other agencies, such as Health Canada use a target cancer risk of 1 in 100,000 or 10^{-5}. However, a range of cancer risk levels between 1 in 10,000 and 1 in 1,000,000 may be considered acceptable (Health Canada, 2004).

Summaries of the HQs and ILCRs for surface water ingestion are presented in **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**, and those for fish ingestion are presented in **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**. The HQs and ILCRs are calculated according to the equations described above. The estimated exposures are from Tables 3.17 through 3.20 and Tables 3.22 through 3.25 in the exposure assessment in Section 3.2. The TRVs used are those from **Error! Reference source not found.** in the toxicity assessment in Section 3.3.

Table 3-27: Summary of Estimated Hazard Quotients Due to Ingestion of Maximum COPC Concentrations in Surface Water

COPC	Urban Resident Oshawa/Courtice		Urban Resident Bowmanville		Urban Resident West/East Beach	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Nitrate	**0.3**	0.2	**0.3**	0.2	0.06	0.03
Morpholine	1E-05	8E-06	1E-05	8E-06	2E-06	1E-06

COPC	Farm		Dairy Farm		Rural Resident	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Nitrate	0.02	0.01	Does Not Drink Lake Water		0.06	0.04
Morpholine	9E-07	5E-07			3E-06	2E-06

COPC	Industrial/ Commercial Worker	Sport Fisher		Camper	
	Adult	Toddler	Adult	Toddler	Adult
Nitrate	0.06	Does Not Drink Lake Water		0.20	0.1
Morpholine	2E-06			9E-06	5E-06

Note:
Grey shading indicates when the risk exceeds the associated target value. Cancer Risk < 1.00E-06, HQ < 0.2.

Table 3-28: Summary of Estimated Hazard Quotients Due to Ingestion of Mean COPC Concentrations in Surface Water

COPC	Urban Resident Oshawa/Courtice		Urban Resident Bowmanville		Urban Resident West/East Beach	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Nitrate	0.01	0.006	0.01	0.006	0.002	0.001
Morpholine	2E-06	1E-06	2E-06	1E-06	4E-07	3E-07

COPC	Farm		Dairy Farm		Rural Resident	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Nitrate	0.0006	0.0004	Does Not Drink Lake Water		0.002	0.001
Morpholine	2E-07	9E-08			5E-07	3E-07

COPC	Industrial/ Commercial Worker	Sport Fisher		Camper	
	Adult	Toddler	Adult	Toddler	Adult
Nitrate	0.002	Does Not Drink Lake Water		0.006	0.004
Morpholine	4E-07			1E-06	9E-07

Note:
Grey shading indicates when the risk exceeds the associated target value. Cancer Risk < 1.00E-06, HQ < 0.2.

Table 3-29: Summary of Estimated ILCRs Due to Ingestion of Maximum COPC Concentrations in Surface Water

COPC	Urban Resident Oshawa/ Courtice	Urban Resident Bowmanville	Urban Resident West/East Beach	Farm	Dairy Farm	Rural Resident	Industrial/ Commercial Worker	Sport Fisher	Camper
	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Hydrazine	**5E-06**	**5E-06**	9E-07	3E-07	Does Not Drink Lake Water	1E-06	**1.4E-06**	Does Not Drink Lake Water	**3E-06**

Note:
Grey shading indicates when the risk exceeds the associated target value. Cancer Risk < 1.00E-06, HQ < 0.2.

Table 3-30: Summary of Estimated ILCRs Due to Ingestion of Mean COPC Concentrations in Surface Water

COPC	Urban Resident Oshawa/ Courtice	Urban Resident Bowmanville	Urban Resident West/East Beach	Farm	Dairy Farm	Rural Resident	Industrial/ Commercial Worker	Sport Fisher	Camper
	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Hydrazine	**2E-06**	**2E-06**	4E-07	1E-07	Does Not Drink Lake Water	4E-07	6E-07	Does Not Drink Lake Water	**1.2E-06**

Note:
Grey shading indicates when the risk exceeds the associated target value. Cancer Risk < 1.00E-06, HQ < 0.2.

Table 3-31: Summary of Estimated Hazard Quotients Due to Ingestion of Maximum COPC Concentrations in Fish

COPC	Urban Resident Oshawa/Courtice		Urban Resident Bowmanville		Urban Resident West/East Beach	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Morpholine	2E-06	8E-07	1E-07	4E-08	2E-06	9E-07

COPC	Farm		Dairy Farm		Rural Resident	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Morpholine	8E-07	4E-07	2E-07	8E-08	6E-07	3E-07

COPC	Industrial/ Commercial Worker	Sport Fisher		Camper	
	Adult	Toddler	Adult	Toddler	Adult
Morpholine	Does Not Eat Local Fish	3E-05	1E-05	7E-06	3E-06

Note:
Grey shading indicates when the risk exceeds the associated target value. Cancer Risk < 1.00E-06, HQ < 0.2.

Table 3-32: Summary of Estimated Hazard Quotients Due to Ingestion of Mean COPC Concentrations in Fish

COPC	Urban Resident Oshawa/Courtice		Urban Resident Bowmanville		Urban Resident West/East Beach	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Morpholine	3E-07	1E-07	2E-08	8E-09	3E-07	2E-07

COPC	Farm		Dairy Farm		Rural Resident	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Morpholine	1E-07	7E-08	3E-08	1E-08	1E-07	5E-08

COPC	Industrial/ Commercial Worker	Sport Fisher		Camper	
	Adult	Toddler	Adult	Toddler	Adult
Morpholine	Does Not Eat Local Fish	4E-06	2E-06	1E-06	6E-07

Note:
Grey shading indicates when the risk exceeds the associated target value. Cancer Risk < 1.00E-06, HQ < 0.2.

Table 3-33: Summary of Estimated ILCRs Due to Ingestion of Maximum COPC Concentrations in Fish

COPC	Urban Resident Oshawa/ Courtice	Urban Resident Bowmanville	Urban Resident West/East Beach	Farm	Dairy Farm	Rural Resident	Industrial/ Commercial Worker	Sport Fisher	Camper
	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Hydrazine	5E-07	3E-08	5E-07	2E-07	5E-08	2E-07	Does Not Eat Local Fish	**7E-06**	**2E-06**

Note:
Grey shading indicates when the risk exceeds the associated target value. Cancer Risk < 1.00E-06, HQ < 0.2.

Table 3-34: Summary of Estimated ILCRs Due to Ingestion of Mean COPC Concentrations in Fish

COPC	Urban Resident Oshawa/ Courtice	Urban Resident Bowmanville	Urban Resident West/East Beach	Farm	Dairy Farm	Rural Resident	Industrial/ Commercial Worker	Sport Fisher	Camper
	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult	Adult
Hydrazine	2E-07	1E-08	2E-07	9E-08	2E-08	6E-08	Does Not Eat Local Fish	**3E-06**	8E-07

Note:
Grey shading indicates when the risk exceeds the associated target value. Cancer Risk < 1.00E-06, HQ < 0.2.

3.4.2 Discussion of Chemical and Radiation Effects

3.4.2.1 Effects Monitoring Evidence

Two studies of health indicators in Durham Region (Durham Region Health Department, 1996, 2007) compared the incidence of cancer deaths and birth defects for Durham Region, and for municipalities within Durham Region including Ajax-Pickering, Oshawa-Whitby, Clarington, and North Durham against the same statistics for the Province of Ontario. In the 1996 study, Halton Region and Northumberland were used for comparison purposes and in the 2007 study Halton Region and Simcoe County were used for comparison against Durham Region. Both studies found no evidence that any emissions from the CANDU stations at DN and at Pickering Nuclear Generating Station had any adverse health effects on nearby residents.

3.4.2.2 Likelihood of Effects

3.4.2.2.1 Likelihood of Effects from Radiological COPCs

The 2011-2015 public dose estimates for the critical groups are at most approximately 0.06% of the regulatory public dose limit of 1 mSv/a, and at most approximately 0.04% of the dose from background radiation in the vicinity of DN. Since these critical groups receive the highest dose from DN, demonstration that they are protected implies that other receptor groups near DN are also protected.

Facility releases are considered to be adequately controlled, and further optimization of DN operations is not required. Nevertheless, the ALARA principle is applied at DN to keep 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 DN.

3.4.2.2.2 Likelihood of Effects from Chemical COPCs

For surface water ingestion exposures, potential non-carcinogenic effects were evaluated for nitrate and morpholine, as shown in **Error! Reference source not found.** and **Error! Reference source not found.**. For these two COPCs, estimated maximum and mean hazard quotients for all receptors were at or below 0.2, with the exception of the maximum HQs estimated for Oshawa/Courtice and Bowmanville urban resident Toddler's exposure to nitrate. For the majority of receptors assessed for nitrate and for all of the receptors assessed for morpholine, no human health risks are expected due to ingestion of surface water. For the Oshawa/Courtice and Bowmanville urban resident Toddlers, although the HQs based on maximum concentration exceeded 0.2, the corresponding HQs based on mean concentration did not exceed 0.2. In addition, the nitrate concentration at each of the WSPs was estimated in the Lake prior to treatment; the treatment process may remove nitrate from the water supply before distribution to local residents. The 2016 effluent characterization study has also indicated that DN effluents do not appear to be sources of nitrate, in that the maximum analyzed concentration of nitrate in any stream is 4.88 mg/L from the WTP, which is less than half the drinking water quality guideline of 10 mg/L. As such, adverse effects to humans due to nitrate originating from DN through surface water ingestion are not considered likely.

Potential carcinogenic effects to the receptors were also assessed due to exposure to hydrazine through surface water ingestion, as shown in **Error! Reference source not found.** and **Error! Reference source not found.**. The resulting estimated ILCRs exceeded one in one million for maximum and mean surface water concentrations for the Oshawa/Courtice and Bowmanville urban residents, as well as the camper receptors. Although the hydrazine concentration at each of the WSPs was estimated in the Lake prior to treatment, and the treatment process may remove hydrazine from the water supply before distribution to local residents, DN CCW effluent is known to be a source of hydrazine to Lake Ontario. As such, human health risks to any of these receptors cannot be ruled out due to hydrazine, and human health effects could potentially occur.

As shown in **Error! Reference source not found.** and **Error! Reference source not found.**, maximum hydrazine ILCRs exceeded one in one million for the industrial/commercial workers, but ILCRs based on mean concentrations did not exceed one in one million for these receptors. Since cancer risks are estimated over a period of several years due to the time scale of carcinogenesis, and the ILCRs based on mean concentration are considered to be more representative of long-term exposures, health risks to these receptors due to hydrazine are not expected, and adverse effects due to surface water ingestion are considered unlikely. Health effects are also not considered likely for any of the other receptors, for whom all ILCRs, based on mean or maximum concentration, did not exceed one in one million.

For fish ingestion exposures, potential non-carcinogenic effects were evaluated for morpholine only, as nitrate is not expected to bioaccumulate. The results of this assessment are shown in **Error! Reference source not found.** and **Error! Reference source not found.**. Estimated maximum and mean hazard quotients for morpholine for all receptors were below 0.2. As such, adverse effects to humans due to ingestion of fish from the DN area that potentially contain morpholine are not considered likely.

Potential carcinogenic effects to the receptors were also assessed due to exposure to hydrazine through fish ingestion, as shown in **Error! Reference source not found.** and **Error! Reference source not found.**. The resulting estimated ILCRs exceeded one in one million for maximum and mean surface water concentrations for the Sport Fisher. This receptor was assumed to eat all of the fish portion of their diet from Lake Ontario fish caught at DN, which is considered to be an unlikely scenario because a person would not be expected to catch and eat all of their fish in one specific place, but the approach is consistent with OPG's DRL calculations and EMP calculations for radionuclides. As such, human health risks to these receptors cannot be ruled out due to hydrazine, and human health effects may be likely.

As shown in **Error! Reference source not found.** and **Error! Reference source not found.**, hydrazine ILCRs based on maximum concentrations exceeded one in one million for the campers, but ILCRs based on mean concentrations did not exceed one in one million for this receptor. Since cancer risks are estimated over a period of several years due to the time scale of carcinogenesis, and the ILCRs based on mean concentration are considered to be more representative of long-term exposures, health risks to this receptor due to hydrazine are not expected, and adverse effects due to surface water ingestion are considered unlikely. Health effects are also not considered likely for any of the other receptors, for whom all ILCRs, based on mean or maximum concentration, did not exceed one in one million.

Overall, health risks are not expected for human receptors due to nitrate and morpholine in water and in fish. Risks could not be ruled out for the Sport Fisher due to hydrazine in fish, and to the Oshawa/Courtice and Bowmanville Urban Residents as well as campers due to hydrazine in drinking water.

3.4.3 Uncertainties in the Risk Characterization

The uncertainties in the characterization of risk consist of those in the exposure and toxicity assessments (Sections 3.2 and 3.3), since the function of this section in a risk assessment is to combine the results of these two sections. Important uncertainties from the exposure assessment include the use of estimated pre-treatment concentrations at Oshawa and Bowmanville WSPs that do not account for water treatment before distribution to residents, use of QSAR models to develop BCFs for hydrazine and morpholine, and use of Gaussian plume models to derive dilution factors for transport of the COPCs in Lake Ontario. Those from the toxicity assessment include conservatisms built into the selected TRVs. Taken together, these approaches have ensured that the risk characterization has been undertaken in a manner that has not underestimated risk; the resulting hazard quotients are either overestimates or realistic estimates of risk, both of which are considered acceptable.

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 (2012), a qualitative or semi-quantitative evaluation of uncertainty is considered sufficient for evaluation of uncertainty.

4.0 ECOLOGICAL RISK ASSESSMENT

4.1 Problem Formulation

The Problem Formulation defines the problem to be addressed in the EcoRA and the framework and general methodology by which the EcoRA will address the defined problem (FCSAP, 2012a). Consistent with the FCSAP (2012a), the problem formulation typically includes the following elements:

- A description of the EcoRA objectives or management goals;
- A description of the regulatory context of the EcoRA;
- A review of existing Study Area information;
- The selection of COPCs;
- The selection of Valued Ecosystem Components (VECs) that may be present in the Study Area;
- A description of the exposure pathways by which COPCs in the Study Area may come into contact with the VECs,
- An ecological conceptual model (CSM) that illustrates the connections between the sources of contaminants, the exposure pathways and VECs;
- An explanation of protection goals;
- Identification of assessment endpoints and measurement endpoints;
- The development of lines of evidences for each assessment endpoint and how the measurement endpoints will be used to evaluate risk to VECs;
- How risks will be characterized; and
- The description of any uncertainties associated with the Problem Formulation.

These elements are discussed in the following sections.

The EcoRA focuses on the DN site and surrounding area (SSA), as shown in **Error! Reference source not found.**. The assessment has been divided into polygons consistent with past EcoRAs. The assessment also looks at nearshore Lake Ontario, generally in the area surrounding the outfall from the DN diffuser.

Figure 4-1: Area of Assessment for Ecological Risk Assessment

4.1.1 EcoRA Objectives and Management Goals

The objectives of the EcoRA are to:

- Characterize and evaluate potential health risks to current and future VECs exposed to affected air, surface water, sediment, and soil in the receiving environments surrounding DN, and
- Assess the potential for effects on VEC populations or communities in order to inform the environmental protection program.

The management goal of the EcoRA is to provide information about the potential for DN effects on VEC populations or communities in order inform the environmental protection program.

4.1.2 Receptor Selection and Characterization

4.1.2.1 Receptor (VEC) Selection

It is generally an impractical task to assess the effect of radiological and non-radiological emissions on all the species of biota within a natural ecosystem, and specifically within the ecosystem around the DN site. Therefore, a representative group of organisms are chosen for dose and risk analysis. These organisms are selected because they are known to exist on the site, and are representative of major taxonomic groups or exposure pathways, or have a special importance or value. These organisms are known as valued ecosystem components (VECs).

VECs were selected in previous ecological assessments for the DN site in 2011 (SENES 2011c) and 2009 (SENES 2009a). For the 2009 ERA, a number of VECs were selected that were representative of the various feeding habits and characteristics of the species present at the site.

The selection process was described in SENES (2009a) Appendix C and included a staged approach to VEC selection. This process was adapted for the current EcoRA:

- Preliminary selection: a list of ecological receptors for the DN site was compiled from previous DN assessment reports;

- Secondary selection: The list of ecological receptors was expanded to include other species identified in the terrestrial and aquatic environment TSDs for the 2009 EA that were found to frequent the DN site;

- Final selection: The list of ecological receptors was refined. In some instances, individual species with similar exposure pathways were grouped together and analyzed as one generic type of ecological receptor. For example, all terrestrial trees and grasses were analyzed as “terrestrial vegetation,” and various benthic invertebrate species were analyzed as "benthic invertebrates." In other cases particular species were selected as representatives of different feeding habits. For example, American robin, bank swallow, yellow warbler, and song sparrow were analyzed with species-specific feeding habits.

Stakeholder input into VEC selection was also considered, as documented in the Communications and Consultation TSDs from both EAs (SENES 2009a; 2011c). The ecological receptors from the two ERAs, along with their rationale for selection, were reviewed and assessed based on the criteria listed in Table 7.1 of CSA N288.6 (2012). The 2009 and 2011 lists of ecological receptors known to frequent the Site were reviewed, with data provided in DN Biodiversity reports for the most recent 5-year period (2011 to 2015). Common nesting bird species, bats, as well as amphibians and reptiles identified in the 2011 to 2015 biodiversity reports were added to the list. **Error! Reference source not found.** presents the assessment of ecological receptors for the DN site based on the CSA criteria.

VECs were selected as receptors for the conceptual model based on the criteria in **Error! Reference source not found.**. This table summarizes the key information used in the selection process. Receptors in bold are selected as VECs for further assessment.

Table 4-1: Criteria for the Selection of Ecological Receptors

<table>
<tr><th rowspan="2">Organism Category</th><th rowspan="2">Species</th><th colspan="4">Selection Criteria</th><th rowspan="2">Applicable Selection Criteria</th></tr>
<tr><th>1
Major Plant or Animal Group</th><th>2
Facility or Stakeholder Importance</th><th>3
Socio-economic/ ecological Significance</th><th>4
Exposed to and/or Sensitive to Stressor</th></tr>
<tr><td rowspan="3">Bottom-Feeding Fish</td><td>Northern Redbelly Dace</td><td>Benthopelagic forage fish</td><td>Present on Site - Coots Pond</td><td>-</td><td rowspan="2">waterborne emissions; non-radioactive emissions; radioactive emissions</td><td>Selected as VEC: 1, 2, 4</td></tr>
<tr><td>Round Whitefish</td><td>Benthic forage fish</td><td>Present near Site - VEC for previous EAs</td><td>Commercial fish - nearshore spawning shoals in the area</td><td>Selected as VEC: 1, 2, 3, 4</td></tr>
<tr><td>White Sucker</td><td>Common nearshore benthic forage fish</td><td>Present near Site - VEC for previous EAs</td><td>Dominant member of sparse nearshore fish community;</td><td>waterborne emissions; thermal emissions; impingement concern; non-radioactive emissions; radioactive emissions</td><td>Selected as VEC: 1, 2, 3, 4</td></tr>
</table>

Organism Category	Species	Selection Criteria 1 Major Plant or Animal Group	 2 Facility or Stakeholder Importance	 3 Socio-economic/ ecological Significance	 4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
Bottom-Feeding Fish	Lake Sturgeon	Benthic forage fish	Present near Site - VEC for previous EAs - found in Lake Ontario and adjacent tributary mouths	Conservation concern in Lake Ontario - Subject to recovery efforts in Lake Ontario - Historical fisheries species	waterborne emissions; thermal emissions; impingement concern; non-radioactive emissions; radioactive emissions	Not selected as VEC: Assessment of other bottom-feeding fish will be protective of Lake Sturgeon
Pelagic Fish	**Alewife**	Common pelagic forage fish	Present on Site - VEC for previous EAs - Common impinged species	Dominant member of sparse nearshore fish community	waterborne emissions; thermal emissions; impingement concern; non-radioactive emissions	Selected as VEC: 1, 2, 3, 4
	Lake Trout	Common pelagic predator fish	Present near Site - VEC for previous EAs	Potentially spawns in the area - Commercial and sport fish	waterborne emissions; thermal emissions	Selected as VEC: 1, 2, 3, 4

Organism Category	Species	Selection Criteria 1 Major Plant or Animal Group	2 Facility or Stakeholder Importance	3 Socio-economic/ ecological Significance	4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
Pelagic Fish	**American Eel**	Benthopelagic predator fish	Present near Site - Highly valued by Aboriginal peoples	Conservation concern in Lake Ontario - Highly valued by Aboriginal peoples	waterborne emissions; thermal emissions; impingement concern; non-radioactive emissions	Selected as VEC: 1, 2, 3, 4
	Emerald Shiner	Nearshore schooling pelagic forage fish	Present on Site - VEC for previous EAs - found in Forebay and Lake Ontario	numerically important in nearshore fish community		Not selected as VEC: Assessment for other pelagic fish expected to be protective of Emerald Shiner
	Spottail Shiner	Pelagic forage fish	Present near Site - found in forebay and Lake Ontario	-		Not selected as VEC: Assessment for other pelagic fish expected to be protective of Spottail Shiner
	Round Goby	Nearshore pelagic forage fish	Present near Site - VEC for previous EAs - found in Lake Ontario	Exotic species in Lake Ontario		Not selected as VEC: Invasive species; assessment for other pelagic fish expected to be protective of Round Goby

Organism Category	Species	Selection Criteria				Applicable Selection Criteria
		1 Major Plant or Animal Group	**2 Facility or Stakeholder Importance**	**3 Socio-economic/ ecological Significance**	**4 Exposed to and/or Sensitive to Stressor**	
Reptiles and Amphibians	American Toad	Toad	Present on Site	-	Airborne emissions; waterborne emissions; non-radioactive emissions; radioactive emissions	Not selected as VEC: Insufficient information available to determine toxicity to reptiles
	Midland Painted Turtle	**Turtle**	Present on Site - VEC for previous EAs	On-Site breeder		Selected as VEC: 1, 2, 3, 4
	Snapping Turtle	**Turtle**	Present on Site	-		Selected as VEC: 1, 2, 4
	Green Frog	**Frog**	Present on Site - VEC for previous EAs	On-Site breeder		Selected as VEC: 1, 2, 3, 4
	Northern Leopard Frog	**Frog**	Present on Site	-		Selected as VEC: 1, 2, 4
Aquatic Plants	Bur-reed	**Aquatic plant**	VEC for previous EAs	Heavily used by wildlife - represents permanent shallow water marshland areas	Waterborne emissions; non-radioactive emissions; radioactive emissions	Selected as VEC: 1, 2, 3, 4

Organism Category	Species	Selection Criteria 1 Major Plant or Animal Group	 2 Facility or Stakeholder Importance	 3 Socio-economic/ ecological Significance	 4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
Aquatic Invertebrates	Amphipods	**Benthic invertebrates**	VEC for previous EAs	Food source	Waterborne emissions; non-radioactive emissions; radioactive emissions	Selected as VEC: 1, 2, 3, 4
	Oligochates/ chironomids					
	Molluscs					
	Crayfish					
	Zebra mussels					
Riparian Birds	**Bufflehead**	Diving bird - invertebrates	Present on Site -VEC for previous EAs - Inshore and Coots Pond	Value to the general public	Waterborne emissions; radioactive emissions; non-radioactive emissions; exposed to sediment contamination	Selected as VEC: 1, 2, 3, 4
	Mallard	Dabbling bird - invertebrates	Present on Site -VEC for previous Eas - Inshore and Coots Pond	Value to the general public		Selected as VEC: 1, 2, 3, 4
	Pied-billed Grebe	Diving bird - invertebrates	Present on Site -VEC for previous EAs - Inshore and Coots Pond	-		Not selected as VEC: Assessment of Mallard and Bufflehead is expected to be protective of Pied-billed Grebe
Riparian Mammals	**Muskrat**	Mammalian herbivore	Present on Site -VEC for previous EAs	On-site breeder - year round presence	Non-radioactive emissions	Selected as VEC: 1, 2, 3, 4

Organism Category	Species	Selection Criteria 1 Major Plant or Animal Group	2 Facility or Stakeholder Importance	3 Socio-economic/ ecological Significance	4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
Terrestrial Invertebrates	Butterflies	Long-distant migrant	Present on Site	Conservation concern for winter habitat stress (Mexico)	Airborne emissions; non-radioactive emissions; radioactive emissions	Not selected as VEC: Assessment for Earthworm is expected to be protective of butterflies
	Dragonflies	Aquatic early lifestage - Insectivore	Present on Site	-		Not selected as VEC: Assessment for Earthworm is expected to be protective of dragonflies
	Earthworms	Soil dwelling - Detritivore	Present on Site - VEC for previous EAs	-		Selected as VEC: 1, 2, 4
Terrestrial Birds	**American Robin**	Ground feeding insectivore	Present on Site - VEC for previous EAs	On-Site breeder - Common to the upland community	Exposed to non-radioactive emissions through diet	Selected as VEC: 1, 2, 3, 4
	Bank Swallow	Aerial insectivore	Present on Site - VEC for previous EAs	Breeds along Lake Ontario shoreline		Selected as VEC: 1, 2, 3, 4
	Song Sparrow	Tree/shrub feeding omnivore	Present on Site - VEC for previous EAs	On-Site breeder - Common to upland successional habitat		Selected as VEC: 1, 2, 3, 4

Organism Category	Species	Selection Criteria				Applicable Selection Criteria
		1 Major Plant or Animal Group	2 Facility or Stakeholder Importance	3 Socio-economic/ ecological Significance	4 Exposed to and/or Sensitive to Stressor	
Terrestrial Birds	**Yellow Warbler**	Tree/shrub feeding insectivore	Present on Site - VEC for previous EAs	On-Site breeder - Common to Coots pond, upland successional habitat	Exposed to non-radioactive emissions through diet	Selected as VEC: 1, 2, 3, 4
	House Wren	Tree/shrub feeding insectivore	Present on Site -	On-site breeder		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of House Wren
	Barn Swallow	Aerial insectivore	Present on Site -	On-Site breeder		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of –Barn Swallow
	Tree Swallow	Aerial insectivore	Present on Site -	On-Site breeder		Not selectede as VEC: Assessment of other terrestrial birds is expected to be protective of Tree Swallow
	Mourning Dove	Ground feeding herbivore	Present on Site	On-Site breeder		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Mourning Dove
	Downy Woodpecker	Tree feeding insectivore	Present on Site	On-Site breeder - common to		Not selected as VEC: Assessment of other terrestrial birds is

Organism Category	Species	Selection Criteria 1 Major Plant or Animal Group	2 Facility or Stakeholder Importance	3 Socio-economic/ ecological Significance	4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
				woodland habitat		expected to be protective of Downy Woodpecker
	Eastern Wood-Pewee	Aerial insectivore	Present on Site	On-Site breeder - common to woodland habitat		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Eastern Wood-Pewee
Terrestrial Birds	Willow Flycatcher	Aerial insectivore	Present on Site	On-Site breeder - Common to Coots pond, upland successional habitat	Exposed to non-radioactive emissions through diet	Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Willow Flycatcher
	Great Crested Flycatcher	Aerial insectivore	Present on Site	On-Site breeder		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Great Crested Flycatcher
	Eastern Kingbird	Aerial insectivore	Present on Site	On-Site breeder - Common to Coots pond		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Eastern Kingbird
	Black-capped chickadee	Tree feeding insectivore	Present on Site	On-Site breeder - common to		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective

Organism Category	Species	Selection Criteria: 1 Major Plant or Animal Group	2 Facility or Stakeholder Importance	3 Socio-economic/ ecological Significance	4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
				woodland habitat		ofBlack-capped Chickadee
	Grey Catbird	Ground feeding insectivore	Present on Site	On-Site breeder - Common to upland successional habitat		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Grey Catbird
Terrestrial Birds	Cedar Waxwing	Tree feeding herbivore (berries and fruit)	Present on Site	On-Site breeder - Common to upland successional habitat	Exposed to non-radioactive emissions through diet	Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Cedar Waxwing
	American Redstart	Aerial insectivore	Present on Site	On-Site breeder - common to woodland habitat		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of American Redstart
	Common Yellowthroat	Shrub/ ground feeding insectivore	Present on Site	On-Site breeder - Common to upland successional habitat		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Common Yellowthroat
	Savannah Sparrow	Ground feeding insectivore	Present on Site	On-Site breeder		Not selected as VEC:Assessment of other terrestrial birds is

Organism Category	Species	Selection Criteria 1 Major Plant or Animal Group	2 Facility or Stakeholder Importance	3 Socio-economic/ ecological Significance	4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
						expected to be protective of Savannah Sparrow
	Red-winged Blackbird	Shrub/ ground feeding omnivore	Present on Site	On-Site breeder - Common to Coots pond, upland successional habitat		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Red-winged Blackbird
Terrestrial Birds	Common Grackle	Shrub/ ground feeding omnivore	Present on Site	On-Site breeder	Exposed to non-radioactive emissions through diet	Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Common Grackle
	American Goldfinch	Tree/shrub feeding herbivore (seeds)	Present on Site	On-Site breeder		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of American Goldfinch
	American Crow	Omnivore	Present on Site -VEC for previous EAs	Common to the Site		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of American Crow
	Red-eyed Vireo	Tree/ shrub feeding insectivore	Present on Site -VEC for previous EAs	Infrequent on-Site breeder - woodland habitat		Not selected as VEC: Assessment of other terrestrial birds is expected to be protective of Red-eyed Vireo

Organism Category	Species	Selection Criteria 1 Major Plant or Animal Group	2 Facility or Stakeholder Importance	3 Socio-economic/ ecological Significance	4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
Terrestrial Plants	Grass of Parnassus	**Grasses**	Present on Site - VEC for previous EAs - Bluff community - rare to the Region	Reflects groundwater seepage and associated flora and fauna	Non-radioactive emissions	Selected as VEC: 1, 2, 3, 4
	Sugar Maple	Deciduous tree	Present on Site -VEC for previous EAs	Important element in woodland community		Selected as VEC: 1, 2, 3, 4
Mammals	**Eastern Cottontail**	Mammalian herbivore	Present on Site -VEC for previous EAs	Common to upland habitat	Non-radioactive emissions	Selected as VEC: 1, 2, 3, 4
	Meadow Vole	Mammalian herbivore	Present on Site -VEC for previous EAs	On-site breeder - year round presence - Common to upland habitat - common prey item	Non-radioactive emissions	Selected as VEC: 1, 2, 3, 4
	White-tailed Deer	Mammalian herbivore	Present on Site -VEC for previous EAs	Common to upland habitat	Sensitive to human activities	Selected as VEC: 1, 2, 3, 4
	Common Shrew	Mammalian insectivore		Common in similar habitats to the Site	Non-radioactive emissions	Selected as VEC: 1, 3, 4

Organism Category	Species	Selection Criteria 1 Major Plant or Animal Group	2 Facility or Stakeholder Importance	3 Socio-economic/ ecological Significance	4 Exposed to and/or Sensitive to Stressor	Applicable Selection Criteria
	Raccoon	Mammalian omnivore	Present on Site -VEC for previous EAs	Common to upland habitat	Non-radioactive emissions	Selected as VEC: 1, 2, 3, 4
	Red Fox	Mammalian carnivore	Present on Site -VEC for previous EAs	Common to upland habitat	Sensitive to human activities	Selected as VEC: 1, 2, 3, 4
	Short Tailed Weasel	Mammalian carnivore	Present on Site -VEC for previous EAs	Common to upland habitat	Sensitive to human activities	Selected as VEC: 1, 2, 3, 4
Mammals	Deer Mouse	Mammalian omnivore	Present on Site -VEC for previous EAs	Common to upland habitat	Non-radioactive emissions	Not selected as VEC: Assessment of other terrestrial mammals is expected to be protective of Deer Mouse
	Little Brown Myotis (Bat)	Mammalian insectivore	Present on Site	Uncommon to Site-Conservation concern due to fungal disease		Not selected as VEC: Assessment of other terrestrial mammals is expected to be protective of Little Brown Myotis

The 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 site. In making the selection, species that were ecologically similar to other species and could be represented by another species, were not selected, in order to reduce redundancy in the exposure calculations. For example, the alewife and emerald shiner are similar across all criteria, and could be assessed interchangeably. However, according to impingement reports, of these two species, the alewife is the dominant native species impinged at PN, so it was chosen to be a receptor. Other effects on the alewife are considered to be representative of effects on the emerald shiner. Further descriptions regarding the chosen VECs, such as habitat and feeding habits, are provided in Appendix B.

Error! Reference source not found. shows the VECs chosen for assessment and the assessment models used in estimating their COPC exposure, dose and risk. Six species of fish were chosen as VECs to represent the fishes likely to be influenced by the operation of DN. However, due to the limited species-specific exposure factor and toxicity data available, risks to fish are estimated by assessing the fish in two categories (bottom-feeding fish and pelagic fish) for the radiological assessment, and as one category of fish for the non-radiological assessment. Similarly, for terrestrial plants, all species were assessed in one category (terrestrial plants) using generic bioaccumulation factors and toxicity reference values.

A fish model is used for assessment of frogs because the sensitive life stages for frogs (i.e., egg and tadpole) are aquatic and similar to the sensitive life stages for fish. For example, during the tadpole stage, tadpoles and fish have similar exposure pathways (e.g., absorption through skin and gills). In addition, exposure factor and toxicity data for amphibians are limited. Therefore, the fish assessment model is considered to be appropriate for frogs during their sensitive life stages.

A fish model is also used for assessment of turtles, since there is a lack of exposure factor and toxicity data for turtles. Both organisms reside in water, and they share similar exposure pathways.

Several of the buildings on the DN site may provide a suitable habitat for birds. Geese and gulls typically nest on most of the building roofs in the protected area. The assessment of other riparian birds as VECs, such as the Bufflehead and the Mallard, is expected to be protective of geese and gulls.

Table 4-2: Summary of VECs and their Assessment Models used in the EcoRA

VEC Category	Assessment Model	VEC
Fish	Bottom Feeding Fish	Northern Redbelly Dace
		Round Whitefish
		White Sucker
	Pelagic Fish	Alewife

VEC Category	Assessment Model	VEC
		Lake Trout
		American Eel
Reptiles and Amphibians	Bottom Feeding Fish	Turtles
		Frogs
Aquatic Plants	Aquatic Plant	Aquatic Plants
Aquatic Invertebrates	Benthic Invertebrate	Benthic Invertebrates
Riparian Birds	Bufflehead	Bufflehead
	Mallard	Mallard
Riparian Mammals	Muskrat	Muskrat
Terrestrial Invertebrates	Soil Invertebrate	Earthworm
Terrestrial Birds	American Robin	American Robin
	Bank Swallow	Bank Swallow
	Song Sparrow	Song Sparrow
	Yellow Warbler	Yellow Warbler
Terrestrial Plants	Terrestrial Plant	Grass
	Terrestrial Plant	Sugar maple
Terrestrial Mammals	Eastern Cottontail	Eastern Cottontail
	Meadow Vole	Meadow Vole
	White-tailed Deer	White-tailed Deer
	Common Shrew	Common Shrew
	Raccoon	Raccoon
	Red Fox	Red Fox
	Short-tailed Weasel	Short-tailed Weasel

4.1.2.2 Consideration of Species at Risk

A review of all flora and fauna identified in the DN Species at Risk and Biodiversity reports from 2011 to 2015 was performed against the Species at Risk in Ontario (SARO) list, the federal Species at Risk Act, Schedule 1, and the COSEWIC list. Consistent with the information presented in Sections 2.3.5 and 2.3.6, a number of threatened and endangered species have been identified within the DN Site Study Area during the 2011 to 2015 time period, as shown in Table 4.3. Exposure models for specific assessment of these species are typically lacking. Most of these species can be assessed by reference to surrogate species already selected as VECs for the EcoRA. Detailed justifications for selections of each of the surrogate species, based on habitat, diet, and ecological niche considerations, are presented below.

Table 4-3: Surrogate Species for Identified Species at Risk

Species at Risk (Common and Scientific Name)	Federal/ Provincial Status	Surrogate Species	Last Observed
Birds			
Bank Swallow (*Riparia riparia*)	Threatened/ Threatened	Bank Swallow (*Riparia riparia*)	2015
Barn Swallow (*Hirundo rustica*)	Threatened/ Threatened	Bank Swallow (*Riparia riparia*)	2015
Olive-sided Flycatcher (*Contopus cooperi*)	Threatened/ -	Bank Swallow (*Riparia riparia*)	2012
Bobolink (*Dolichinyx oryzivorus*)	Threatened/ Threatened	American Robin (*Turdus migratorius*)	2015
Eastern Meadowlark (*Strunella magna*)	Threatened/ Threatened	American Robin (*Turdus migratorius*)	2015
Wood Thrush (*Hylocichla mustelina)*	Threatened/ -	American Robin (*Turdus migratorius*)	2014
Canada Warbler (*Cardellina canadensis*)	Threatened/ -	Bank Swallow (*Riparia riparia*)	2011
Mammals			
Little Brown Myotis (Bat) (*Myotis lucifugus*)	Endangered/ Endangered	Common Shrew (*Sorex araneus*)	2013
Plants			
Butternut Tree (*Juglans cinerea*)	Endangered/ Endangered	Sugar Maple (*Acer saccharum*)	2015
Fish			
American Eel (*Anguilla rostrata*)	Threatened/ Endangered	American Eel (*Anguilla rostrata*)	2016

Note:
These species were identified at the DN Site during the 2011 to 2015 period
For birds, only species possibly breeding on-Site are included
Federal and Provincial status may change. The status of these species was last verified June 28, 2016 from:
Federal: COSEWIC (October 24, 2016), SARA (Species at Risk Act), Schedule 1 Status (modified June 22, 2016). The habitat of listed species (Schedule 1) is protected under SARA.
Provincial: Committee on the Status of Species at Risk in Ontario (COSSARO) status (Updated June 20, 2016).

Seven bird species, and one each of mammal, plant and fish, were identified as threatened or endangered species at the Site over the 2011 to 2015 period. Species designations change over time, therefore the most recent designation guided the selection of Species at Risk for the 2011 to 2015 period. During this time, Peregrine Falcon was downgraded from Threatened to Special Concern (SARO) at the end of 2012 and therefore does not appear on the list of species at risk, and Bank Swallow was newly listed as Threatened (SARO) in 2014 and does appear on the list.

Least Bitterns are aquatic carnivores. Their diet consists mainly of fish, frogs, crustaceans and insects, which they capture directly from the water while climbing through or perching on marsh plants. They are visual predators and prefer dense marshes with some open water areas to forage for prey. Least Bitterns generally nest in marshes with dense vegetation. Least Bittern is considered to be an occasional user of the Site. It was identified at the Site in 2012 at Coots Pond and was considered unlikely to be breeding there. It was the subject of species-specific searches in suitable habitat but was not recorded at the DN site since 2012. Because it is only an occasional user of the Site and is not expected to breed on-Site, this species is not assessed in the ERA.

Bank Swallow and Barn Swallow are aerial insectivores and feed over open areas such as fields, meadows watercourses and waterbodies. Bank swallows nest colonially in small to large colonies where there are natural or artificial soft soil banks, such as natural river and lake bluffs, in which they create nesting burrows. The lakeshore Bank Swallow colonies at the DN site during the 2011 to 2015 period were estimated to be between 1,500 and 2,500 burrows, the majority of which are found along the eastern-most third of the shoreline of the DN site. Bank Swallow was considered as a VEC in the ERA.

Barn Swallow, in Ontario, typically nests in small openings in man-made buildings, such as barns. Barn Swallows are annual breeders at the Site, all around the existing station. Over the 2011 to 2015 period 20 to 63 active nests were observed in any one year in and around the buildings on the site, including an artificial nesting site created by OPG. Barn Swallows are typically observed foraging over lawns, open field areas, wetlands and along the lakeshore at the DN Site. Several of the buildings on the DN site may provide a suitable habitat for birds: in 2015, Barn Swallows nested on various buildings within the protected area such as the TRF, Vacuum Building, Emergency Power Generator Fuel Maintenance Building, Drawing storage Facility, SG Building 1-4, Compressed gas Storage Building, D2O Management Building, Reactor Building 1 & 2, Turbine Building at U4 end, and Emergency Power Supply Building (M. Crouch, personal communication, September 7, 2016). The Bank Swallow is considered a suitable surrogate species for the Barn Swallow, and the assessment of ecological risks for the Bank Swallow in this ERA is expected to be adequate for protection of the Barn Swallow.

The Bank Swallow is also considered a suitable surrogate species for the Canada Warbler. The Canada Warbler eats insects such as spiders that have been gleaned off of foliage (COSEWIC, 2008).

Olive-sided Flycatcher is also an aerial insectivore. They are most often found along natural forest edges and openings where they typically hunt from foraging perches such as trees. Olive-sided flycatchers' breeding habitat usually consists of coniferous or mixed forest adjacent to rivers or wetlands. It is not considered to breed onsite. During the 2011 to 2015 period, a single bird was observed on migration in 2012. Potential risk to this species is expected to be adequately assessed by reference to other avian insectivores such as the Bank Swallow.

Bobolink and Eastern Meadowlark are omnivores which typically forage on or near the ground for insects, seeds and berries. The Bobolink typically breeds in large agricultural grasslands or fields such as hayfields and other fields with tall lush forb vegetation. It is an annual breeder at the DN Site mostly at the Bobolink Hill area. Eastern Meadowlark also breeds in grasslands and prairie, as well as pastures and hay fields. The Eastern Meadowlark builds its nest on the ground, covered with a roof woven from grasses. The species is an annual breeder at the DN site mostly at the Bobolink Hill area. Wood Thrush are omnivores which typically forage on invertebrates and fruits. They prefer woodlands and are not typically found at DN. However, in 2014, a singing male was heard near the east end of Coots Pond and another was recorded in the New Build area in 2015 (Beacon, 2016b). Potential risk to these species is expected to be adequately assessed by reference to other avian omnivores such as the American Robin.

Little Brown Myotis is in an aerial insectivore. Like other bats, it forages during the night and roosts in trees or buildings during the day. Little Brown Myotis will often select attics, abandoned buildings and barns for summer colonies to raise their young. One bat was recorded near Treefrog Pond in 2013 using bat monitoring equipment. It was not determined if this record was a breeding individual. Potential risk to this species is expected to be adequately assessed by reference to other mammalian insectivores such as the Common Shrew.

Butternut is a medium-sized tree, belonging to the walnut family, which can reach up to 30 m in height. In Ontario, Butternut usually grows alone or in small groups in deciduous forests, in sunny openings and near forest edges. It prefers moist, well-drained soil and is often found along streams, or on well-drained gravel sites. Potential risk to this species is expected to be adequately assessed by reference to other terrestrial plant species such as the Sugar Maple.

American Eel is believed to feed primarily on detritus. The American Eel uses a variety of marine and freshwater habitats over the course of its life history. It spawns in the Sargasso Sea. During its migrations to and from spawning areas in the Sargasso Sea it occurs in continental and oceanic habitats. In fresh water, its preferred habitat is in lakes and rivers including all waters to a depth of least a 10 m. The American Eel has been assessed as a VEC in this ERA.

4.1.2.3 Receptor Characterization

Receptor profiles in Appendix B describe the habitat and the feeding habits of the selected receptor species. The receptor species were assigned to assessment locations on the site based on habitat features at each location and species habitat preferences. Receptor locations for assessment purposes are discussed in Section 4.1.5.

For mammals and birds, dietary assumptions were made based on the described feeding habits. Diets were simplified to represent the main food chain pathways without trying to capture their full taxonomic complexity. For example, muskrats are assumed to eat aquatic plants. Additionally, although some species may primarily eat insects (i.e., red-winged blackbird), earthworm is used as a representative for all terrestrial insects and soil invertebrates, since limited bioaccumulation data are available for insects and other invertebrates. The dietary assumptions for bird and mammal receptors are detailed in **Error! Reference source not found.**.

Species-specific exposure parameters, including bioaccumulation factors, food and water ingestion rates, transfer factors and body weights, are described Section 4.2.4.

4.1.3 Assessment and Measurement Endpoints

Assessment endpoints are explicit expressions of the environmental values that are to be protected (FCSAP, 2012). Assessment endpoints should include the VEC and the attribute of the VEC that is to be protected (e.g. abundance and viability) (FCSAP, 2012). The assessment endpoints to be evaluated in this EcoRA are presented in **Error! Reference source not found.**.

Measurement endpoints are conceptually related to assessment endpoints and are defined as the tools that are used to measure exposure of or effects on each VEC. Based on these measures, a potential for effect on the attribute of an assessment endpoint can be inferred. Measurement endpoints are the foundation for the lines of evidence that are used to estimate risks to VECs (FCSAP, 2012).

Measurement endpoints for COPCs are often linked to low-effect threshold concentrations or doses, also known as toxicological reference values (TRVs). The TRV represents the level of COPC exposure that is associated with a minimal and acceptable level of effect to the VEC. The TRVs typically used in EcoRA are based on growth, survival and reproduction measurement endpoints. They represent effects on individuals that are relevant to the viability of VEC populations.

For benthic invertebrates, TRVs are often chosen from the low end of a species sensitivity distribution, but do not necessarily represent the most sensitive species of their group, recognizing that the ecological function of benthic invertebrates as a food source does not depend on protecting all species.

For this EcoRA, sediment concentration-based TRVs (mg/kg dry weight) were selected for the benthic community, water concentration-based TRVs (mg/L or µg/L) were selected for aquatic plants, plankton and forage fish, and dose-based TRVs (mg/kg body weight/day) were selected for mammalian and avian wildlife. These TRVs were based on the lowest low-effect threshold concentrations or doses for survival, growth or reproduction.

For most VECs, the assessment endpoint is the viability of the population. This implies that very localized areas of effect on individuals may be tolerated, based on minimal expected effect at the population level. For species at risk (SAR) the assessment endpoint is individual health, recognizing that each individual is important to the population, thus any TRV exceedance is considered unacceptable.

Table 4-4: Assessment Endpoints, Measurement Endpoints, and Lines of Evidence

Valued Ecosystem Components	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Use of Measurement Endpoints for Specific LOEs
Bottom Feeding Fish (Northern Redbelly Dace, Round Whitefish, White Sucker, American Eel*)	Population	Maintenance of bottom feeding fish populations in Lake Ontario as source of food for piscivorous fish and wildlife.	Viability of bottom-feeding fish populations	Water Chemistry	Comparison of COPC concentrations to growth, survival and reproduction toxicological reference values (low-effect threshold concentrations).
				Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Pelagic Fish (Alewife, Lake Trout)	Population	Maintenance of pelagic fish populations in Lake Ontario as source of food for piscivorous fish and wildlife.	Viability of pelagic fish populations.	Water Chemistry	Comparison of COPC concentrations to growth, survival and reproduction toxicological reference values (low-effect threshold concentrations).
				Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.

Valued Ecosystem Components	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Use of Measurement Endpoints for Specific LOEs
Reptiles and Amphibians (Turtles, Frogs)	Population	Maintenance of turtle and frog populations in Coots Pond and Treefrog Pond as sources of food for fish and wildlife.	Viability of turtle and frog populations.	Water Chemistry	Comparison of COPC concentrations to growth, survival and reproduction toxicological reference values (low-effect threshold concentrations).
				Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Aquatic Plants	Population	Maintenance of aquatic plant populations in Coots Pond and Treefrog Pond as a source of food and cover for wildlife.	Viability of aquatic plant populations.	Water Chemistry	Comparison of COPC concentrations to growth, survival and reproduction toxicological reference values (low-effect threshold concentrations) for aquatic plants.
				Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.

Valued Ecosystem Components	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Use of Measurement Endpoints for Specific LOEs
Benthic Invertebrates	Community	Maintenance of a diverse aquatic and benthic invertebrate community in Lake Ontario, Coots Pond, and Treefrog Pond as source of food for fish and wildlife.	Richness, diversity, abundance of benthic invertebrates.	Water Chemistry	Comparison of COPC concentrations to water quality guidelines.
				Sediment Chemistry	Comparison of COPC concentrations to sediment quality guidelines.
				Radiological Dose	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Riparian Birds (Bufflehead, Mallard)	Population	Maintenance of riparian bird populations along Lake Ontario shoreline and Coots Pond as source of food for predatory wildlife.	Viability of aquatic riparian bird populations	Radiological and Toxicological Doses	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Riparian Mammals (Muskrat)	Population	Maintenance of riparian mammal population along Coots Pond as source of food for predatory wildlife.	Viability of aquatic riparian mammal populations		
Terrestrial Invertebrates (Earthworm)	Population	Maintenance of terrestrial invertebrate population at the DN site as a source of food for wildlife.	Viability of terrestrial invertebrate populations		

Valued Ecosystem Components	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Use of Measurement Endpoints for Specific LOEs
Terrestrial Birds (American Robin, Bank Swallow*, Song Sparrow, Yellow Warbler)	Population	Maintenance of the terrestrial bird population at the DN site.	Viability of terrestrial bird populations	Radiological and Toxicological Doses	Comparison of estimated doses of COPCs to growth, survival and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Terrestrial Plants (Grasses, Sugar Maple)	Population	Maintenance of the terrestrial plant population at the DN site.	Viability of terrestrial plant populations		
Terrestrial Mammals (Eastern Cottontail, Meadow Vole, White-Tailed Deer, Common Shrew, Raccoon, Red Fox, Short-Tailed Weasel)	Population	Maintenance of terrestrial mammal population at the DN site.	Viability of terrestrial mammal populations		

Notes:
LOE: Line of evidence
* For Species at Risk (SAR) the goal is protection of individuals, recognizing that each individual’s health is important to the population, thus any toxicological reference value exceedance is considered unacceptable.

4.1.4 Selection of Chemical, Radiological, and Other Stressors

The same monitoring data sources previously screened for the HHRA (Section 3.1.2) were screened for the EcoRA using the more conservative of available federal and provincial guidelines and objectives as screening criteria. If there was no such guideline or objective, screening criteria were obtained from the literature, and/or derived using federally and/or provincially accepted methods. For COPCs where these criteria are not available, upper estimates of background concentrations or conservative toxicity benchmarks (e.g., no effects levels) are used as screening criteria. Maximum measured concentrations of parameters in surface water, sediment, soil, and air are compared to the selected screening criteria in order to determine the list of COPCs. Contaminants are also retained as COPCs if no screening criteria are available.

4.1.4.1 Selection of Chemical COPCs in Air

Section 3.1.2.1 describes the atmospheric releases due to the operations at the DN site. As per clause 7.3.4.2.5 in N288.6-12, inhalation exposures to biota are usually minor compared to the soil and food ingestion pathways, and can be ignored for most substances, except for substances that do not partition to soil (CSA, 2012). These substances may include gases such as nitrogen oxides (NOx), hydrazine, and morpholine, as for these substances air concentrations dominate the exposure pathway to terrestrial biota For completeness, all chemicals identified in the ESDM (OPG, 2012a, 2013a, 2014a, 2015a) have been screened against relevant ecological benchmarks (Appendix A, Table A.7). The MOECC AAQC has been used as the preferred screening level as AAQCs are developed to be protective of health and the environment. Where AAQCs were not available other screening levels such as Effects Screening Levels from the Texas Commission on Environmental Quality (TCEQ, 2015) were used. Effects Screening Levels are based on data for health effects, odour and effects on vegetation and can therefore be applied as ecological screening levels.

For NOx, air concentrations dominate the exposure pathway to terrestrial biota. As discussed in Section 3.1.2.1, the main source of NOx includes combustion emissions from the Standby Gas Turbines, Auxiliary Power System Combustion Turbine Units, Auxiliary Power System Diesel Generators and minor sources. The maximum concentrations at the DN property line POI for NOx were predicted using estimated atmospheric emissions and a dispersion factor. The ½ hour POI concentrations were converted to concentrations with averaging periods comparable to the relevant MOECC AAQC. The AAQCs are developed to be protective of health and the environment. The 24-hr NOx concentration at the property line is 109 μg/m^3, compared to the 24-hr AAQC of 200 μg/m^3. The predicted maximum NOx concentration at the property line is well below the AAQC, therefore NOx is not likely to have potential effects on ecological receptors located at or beyond the property line.

Hydrazine and morpholine are released to the air through atmospheric boiler emissions, as described in Section 3.1.2.1, and also do not partition well to soil. The releases due to boiler venting were compared against an acute toxicity benchmarks. The benchmarks considered were Lowest Observable Adverse Effect Levels (LOAELs) converted to No Observable Adverse Effect Levels (NOAELs) by applying a safety factor of 10. This conversion factor has been used to derive the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 1999a), and is the most conservative factor cited in Suter *et al.* (1993).

The maximum ½ -hour POI concentration for morpholine was 36.9 µg/m^3 (Appendix A, Table A.7), below the acute toxicity benchmark for morpholine of 780,000 µg/m^3 (WHO, 1996). Therefore, morpholine was not carried forward for further assessment.

The ½ -hour POI for hydrazine has been replaced in the ESDM with an annual average concentration since 2013; therefore, the maximum annual average concentration for hydrazine was also compared against a chronic toxicity benchmark. The maximum ½ -hour POI for hydrazine was 1.76 µg/m^3, below the acute toxicity benchmark for hydrazine of 10,600 µg/m^3 (EC/HC, 2011) (Appendix A, Table A.7). The maximum annual average concentration for hydrazine was 0.00089 µg/m^3, below the chronic toxicity benchmark for hydrazine of 6 µg/m^3 (EC/HC, 2011) (Appendix A, Table A.7). These concentrations did not exceed their toxicity benchmarks. Therefore, hydrazine was not carried forward for further assessment.

Based on the screening presented in Appendix A, Table A.7 for chemicals released to air, maximum concentrations are below their respective screening levels; therefore, no air COPCs are carried forward for further assessment in the EcoRA.

There may be individuals located within the DN site boundary, including potential species at risk, which may be exposed to chemicals in air; however, this pathway is expected to be minor, and there is not a robust assessment approach that can assess exposure via inhalation and evaluate toxicity to mammals and birds. As such, overall, no chemical COPCs were carried forward in air for assessment of risks to ecological receptors.

4.1.4.2 Selection of Chemical COPCs in Surface Water

The surface water screening is based primarily on measurements of chemical COPCs in Lake Ontario water, as well as Coots Pond and Treefrog Pond water. In addition, concentrations of chemical parameters in the CCW discharges from 2011 to 2015, and concentrations of chemical parameters in storm water discharges to Lake Ontario from 2011 to 2015, were screened to ensure that the list of chemical COPCs was complete. If a COPC was identified in lake water, pond water, effluent or storm water, it was carried forward for further consideration in the EcoRA.

4.1.4.2.1 Lake Water Sampling

As documented in the Darlington Nuclear Refurbishment and Continued Operation Environmental Assessment Follow-Up Program – Effluent Characterization Sampling Plan

(NK38-PLAN-03480-10003-R000), OPG identified a list of potential contaminants in liquid effluent that may be related to DN operations. This list of contaminants has been used as a basis for the screening of COPCs in Lake Ontario. The data set used in this screening was the same as that used in the human health screening in Section 3.1.2.2.1.

For each analyzed chemical, its maximum concentration in surface water was screened against its provincial water quality objective (PWQO) or Canadian Council of Ministers of the Environment (CCME) water quality guideline for the protection of freshwater aquatic life. Toxicity based water quality benchmark values were selected from the literature for those COPCs which do not have a PWQO or CCME value. The toxicity benchmark values selected for screening are chronic low-effect threshold concentrations for sensitive test species. Toxicity benchmark values were selected for hydrazine, morpholine, gadolinium and lithium.

Chemicals with maximum concentrations exceeding the most conservative of these benchmarks were carried forward as chemical COPCs in this assessment. Chemicals were not deemed to be COPCs if they exceeded mean background concentrations by less than 20% as differences of less than 20% are typically not statistically discernible or measurable in the field or laboratory (Suter et al, 1995, 1996). The results of this screening can be found in Table A.8 in Appendix A.

The maximum measured concentration for total aluminum in Lake Ontario water was 3.5 mg/L, as compared to a Canadian Drinking Water Quality Guideline of 0.1 mg/L. However, the maximum measured concentration for dissolved aluminum (in a filtered sample) was 0.01 mg/L, which is an order of magnitude below the CDWG. The relatively high concentration of aluminum in the unfiltered samples is therefore considered to be indicative of the presence of suspended solids in the samples. Since the dissolved phase of aluminum is expected to be considerably more bioavailable than any aluminum in a suspended phase, which is likely to be in the oxide form, aluminum has not been carried forward as a chemical COPC for ecological health.

As shown in Table A.8, the detection limits for chromium (VI), mercury, PHC F2, and phosphorus exceeded their respective screening benchmarks for ecological health. None of these chemicals has been detected in samples of Lake Ontario water, and therefore none of them have been considered to be COPCs for ecological health. Copper, nitrate, and TRC were detected at concentrations exceeding their respective ecological screening benchmarks, and these contaminants have been carried forward as chemical COPCs in the ecological risk assessment.

4.1.4.2.2 Liquid Effluent Sampling

As in the HHRA, information from 2011 to 2015 on the concentrations of COPCs in liquid effluents was available and was assessed to aid in COPC selection to ensure that the lake water chemical COPC selection was complete. As in the HHRA, only the final discharge released from the CCW duct was assessed as the exposure point for this screening.

4.1.4.2.2.1 Monitoring for ECA Requirements

As part of the ECA requirements, the effluent from the CCW is sampled and analyzed for compliance with effluent limits for unionized ammonia, hydrazine, morpholine, pH, and total residual chlorine (TRC). For each of these chemicals, the maximum measured concentration in the CCW effluent from 2011 to 2015 was screened against the same benchmarks as the lake water samples. This approach is conservative because these CCW concentrations were measured before dilution in the lake.

Environment Canada has developed a Federal Environmental Quality Guideline (FEQG) for hydrazine of 2.6 µg/L for fresh water (EC, 2013a). This value represents a chronic no-effect concentration based on an acute toxicity threshold with a safety factor (EC/HC, 2011). Since the maximum observed hydrazine concentration (8 µg/L) in lake water was above the screening level of 2.6 µg/L, hydrazine was carried forward for further quantitative assessment in the EcoRA. Similarly, the maximum measured morpholine concentration was greater than its selected screening benchmark, so morpholine was carried forward.

The MOE (1979) water quality objective for pH in freshwater is within the range from 6.5 to 8.5. The MOE considers the PWQO for pH to be the range within which waters are the most productive (MOE, 1979). Surface water with pH above the upper limit of the PWQO may be less productive. The Canadian water quality objective for pH for freshwater biota is within the range from 6.5 to 9.0 (CCME, 2008). This same pH range has been recommended by the International Joint Commission (1977) and the U.S. EPA (1986). The range from 6.5 to 9.0 is considered to be harmless to fish and benthic invertebrates, although the toxicity of other contaminants, such as ammonia, may be affected by pH changes within this range. Since the maximum measured pH is less than the CCME upper bound, and the effluent will be diluted in Lake Ontario, pH has not been carried forward for assessment in the EcoRA.

TRC exceeded the PWQO (0.002 mg/L) during the 2011 to 2015 period (maximum 0.008 mg/L), and it has been carried forward for further quantitative assessment in the EcoRA.

Based on these arguments, and as shown in Table A.9 in Appendix A, hydrazine, morpholine, and TRC were identified as COPCs for the EcoRA.

4.1.4.2.2.2 Monitoring for MISA Requirements

Effluent monitoring is required under the MISA program, as described in Section 2.2.2.1.6. As outlined in Section 3.1.5.2.2.2, for MISA monitoring parameters measured in the RLW and WTP effluents (phosphorus, TSS, zinc, iron, oil and grease, and aluminum), Golder (2011a) conducted mixing calculations to obtain expected concentrations of COPCs in the CCW based on effluent discharge to the CCW from the RLW and the WTP, and these calculations have been updated in this ERA report. Mixing calculations were based on a worst case scenario, assuming effluent was discharged at the MISA limits. The calculated CCW concentrations were compared against the ecological health screening benchmarks and were found to be well below these limits.

Based on MISA reports from 2011 to 2014, only one exceedance of MISA limits has been observed. The April 2011 acute toxicity sample failed for rainbow trout with 80% mortality (the *Daphnia magna* result was 0%). As this was the first ever failure at this Control Point, the sample was retested at the same laboratory as well as at a second independent laboratory. Both samples passed and subsequent testing by University of Guelph experts confirmed that the fish used by the initial contract laboratory, despite an aggressive sterilization treatment, had an unusually resistant infection, which was hard to detect.

Based on this information and on the mixing calculations performed by Golder, no exceedances of screening benchmarks in the CCW are expected for the MISA parameters, as shown in Table A.10 in Appendix A. No additional chemical COPCs for water were identified through this screening.

4.1.4.2.2.3 2016 Effluent Characterization Study

In support of the review and update of the existing EcoRA and HHRA for DN, liquid effluent sampling and analysis was performed in 2016 to provide data for characterization of non-radiological parameters. As in the HHRA, screening of the CCW results from this study against ecological health screening benchmarks was the focus of this screening exercise. Parameter concentrations from CCW samples were screened against the same ecological health screening benchmarks used for the lake water screening.

Morpholine exceeded its screening benchmark in the RLW, as shown in Table A.11a, and it was not measured in the CCW in the 2016 Effluent Characterization sampling program. Since the RLW stream flows at 0.0126 m^3/s (C. Cheng, pers. comm., September 30, 2016), and the average daily CCW flow rate between 2011 and 2015 was equivalent to 114.56 m^3/s, a multiplicative dilution factor of roughly 1×10^{-4} (equivalent to division by a factor of about 9,000) is expected to apply, and morpholine from the RLW stream is not expected to lead to an exceedance of morpholine in the CCW. Morpholine is therefore not considered a COPC based on the effluent characterization study results.

Similarly, TRC exceeded its screening benchmark in the WTP stream, as shown in Table A.11a, and it was not measured in the CCW stream during the 2016 Effluent Characterization Program. Since the WTP stream was assumed to flow at 0.04 m^3/s (Golder, 2011a), and the average daily CCW flow rate from 2011 through 2015 was equivalent to 114.56 m^3/s, a multiplied dilution factor of roughly 9×10^{-5} (or, equivalently, a divided dilution factor of about 10,000) is expected to apply, and TRC from the WTP stream is not expected to lead to an exceedance of TRC in the CCW. TRC is therefore not considered a COPC based on the 2016 effluent characterization study results.

The maximum analyzed concentration of aluminum in the CCW exceeded its selected ecological screening benchmark. Because dissolved aluminum in the CCW was not measured as part of the effluent monitoring study, it is not possible to exclude aluminum, as done in the lake water screening. Therefore, aluminum has been included as a chemical COPC for ecological health in this assessment.

Concentrations of cadmium, chromium, copper, lead, nickel, and selenium exceeded their respective ecological health screening benchmarks in one or more of the RLW, IAD, or WTP streams. Maximum concentrations of all of these contaminants in the CCW, however, did not exceed their screening benchmarks, and since the CCW is the stream discharged to Lake Ontario, these contaminants in DN effluent have not been carried forward as chemical COPCs for the EcoRA.

As shown in Table A.11a, the maximum measured concentration of phosphorus in the CCW exceeds its ecological screening benchmark. It exists in the environment as phosphate, where it acts as a nutrient rather than a toxicant. As such, phosphorus has not been considered a COPC for ecological health.

PHC F2 was not detected in any analyzed samples in the 2016 Effluent Characterization Study, but its detection limit of 100 µg/L exceeded its ecological health screening benchmark of 42 µg/L. No PHC fractions have been detected in any samples from this study, however, so PHC F2 has not been considered a COPC for ecological health.

A screening of alcohol ethoxylates (AEOs), nonylphenol ethoxyacetic acid (nonylphenol ethoxycarboxylate, or NP1EC), and linear alkylbenzene sulphonates (LASs) in surface water samples taken from the CCW is summarized in Table A.11b. Ecological health benchmarks were available from Environment Canada (2013b), CCME (2002), and the Human and Environmental Risk Assessment (HERA) on Ingredients of Household Cleaning Products (HERA, 2013). For a given contaminant, the most conservative available benchmark was selected as the screening benchmark.

Concentrations of the total C12-C13 and C14-C15 AEOs exceeded their respective ecological screening benchmarks, so were carried forward to a detailed screening of individual homologues within each grouping, which is presented in Table A.11c. None of the individual analyzed homologues exceeded their respective EC Fresh Water Quality Guidelines (FWQGs), so none of the AEOs in these groupings were carried forward as COPCs for ecological health. In addition, neither of the C12-C13 nor C14-C15 groupings, nor total AEOs were carried forward as ecological health COPCs, since none of their individual homologue components exceeded their respective guidelines.

NP1EC and individual LAS fractions did not exceed their respective ecological screening benchmarks, and these chemicals, as well as total LAS, were therefore not carried forward as chemical COPCs for ecological health.

4.1.4.2.3 Storm Water Sampling

The Storm Water Management (SWM) System, or Yard Drainage System, collects storm runoff from the entire DN site and discharges to Lake Ontario, either directly through the storm sewer drainage system, or through drainage swales/creeks via culverts which eventually discharge to the Lake.

As described in the HHRA (see Section 3.1.5.2.3), the available storm water chemical analyses from 2010 and 2011 were compiled and maximum concentrations from this data set were converted to equivalent loadings to Lake Ontario using the maximum measured peak flow rates at the time of sampling (Golder 2011b, 2011c). These equivalent loadings were then converted to estimated Lake Ontario concentrations in a nearshore zone. The flow in this zone was defined by an average alongshore current speed of 0.09 m/s (Golder, 2011a) and the cross-sectional area of the wave zone. The wave zone in Lake Ontario extends to about 2 m depth, which is typically about 120 m from the shoreline. These assumptions resulted in an estimated average shoreline flow rate of 10,800 L/s.

The estimated Lake Ontario concentrations were then screened against the same ecological screening benchmarks used in the lake water screening, as shown in Table A.12 in Appendix A. None of the estimated Lake Ontario concentrations exceeded the selected ecological screening benchmarks. Chemicals for which no ecological screening benchmarks were available were not considered to be COPCs. As such, none of the contaminants in storm water were assessed as chemical COPCs in the EcoRA.

4.1.4.2.4 Pond Water Sampling

SENES (2009) collected surface water samples from Coots Pond in Polygon AB and Treefrog Pond in Polygon D in the course of the preparation of the NND EA. These ponds are not exposed to liquid effluent from DN, but Coots Pond is exposed to stormwater runoff from the construction landfill. The ponds are also expected to be exposed to chemical contaminants in air, which could be deposited in surface water after release to the atmosphere from DN. Available surface water data for these ponds do not include analyses for any of the chemicals modeled by OPG in air from significant sources (see the list in Table A.1 in Appendix A), so no screening of surface water data for these particular chemicals could be undertaken to corroborate the air deposition pathway. However, many of the chemical contaminants screened in air are not expected to deposit in surface water, and none were modeled to be present in air at concentrations of concern (see Section 4.1.4.1), so potential deposition of these chemicals to the ponds is not expected to lead to environmental risks. A screening of the available data from SENES (2009) was nevertheless conducted to determine if any COPCs could be present in surface water in either of these ponds. This screening used the same benchmarks as the other surface water screenings for ecological health, supplemented by other toxicity information where required. This screening is presented in Table A.13 in Appendix A.

For boron, the PWQO of 0.2 mg/L is an emergency value set based on readily available information, which was not developed to be explicitly protective of environmental health, so the higher CCME CWQG of 1.5 mg/L was selected as a more appropriate screening benchmark.

For Coots Pond, pH, aluminum, ammonia, barium, calcium, cobalt, iron, magnesium, and potassium were identified as COPCs. For Treefrog Pond, barium, boron, calcium, cobalt, iron, magnesium, manganese, nitrate, potassium, and zirconium were identified as COPCs.

As shown in Table A.13 in Appendix A, chromium (VI), mercury, PCBs, PHC F2, and TRC were not detected in any of the surface water samples from the ponds, but their detection limits exceeded their respective screening benchmarks. Because these chemicals were not detected in the pond water, they are not expected to be present in the ponds at concentrations of concern, and as such, they have not been carried forward as ecological COPCs.

PHC F3 was not detected in water in Coots Pond, but was detected in water in Treefrog Pond at a maximum concentration of 0.13 mg/L. This sample was one of two in which PHC F3 was detected in Treefrog Pond water. The detection limit for PHC used in the SENES (2009) study was 0.1 mg/L. Since the detected concentrations of PHC F3 are within 30% of the detection limit, considerable uncertainty exists as to whether these concentrations are truly present in surface water in Treefrog Pond, especially since PHC F3 is not soluble in water (CCME, 2008) and therefore is not directly toxic to aquatic organisms. As such, PHC F3 has not been carried forward as a chemical COPC for ecological health in this assessment.

The maximum measured concentration of phosphorus in both ponds exceeds their ecological screening benchmark. Phosphorus exists in the environment as phosphate, where it acts as a nutrient rather than a toxicant. As such, phosphorus has not been considered a COPC for ecological health.

4.1.4.3 Selection of Chemical COPCs in Soil

In order to determine whether any potential contaminants may pose a risk to ecological receptors, available soil concentrations measured by SENES (2009a and 2011c) were screened against ecological screening benchmarks protective of plants, soil organisms, birds, and mammals. In particular, maximum measured concentrations of soil parameters were compared against two MOECC (2011a) component values, one based on protection of Plants and Soil Organisms (PSO), and the other based on protection of Birds and Mammals (BM). From a federal perspective, CCME Soil Quality Guidelines for Environmental Health (SQG_E) were also consulted, as were Interim Canadian Soil Quality Criteria (ICSQC; CCME 1991) if SQG_E was not available. The more conservative of these provincial and federal screening values was chosen for protection of plants, soil organisms, mammals, and birds. Agricultural SQG_E values were used because these guidelines account for bird and mammal ingestion of plants. If none of these criteria, guidelines, or component values were available, MOECC's Ontario Typical Range (OTR_{98}) concentrations were used instead. These are upper limit of background values, calculated as the 97.5th percentile of concentrations measured in surface soils in Ontario that have not been affected by point sources of contamination (MOECC, 2011). The MOECC used these values to set concentrations for remediation of environmentally sensitive contaminated sites to background, known as Table 1 Site Condition Standards under Ontario Regulation 153/04, indicating that they are suitable for use in determining if a site is contaminated or not. If OTR_{98} was not available, the upper end of the range of crustal abundance for the United States of America from Dragun and Chiasson (1991) was used to represent the background soil concentration.

Of the screening benchmarks derived in this way, the benchmark for vanadium was given more detailed scrutiny because of its use by MOECC in deriving a Site Condition Standard under O.Reg. 153/04 for that metal. MOECC derived a vanadium soil protection value for mammals and birds of 18 mg/kg, with the American Woodcock as the most sensitive receptor (MOE, 2011). This concentration is less than the OTR_{98} concentration for vanadium of 86 mg/kg in rural parkland. The implication is that at background soil concentrations in Ontario, birds such as the American Woodcock would be at risk province-wide if 18 mg/kg were truly toxic. In setting their Site Condition Standard, MOECC chose the Ontario background concentration for vanadium over the mammal and bird soil protection value. A similar approach is used here, in that the OTR_{98} for vanadium was selected as the more appropriate screening benchmark for birds and mammals than the MOECC's derived 18 mg/kg for vanadium in soil. This approach is also consistent with guidance in N288.6-12 (CSA, 2012) that screening benchmarks should not be set below an upper limit of background.

As shown in Table A.14 in Appendix A, measured maximum soil concentrations in polygons AB, C, D, and E exceeded the BM component value for barium, and barium has therefore been carried forward as a soil COPC for birds and mammals in all polygons. The maximum barium concentrations were lower than the PSO component value and the ICSQC, indicating that barium should not cause any risks to plants and soil organisms.

The maximum measured concentration of hot water soluble boron measured by SENES in 2011 in polygon AB exceeded its PSO component value, and boron has therefore been carried forward as a COPC for plants and soil organisms in polygon AB. Hot water soluble boron is only a parameter of concern for plants, and all other boron measurements were below their respective screening benchmarks, so boron has not been carried forward as a COPC for birds and mammals in any polygons.

The maximum measured lead concentration in polygon AB exceeded its BM component value, and lead has therefore been carried forward as a soil COPC for birds and mammals in polygon AB. All of the lead concentrations were lower than the PSO component value and the ICSQC, indicating that lead should not cause any risks to plants and soil organisms in polygon AB or in any other polygons.

Maximum measured strontium concentrations in all polygons exceeded the strontium OTR_{98}, and strontium has therefore been carried through the EcoRA as a chemical COPC for plants, soil organisms, birds, and mammals in all polygons. Similarly, tin concentrations in polygons C and D exceeded the ISQC for tin, and tin has been carried through the EcoRA as a COPC for plants, soil organisms, birds, and mammals in polygons C and D.

Maximum measured concentrations of aluminum, calcium, potassium, and sodium also exceeded their respective OTR_{98} values, but these elements are all either common constituents of the Earth's crust or essential nutrients for life. None of these elements is expected to pose any ecological risks in soil, and none of them have been carried forward as COPCs in the EcoRA.

Measured maximum nickel and selenium concentrations exceeded their respective SQG_E, values but did not exceed either of their provincial PSO or BM component values. As such, neither of these elements is expected to pose an ecological risk to terrestrial receptors, and neither has been carried through the EcoRA as a chemical COPC.

No ecological screening benchmarks were available for bismuth, lithium, thorium, tungsten, and zirconium, but maximum concentrations of each of these elements fell within or below their ranges of background concentrations for the continental USA (Dragun and Chiasson 1991). None of these metals has been carried through the EcoRA as a COPC. In addition, no toxicological information is available for terrestrial receptors for cesium, so that metal was also excluded from the list of COPCs.

In summary, the chemical COPCs carried forward in soil are as follows:

- Barium for birds and mammals in polygons AB, C, D, and E;
- Hot water soluble boron for plants and soil organisms in polygon AB;
- Lead for birds and mammals in polygon AB;
- Tin for plants, soil organisms, birds, and mammals in polygons C and D; and,
- Strontium for plants, soil organisms, birds, and mammals in polygons AB, C, D, and E.

4.1.4.4 Selection of Chemical COPCs in Groundwater

OPG initiated an annual groundwater monitoring program to understand the groundwater quality beneath the DN site. The groundwater monitoring program includes sampling groundwater monitoring wells for tritium, and certain locations for selected hazardous substances, such as petroleum hydrocarbons (PHCs), benzene, toluene, ethylbenzene and xylenes (BTEX), metals and chloride. Based on the results of this program, groundwater on the DN site was found to generally flow toward Lake Ontario or the Forebay (EcoMetrix 2012, OPG 2012d, OPG 201e3, OPG 2014d, OPG 2015b). In general, groundwater monitoring results were not significantly different from 2011 to 2015. Results from over this time period do not show any evidence of any significant leaks occurring from the DN systems; the PHC and benzene concentrations are naturally elevated in the bedrock groundwater because of the naturally occurring hydrocarbons in the petroliferous rock formation. As such, no additional selection of COPCs in groundwater is considered necessary.

4.1.4.5 Selection of Chemical COPCs in Sediment

Sediment in Lake Ontario was characterized as part of the baseline data collection for the ecological risk assessment in the New Nuclear Darlington EA (SENES 2009a). Except in embayments (St. Marys boat slip) the substrate is predominantly gravel and cobble on top of glacial till or bedrock. Any finer material, mostly sand, is patchy, thin and transient. Lake Ontario in the vicinity of DN is not a depositional environment. As such, any chemical parameters in sediments in Lake Ontario due to DN's influence are likely to be due to liquid effluents, and screening of Lake Ontario water and liquid effluents for COPCs are expected to suffice. The chemical COPCs in sediment have therefore been set to be identical to the chemical COPCs in water, and no separate screening of chemical COPCs in sediments from Lake Ontario is considered to be necessary.

The on-site ponds (Coots Pond and Treefrog Pond, for example) are depositional environments, but other than stormwater runoff these ponds do not receive liquid effluents from DN, so the only potential transport pathway for COPCs to these ponds is through airborne deposition after air emissions from DN. None of the contaminants that OPG models in air from significant sources (see Table A.1 in Appendix A) have been analyzed in sediments in the on-site ponds, so a screening of air chemicals in sediment was not performed. However, many of the chemical contaminants screened in air are not expected to deposit in surface water and partition to sediment, and none were modeled to be present in air at concentrations of concern (see Section 4.1.4.1), so potential deposition of these chemicals to the ponds is not expected to lead to environmental risks. Instead, available sediment data from SENES (2009) for the ponds was screened against benchmark values protective of ecological health.

In order to accomplish this screening, the more conservative of the Ontario Ministry of the Environment Provincial Sediment Quality Objectives (PSQOs; MOE, 1993) and CCME Canadian Sediment Quality Guidelines (CSQGs) was selected as an appropriate screening benchmark. If neither of these benchmarks was available for a given chemical, the toxicological literature and other regulatory sources were consulted for screening benchmarks. If no screening benchmarks at all were available for a given contaminant, it was not carried forward as a chemical COPC for ecological health; only chemicals with demonstrated toxic effects were carried forward as COPCs.

The results of this screening are presented in Table A.15 in Appendix A. For Coots Pond, copper, manganese, phosphorus, and vanadium were carried forward as chemical COPCs in sediment. For Treefrog Pond, chromium, copper, iron, manganese, nickel, phosphorus, and vanadium were carried forward as chemical COPCs for ecological health in sediment.

4.1.4.6 Selection of Radiological COPCs in Air and Water

A summary of radiological emissions from DN is presented in Section 3.1.2.6. Also presented in that Section is information concerning the Derived Release Limits for DN, which are developed to be protective of human health. As noted in that Section, the airborne effluent release groups that are used for DRL calculation and public dose calculation at DN are as follows:

- Elemental tritium (HT),
- Tritium oxide as water vapour (HTO),
- Noble gas mixtures (Noble Gases),
- Radioiodine mixed fission products (Imfp),
- Carbon-14 as $^{14}CO_2$ (^{14}C),
- Mixed beta-gamma emitting radionuclides (Particulate), and
- Mixed alpha emitting radionuclides (Gross alpha).

The liquid effluent release groups that are used for DRL calculation and public dose calculation at DN are:

- Tritium oxide as water (HTO),
- Mixed beta-gamma emitting radionuclides (Gross beta-gamma),
- Carbon-14 as dissolved carbonate/bicarbonate (^{14}C), and
- Mixed alpha emitting radionuclides (Gross alpha).

These release groups were identified as being important for estimating potential impacts on human health partly because they are present in, and measured in, air and water effluents at DN. Because of their presence and importance in DN effluents, these same release groups were considered for estimating potential impacts on ecological health.

Air immersion and inhalation pathways for ecological receptors are considered to be minor compared to the ingestion pathway, and were ignored for radionuclides, with the exception of noble gases, which were considered further (CSA, 2012). Based on air kerma results presented in OPG's annual EMP reports, the average dose rates for noble gases (Ar-41, Xe-133, Xe-135, and Ir-192) at the DN boundary are typically below the detection limits; therefore, the contribution to the total radiation dose for an ecological receptor located at the site boundary would be negligible. As such, exposure from noble gases is also not included in the exposure assessment for ecological receptors.

As discussed in Section 3.1.2.6, the beta-gamma emitters that give the highest human dose per unit release are Co-60 for beta-gamma release to air, and Cs-137^{+} for beta-gamma release to water. For the ecological assessment, on-site measurements for both of these important radionuclides, and for Cs-134, were included in the dose calculation. Non-detects were conservatively considered to be present at the detection limit value.

As discussed in Section 3.1.2.6, since water emissions of gross alpha over this period are on the order of six to seven orders of magnitude smaller than the applicable water DRL, gross alpha and its constituent radionuclides were not considered to be COPCs for the HHRA. In addition, over the period from 2011 to 2015, gross alpha activities in water were at least two orders of magnitude less than all other radionuclides or release groups. As such, the contribution of gross alpha to total radioactive emissions is considered to be minimal. Gross alpha was therefore not considered to be a COPC for the EcoRA.

As such, in accordance with the above, the following radiological stressors measured in the aquatic environment were used in the assessment of ecological health, for Lake Ontario and for the on-Site ponds:

- Carbon-14 (C-14), which is released to both air and surface water by reactor operations at DN;
- Cesium-137 and progeny (Cs-137+), Cs-134 and Co-60, which represent gross beta-gamma emissions released in liquid and/or airborne effluent from DN;
- Tritium oxide, also known as tritiated water (HTO), which is released to both air and water by the reactor operations at DN; and
- Iodine-131 (I-131), which was included for consistency with other EcoRAs conducted for DN.

I-131 was only included as a radiological COPC for consistency with historical EcoRA reports (SENES 2009a, 2011c); it is not expected to be a primary contributor to radiological dose for VECs.

SENES (2009a; 2011c) also identified strontium-90 as a COPC in water. SENES (2009a) noted that this radionuclide is not reported separately, but is captured in the measurement of gross beta-gamma emissions to water. Since the 2011 DRL report indicates that Sr-90 is not a limiting beta-gamma radionuclide, beta-gamma emissions are represented by Co-60 and Cs-137 instead of Sr-90 in this report.

4.1.4.6.1 Darlington Waste Management Facility

As outlined in Section 3.1.5.6.1, waste management operations at DN are undertaken in three locations within the DN site, including in two Fueling Facilities Auxiliary Areas (FFAAs; East and West) and the DWMF. The DWMF is made up of two buildings, each able to hold up to 500 DSCs. As part of the 2015 ALARA update, OPG tabulated air kerma measurements from 12 locations around the DWMF perimeter fence from 2011 through 2014, during which time the average air kerma rate at the perimeter was 0.08 µSv/h. Assuming that this is a whole body effective dose, the tissue absorbed dose at body surface may be slightly higher, but the whole body tissue absorbed dose for wildlife may be lower. It is difficult to translate the human effective dose to a whole body absorbed dose for various wildlife species with different geometries.

For the EcoRA, it has been assumed that the dose to any ecological VEC located at the DWMF perimeter fence is 0.08 µGy/h. This dose rate is orders of magnitude less than the terrestrial dose benchmark of 100 µGy/h. In addition, none of the annual average air kerma rates at individual locations exceeded this dose rate limit. The 2015 ALARA update also noted that all results from stack particulate samples from the DWMF for this period were below the minimum detectable activity. As such, the contribution of the DWMF to dose for ecological receptors at the DWMF perimeter fence would be negligible. Radiological waterborne emissions from the DWMF include yard drainage (runoff) and facility drainage. As discussed in Section 3.1.2.6.1, waterborne emissions have generally been negligible. Any sample with elevated concentrations is shipped off-site for disposal.

For ecological receptors residing on the DN site, in the immediate vicinity of the DWMF (within 5 m distance of the DWMF wall), the expected dose rate could be up to 1 µGy/h (Figure B-9 in OPG, 2011b). This assumes the wildlife whole body absorbed dose is comparable to the human effective dose.

The combined dose from the DWMF and other activities at DN to ecological receptors is discussed in the exposure assessment.

4.1.4.7 Selection of Radiological COPCs in Soil

The primary transport pathway of radiological COPCs to soil on-site and off-site is through deposition from air. However, certain air COPCs, such as HT and noble gases, are not expected to partition to soil. In addition, the radioiodines have short half-lives and would disappear quickly from soil, but I-131 was included as a COPC for consistency with previous EcoRA assessments (SENES 2009a, 2011c). The final list of COPCs for soil was therefore as follows: C-14, Co-60, Cs-134, Cs-137+, HTO, and I-131. Neither Co-60 nor Cs-134 were detected in soil, but detection limit values were used in the assessment.

4.1.4.8 Selection of Radiological COPCs in Groundwater

Of all of the radionuclides under consideration, only tritium has consistently been observed in Site groundwater. Previous groundwater studies at DN have demonstrated that at many locations, tritium concentrations in groundwater have remained relatively constant or have decreased over time. However, tritium concentrations have fluctuated at some locations in recent years due to migration of a spill in 2009 from the Injection Water Storage Tank, located south of Unit 0. Tritium from the spill is migrating towards the westerly end of the Forebay. Since groundwater discharged into the Forebay is significantly diluted by the Forebay water, adverse impact on ecological health is not expected.

In general, the tritium in groundwater on the Site is expected to originate from atmospheric emissions from DN, since no significant leaks appear to have occurred over the period from

2011 to 2015. The tritium concentrations in pore water at the soil surface are expected to exceed those in groundwater at the Site, and since tritium has already been designated a soil COPC, and its presence in pore water has directly formed part of the soil assessment, no additional selection of groundwater COPCs is considered necessary.

4.1.4.9 Selection of Radiological COPCs in Sediment

Sediment in Lake Ontario was characterized as part of the baseline data collection for the ecological risk assessment in the New Nuclear Darlington EA (SENES 2009a). Since the primary pathway for radionuclides to be transported to Lake Ontario sediment is through partitioning from liquid effluents, the same radionuclides were selected for sediment as were selected for surface water. This is conservative, since Lake Ontario in the vicinity of DN is not a depositional environment, and COPCs are unlikely to accumulate in sediment. The final list of COPCs for sediment was therefore as follows: C-14, Co-60, Cs-134, Cs-137+, HTO, and I-131. I-131 was not detected in sediment, but detection limit values were used in the assessment.

4.1.4.10 Selection of Other Stressors

Physical stressors are not subject to a formal screening process; however, CSA N288.6 (2012) recommends that thermal stressors and entrainment and impingement should be carried forward for assessment in the EcoRA since they are widely recognized as being of primary concern at nuclear power plants. As such, thermal stressors and entrainment and impingement have been selected as stressors in the EcoRA.

4.1.4.10.1 Noise

As discussed in Section 3.1.5.10, the noise environment in the vicinity of DN site is typical of an urban setting and is influenced by several noise sources including the DN Generating Station, traffic on Highway 401 and local roads, the CN rail line and the St. Mary's Cement plant. Beacon Environmental (2009; 2011) noted that bird and wildlife communities at DN would likely be adjusted to the high level of baseline noise in the vicinity of the Station, and observed that none of the planned activities, for which the respective EAs were being conducted, were likely to increase noise to beyond levels tolerable by breeding birds from the literature. As such, noise has not been considered a stressor in the EcoRA.

4.1.4.10.2 Bird Strikes and Wildlife Collisions

SENES (2009a) carried out thirteen bird strike surveys at DN between May 7, 2007, and May 28, 2008 as part of the NND EA. These surveys resulted in a total count of 31 dead, injured, or dazed birds, and one labeled as "uninjured," over the course of the year. Several of these birds appeared to have been raptor kills, so were not caused by building strikes. Further details concerning the intensity of the surveys and the complete list of species killed are presented in SENES (2009a). In their conclusions, SENES noted that "the very low number of birds killed or injured that were attributable to structures indicates that further study may not be warranted" (SENES 2009a).

OPG tracks wildlife fatalities and injuries through an informal reporting process. For the period from 2011 to 2015, the fatalities and injuries reported through this method, not including predation deaths, are summarized in **Error! Reference source not found.** (C. Cheng, pers. comm., 2016). The 2011-2015 wildlife list contains fewer fatalities and injuries than the SENES 2007-2008 list, despite containing mammals as well as birds, and documenting weather kills that are not directly due to DN structures. Due to the small number of affected wildlife, bird strikes and other types of physical wildlife incidents are not expected to affect populations of birds and mammals at the DN Site. Wildlife fatalities and injuries are not discussed further in the EcoRA.

Table 4-5: Summary of Reported Wildlife Fatalities at DN (2011 to 2015)

Year	Type	Species	Location	Cause
2011	Fatality	Common Yellowthroat	OSB Tunnel	Strike
	Fatality	Deer	Holt Road	Vehicle Hit
	Fatality	Deer	Holt Road	Vehicle Hit
2012	Fatality	Bird	Inside PA by Unit 1	Unknown
	Fatality	Whistling/Tundra Swan	Forebay	Unknown
	Fatality	Bird	North side of ESB	Strike
	Fatality	American Woodcock	South side of MSB	Unknown
2013	Fatality	Mallard	North of the OSB	Strike
	Fatality	Racing Pigeon	South of Unit 3	Strike
	Fatality	Racing Pigeon	Unknown	Strike
	Fatality	Hermit Thrush	South of OSB Tunnel	Strike
	Fatality	Cormorant	PA	Fence
	Fatality	Deer	Unknown	Fence
	Fatality	Deer	Unknown	Temporary Fence
2014	Fatality	2 Swans	Forebay	Weather or Power Lines
	Injury (taken to vet)	Gull	PA by ASB	Unknown
2015	Fatality	4 Ducks	Forebay	Weather
	Fatality	Cormorant	Forebay	Weather
	Fatality	Gull	PA	Fence
	Fatality	Falcon (Cooper's Hawk)	OSB Walkway	Unknown
	Injury (recovered)	Ruby-Crowned Kinglet	Unknown	Strike
	Injury (taken to vet)	Gull	Unknown	Unknown
	Injury (taken to vet)	Gull	Unknown	Unknown

4.1.4.11 Summary of COPC Selection

Error! Reference source not found. summarizes the radiological and non-radiological COPCs that are carried forward to the exposure assessment in the EcoRA.

Table 4-6: Summary of COPCs Selected for the EcoRA

Environmental Medium	Radiological COPC	Chemical COPC
Air	None	None
Surface water	C-14, Co-60, Cs-134, Cs-137+, HTO, I-131	Aluminum, copper, nitrate, TRC, hydrazine, morpholine (Lake Ontario) pH, aluminum, ammonia, barium, calcium, cobalt, iron, magnesium, potassium (Polygon AB) Barium, boron, calcium, cobalt, iron, magnesium, manganese, nitrate, potassium, zirconium (Polygon D)
Soil	C-14, Co-60, Cs-134, Cs-137+, HTO, I-131	Barium for birds and mammals in polygons AB, C, D, and E; hot water soluble boron for plants and soil organisms in polygon AB; lead for birds and mammals in polygon AB; tin for plants, soil organisms, birds, and mammals in polygons C and D; strontium for plants, soil organisms, birds, and mammals in polygons AB, C, D, and E.
Groundwater	None	None
Sediment	C-14, Co-60, Cs-134, Cs-137+, HTO, I-131	copper, manganese, phosphorus, vanadium (Polygon AB) chromium, copper, iron, manganese, nickel, phosphorus, vanadium (Polygon D)
Other Stressors	Thermal effects, entrainment, and impingement	

4.1.5 Selection of Exposure Pathways

Exposure pathways include the routes of contaminant dispersion from the source to the receptor location, and the routes of contaminant transport through the food chain or other media to the receptor organism. Both are considered, as appropriate to the species and location, using measured concentrations of COPCs wherever such data exist, and estimating concentrations where measured values are not available.

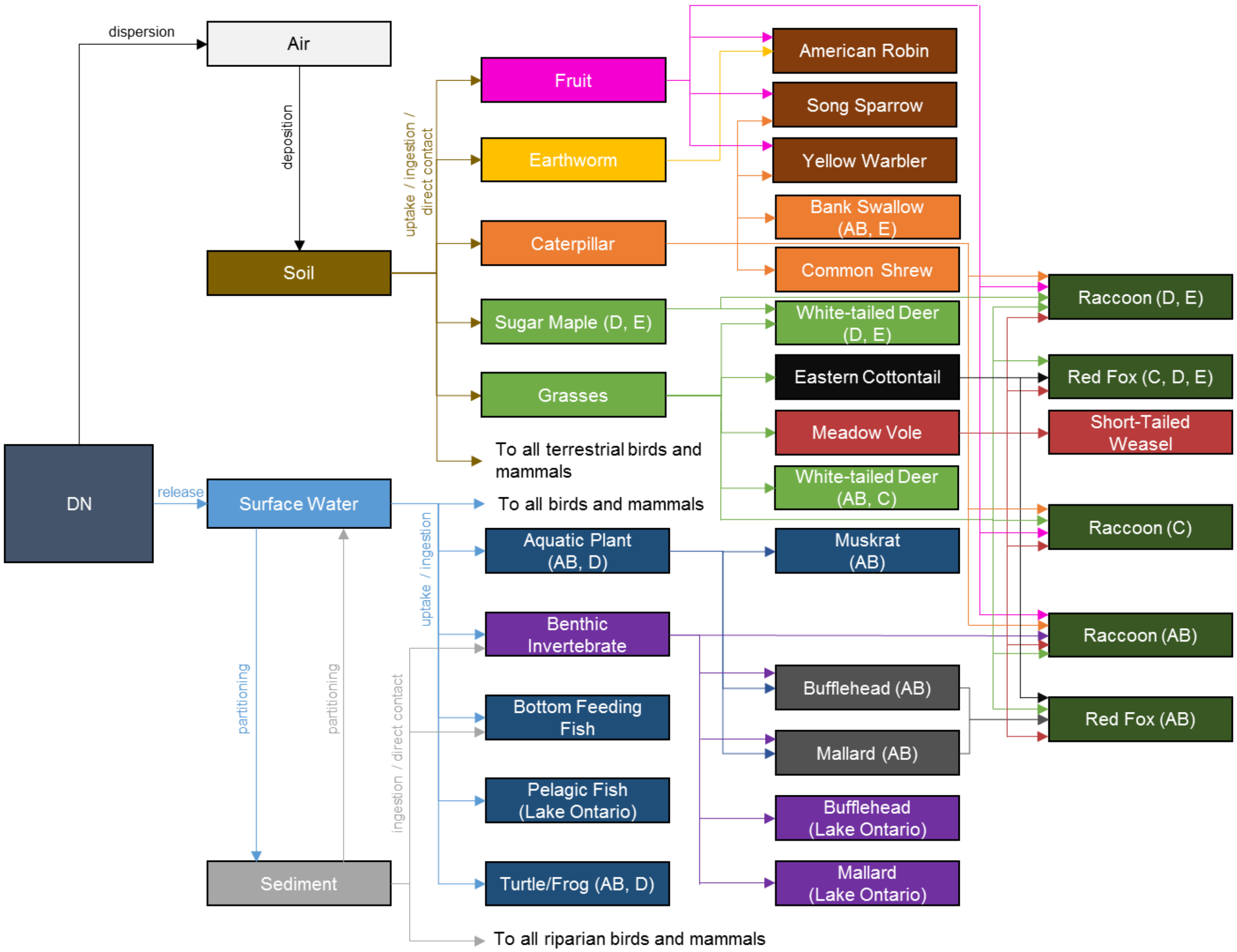
For fish, frog and aquatic plants, contact with water and contaminant uptake from water via bioaccumulation represents the main exposure pathway. For soil invertebrates and terrestrial plants, the main exposure pathway is through contact with soil and contaminant uptake from soil via bioaccumulation.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

Airborne COPCs partition to soil and plants, and ingestion pathways dominate over inhalation and air immersion for most COPCs. The latter pathways will be omitted for ecological receptors in this assessment. Noble gases can be important COPCs in air; however, they are not considered significant for this assessment as described in Section 4.1.4.6.

4.1.6 Ecological Health Conceptual Model

The conceptual model illustrates how receptors are exposed to COPCs. It identifies 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. **Error! Reference source not found.** summarizes the relevant exposure pathways for each type of ecological receptor. The conceptual model for the EcoRA is illustrated in **Error! Reference source not found.**. The air exposure pathway can usually be ignored since it is usually minor compared to the soil or sediment ingestion exposure (CSA, 2012). Exposures to noble gases in air can be important, since air is the dominant pathway for noble gases; however, they are not considered significant for this assessment as described in Section 4.1.4.6.

All the avian receptors to be assessed are migratory, and are likely to reside at the DN site for half of the year.



Note: Terrestrial VECs were assumed to be present in all polygons, and riparian and aquatic VECs were assumed to be present in all water bodies, unless otherwise indicated.

Figure 4-2: Conceptual Model for the Ecological Receptors

Table 4-7: Complete Exposure Pathways for All Selected VEC Species

VEC Category	VEC	Location	Exposure Pathways	Environmental Media
Bottom Feeding Fish	Northern Redbelly Dace	Coots Pond (AB)	Direct Contact	In Water On Sediment
	Round Whitefish	Lake Ontario	Direct Contact	In Water On Sediment
	White Sucker Americal Eel		Direct Contact	In Water On Sediment
Pelagic Fish	Alewife	Lake Ontario	Direct Contact	In Water
	Lake Trout		Direct Contact	In Water
Reptiles and Amphibians	Turtle	Coots Pond (AB), Treefrog/Dragonfly/ Polliwog Pond (D)	Direct Contact	In Water On Sediment
	Frog		Direct Contact	In Water On Sediment
Aquatic Plants	Aquatic Plant	Lake Ontario, Coots Pond (AB), Treefrog/ Dragonfly/ Polliwog Pond (D)	Direct Contact	In Water
Benthic Invertebrates	Benthic Invertebrate	Lake Ontario, Coots Pond (AB)	Direct Contact	In Water In Sediment
Riparian Birds	Bufflehead	Lake Ontario	Direct Contact	On Sediment
			Ingestion	Water Sediment Benthic Invertebrates
		Coots Pond (AB)	Direct Contact	On Sediment
			Ingestion	Water Sediment Aquatic Plants Benthic Invertebrates
	Mallard	Lake Ontario	Direct Contact	On Sediment
			Ingestion	Water Sediment Benthic Invertebrates
		Coots Pond (AB)	Direct Contact	On Sediment
			Ingestion	Water Sediment Aquatic Plants Benthic Invertebrates
Riparian Mammals	Muskrat	Lake Ontario, Coots Pond (AB)	Direct Contact	On Sediment
			Ingestion	Water Sediment Aquatic Plants
Terrestrial Invertebrates	Earthworm	AB, C, D, E	Direct Contact	In Soil
Terrestrial Birds	American Robin	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Earthworms Fruit
	Bank Swallow	AB, E	Direct Contact	On Soil
			Ingestion	Water Soil Caterpillars

VEC Category	VEC	Location	Exposure Pathways	Environmental Media
Terrestrial Birds	Song Sparrow	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Fruit Caterpillars
	Yellow Warbler	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Fruit Caterpillars
Terrestrial Plants	Grasses	AB, C, D, E	Direct Contact	On Soil
	Sugar maple	D, E	Direct Contact	On Soil
Terrestrial Mammals	Eastern cottontail	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Grasses
	Meadow vole	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Grasses
	White-tailed deer	AB, C	Direct Contact	On Soil
			Ingestion	Water Soil Grasses
		D, E	Direct Contact	On Soil
			Ingestion	Water Soil Grasses Sugar Maple trees
	Common shrew	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Caterpillars
	Raccoon	AB	Direct Contact	On Soil
			Ingestion	Water Soil Grasses Fruit Caterpillar Benthic Invertebrates Meadow Voles
		C	Direct Contact	On Soil
			Ingestion	Water Soil Grasses Fruit Caterpillars Meadow Voles
		D, E	Direct Contact	On Soil
			Ingestion	Water Soil Grasses Sugar Maple trees Fruit

VEC Category	VEC	Location	Exposure Pathways	Environmental Media
				Caterpillars Meadow Voles
Terrestrial Mammals	Red fox	AB	Direct Contact	In and on Soil
			Ingestion	Water Soil Grasses Bufflehead Mallard Eastern Cottontail Rabbits Meadow Voles
		C, D, E	Direct Contact	In and on Soil
			Ingestion	Water Soil Grasses Eastern Cottontail Rabbits Meadow Voles
	Short-tailed weasel	AB, C, D, E	Direct Contact	On Soil
			Ingestion	Water Soil Meadow Voles

For organism losses by entrainment/impingement, the conceptual model illustrated in CSA N288.6 (2012) is appropriate. This conceptual model (**Error! Reference source not found.**) represents the relationship between the individual losses and possible population or community effects.

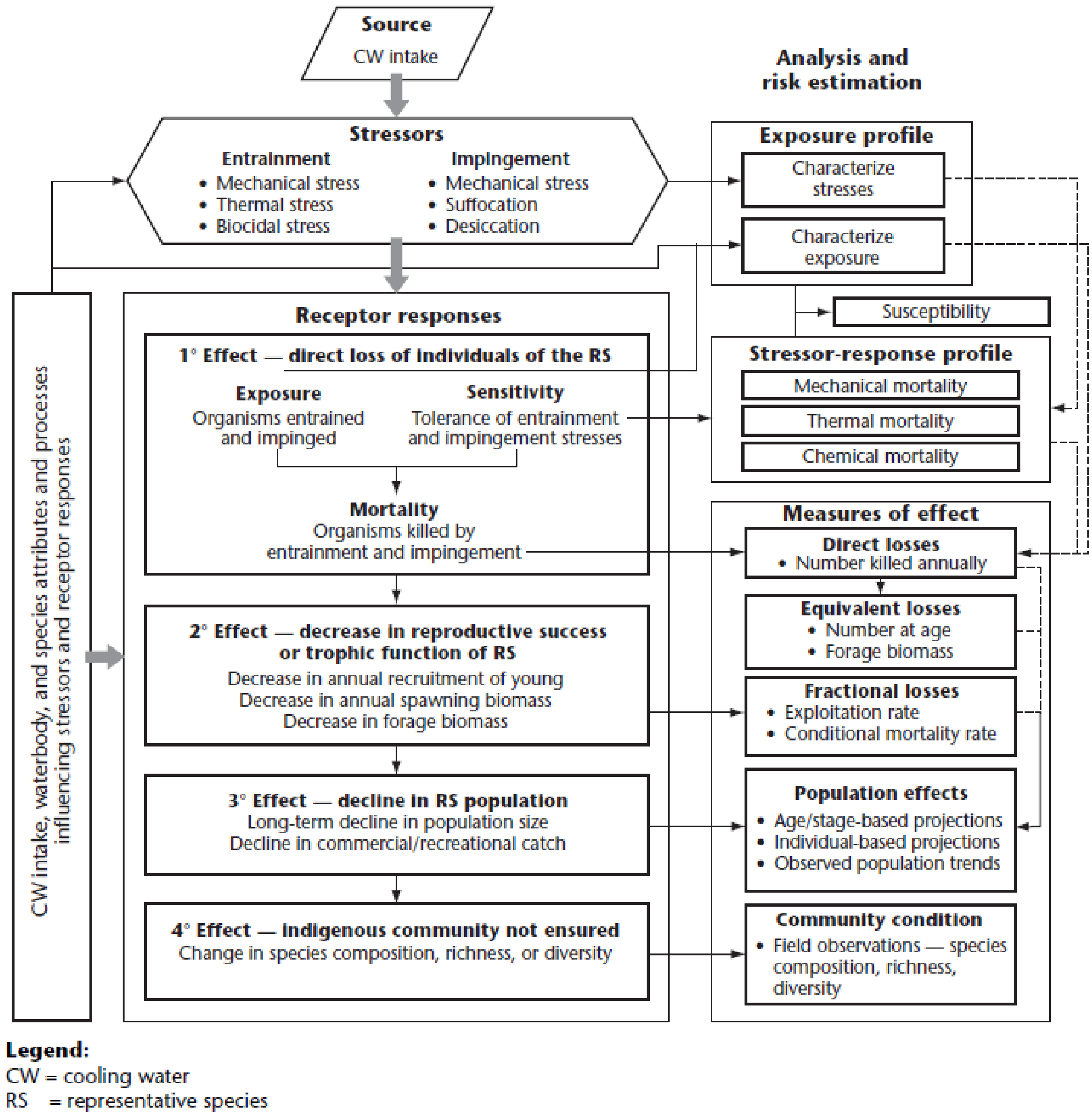


Figure 4-3: Generic Conceptual Model for Relationships between Individual Endpoints and Population/Community Endpoints (CSA, 2012)

4.1.7 Uncertainty in Problem Formulation

The data used in the assessment were concluded to be of adequate quality and quantity to support the objectives of the EcoRA. Maximum measured concentrations were selected for COPC screening; this is considered conservative and is not reflective of typical ecological exposures, with the exception of stationary receptors such as plants; for plants, this selection is realistic. The ecological screening benchmarks for water were generally the lower of applicable provincial and federal aquatic life objectives and guidelines, which is a conservative approach, ensuring that the list of COPCs would be as comprehensive as possible. The COPC screening also considered several media as potential exposure routes, such as air, surface water, soil, ground water, and sediment, and including effluent and storm water. As such, the COPC screening has resulted in a conservative list of COPCs.

Uncertainties were also inherent in the selected ecological screening benchmarks. Several of the screening benchmarks (e.g. MOECC PSO and BM component values) are based on Lowest Observed Adverse Effect Levels (LOAELs), and not on No Observed Adverse Effect Levels (NOAELs). Others were conservatively based on background concentrations for lake water or soil. These concentrations are not based on toxicological considerations. In addition, the CCME does not make available its derivation for the 1991 ICSQCs that were used as screening benchmarks for tin and several other parameters, and the basis for these guidelines is unknown. Nevertheless, these values represent the best available screening criteria for the parameters in question, and are considered to be suitable for screening purposes in the context of a risk assessment.

More generally, the problem formulation has been conservative in its assumptions, to accommodate uncertainties, and to ensure that the subsequent EcoRA does not overlook any issues of potential concern. The conceptual model for ecological health is considered to be complete for the majority of ecological exposures in the vicinity of the DN site. The comprehensive selection of COPCs and receptors is expected to represent all important exposures to contaminants in the vicinity of the DN site.

4.2 Exposure Assessment

4.2.1 Exposure Points

Measured concentrations of COPCs in **Error! Reference source not found.** were generally available for the various media and biota at the receptor locations listed in **Error! Reference source not found.**. The exposure point concentrations for the different polygons and various media and biota are discussed in Section 4.2.6 . The majority of the exposure point concentrations were obtained from:

- SENES (2009a) Ecological Risk Assessment and Assessment of Effects on Non-human Biota Technical Support Document: New Nuclear- Darlington for:
    - Surface water and sediment for Lake Ontario (as part of the surface water study area), Coots Pond and Treefrog Pond;
    - Northern Redbelly Dace for Coots Pond;
    - Alewife, Round Whitefish, White Sucker and Mussel for Lake Ontario;
    - Aquatic vegetation for Coots Pond and Treefrog Pond;

  - Frogs for Treefrog Pond;
  - Soil and fruit for polygons AB, C, D and E; and
  - Terrestrial vegetation, caterpillar and earthworm for polygons AB, C and D.

- SENES (2011c) Non-human Health (Ecological Risk Assessment) Technical Support Document: Darlington Nuclear Generation Station Refurbishment and Continued Operation Environmental Assessment for:

  - Soil and terrestrial vegetation for the South-West Corner of the DN Site

- OPG Annual EMP reports (years 2011 to 2015) for:

  - Surface water, sediment, Round Whitefish and White Sucker for Lake Ontario; and

- Effluent concentrations (years 2011 to 2016)

  - Routine effluent data from 2011 to 2015 for radionuclides and MISA/ECA parameters; and

  - Data collected for non-radionuclides in 2016 for the effluent characterization program.

Effluent concentrations for aluminum, hydrazine, morpholine, C-14, Cs-137 and HTO were used as exposure point concentrations for surface water for polygon AB Lake Ontario. These effluent concentrations were adjusted by a dilution factor of 7 to account for dilution from the diffuser.

4.2.2 Exposure Averaging

When multiple measurements and samples were available for a given COPC in a particular medium at an assessed exposure location, the arithmetic average concentrations were calculated and maximum concentrations were selected.

Birds and mammals are likely to experience something close to average concentrations as they move around the area. However, for less mobile organisms such as plants and invertebrates, both average and upper limit concentrations represent exposures that would be experienced by some organisms on a long term basis.

4.2.2.1 Environmental Partitioning

Although, sediment data were not available for nitrate, TRC, hydrazine and morpholine, these COPCs are not expected to partition into sediments.

Nitrate is not expected to partition to sediment because it is very soluble. Nitrate diffusing from surface water into the top sediment layer would be readily assimilated by primary producers (algae and macrophytes) or reduced by microbes under anaerobic conditions. Nitrate may be produced within aerobic sediments from organic matter by nitrifying microorganisms through the nitrification of nitrogen species, such as ammonium. In this case, nitrate would readily dissolve thereby becoming available for uptake by primary producers (EC, 2003).

TRC is not expected to be measurable in sediment because it reacts and volatilizes rapidly (ATSDR, 2010).

The environmental partitioning of hydrazine was modeled and described in EC/HC (2011). The modeling results show that when hydrazine is released to surface water, it will remain almost entirely in the water (99.9% in water, 0.02% in sediment). Based on these results, the partitioning of hydrazine from water to sediment is negligible.

Due to morpholine’s solubility in water, when it is released into the environment, it moves with soil moisture and water, and does not sorb to sediment or organic matter (Lewis et al.1995 as cited in Poupin et al. 1998). Therefore, the partitioning of morpholine to sediment is negligible.

4.2.3 Exposure and Dose Calculations

Exposure and dose calculations were performed for each COPC for each ecological receptor for each receptor location as outlined in the ecological conceptual model (Ecological Health Conceptual Model).

4.2.3.1 Radiological Dose Calculations

Radiological dose calculations were estimated using the EcoMetrix Incorporated software IMPACT^{TM} DRL Version 5.5.2 (IMPACT). IMPACT^{TM} is consistent with the equations outlined in CSA N288.1 (2014) and the methods outlined in CSA N288.6 (2012). IMPACT^{TM} uses the specific activity model for tritium and C-14 as per CSA N288.1 (2014) and as recommended by CSA N288.6 (2012).

The radiation doses for the aquatic biota were estimated using the methods outlined in CSA N288.6 (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, or at sediment surface, and for 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)

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

For aquatic riparian biota, such as muskrats and waterfowl, sediment was substituted for soil in calculating the external dose, since these animals are typically in shoreline situations.

The total radiation dose to biota is the sum of the internal and external dose components for each radionuclide (D_{int} + D_{ext}). External exposure through the air immersion and inhalation pathway are considered to be minor compared to the ingestion pathway, and were ignored, with the exception of noble gases, which were initially considered (CSA, 2012). However, the DN boundary average dose rates for noble gases (Ar-41, Xe-133, Xe-135, and Ir-192) are typically below the detection limits; therefore the air kerma presented in OPG's annual EMP reports are not added to the total radiation dose.

The dose coefficients and occupancy factors used in the radiological dose estimation are provided in Section 4.2.4

4.2.3.2 Non-Radiological Dose Calculations

The non-radiological dose (D_{ing}) for mammals and birds was estimated using the methods described in CSA (2012), as follows:

$$D_{ing} = \Sigma\, C_x \cdot I_x / W$$

where,

C_x = concentration in the ingested item (x) (mg/kg)
I_x = ingestion rate of item x (kg/day)
W = body weight of consumer (kg fw)

For receptors that drink from contaminated water, the drinking water component was considered. The concentrations in the water and the ingestion rate were in units of volume. In addition, for receptors that have incidental contaminated soil or sediment ingestion, this pathway was considered on a dry weight basis. Other ingested items (foods) were considered on a fresh weight basis. As with the radiological dose calculations, inhalation exposure is considered minor compared to the ingestion exposure, and was ignored (CSA, 2012).

4.2.3.3 Tissue Concentration Calculations

In cases where tissue concentrations (C_t) were not measured in plants, fruits, invertebrates or fish, the tissue concentrations were derived using bioaccumulation factors (BAFs), as per 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 (TFs), 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 times the transfer factor:

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

The BAFs, TFs and ingestion rates used for the calculation of tissue concentrations in biota are further described in Section 4.2.4.

4.2.4 Exposure Factors

There are several COPC- and biota-specific exposure factors required for the dose calculations discussed in Section 4.2.3. These parameters include intake rates, body weights, occupancy factors, BAFs, TFs, and dose coefficients (DCs).

4.2.4.1.1 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 taken from the U.S. EPA (U.S.

EPA, 1993), 2009 ERA (SENES, 2009a), and SENES (2000), where the assumptions and values were considered to be applicable. For receptors, such as the common shrew that were not assessed in the 2009 ERA (SENES, 2009a), body weights were obtained from the Federal Contaminated Sites Action Plan *Module 3: Standardization of Wildlife Receptor Characteristics* (FCSAP, 2012) and feed intake rates were proportioned to body weight using allometric equations from the U.S. EPA (1993). The water intake and inhalation rates were determined using allometric equations from the U.S. EPA (1993) for all birds and mammals. The incidental ingestion of soil and sediment was estimated based on the feed intake. As described by Beyer et al. (1994) incidental ingestion varied from 2% to 10.4% of dry weight food intake depending on the biota. The values are summarized in **Error! Reference source not found.**.

Table 4-8: Bird and Mammal Body Weights and Intake Rates

Receptor	Body weight	Total Feed Intake[b]		Dietary Components[a]	Feed Type Fraction[a]	Feed Intake		Moisture[e]	Intake of Soil/ Sediment[f]	Basis of the Soil and Sediment Intake Value	Total Soil/ Sediment[g]	Water Intake	Inhalation
	kg	kg/d dw	kg/d fw			kg/d dw[c]	kg/d fw[d]	%	%		kg DW/d	L/d	m^3/d
Bufflehead (Lake Ontario)	0.473[a]	0.036	0.143	Benthic invertebrates	1	0.036	0.143	75	10.8	Overall average for all bird species	3.86E-03	0.036	0.23
Bufflehead (Polygon AB)	0.473[a]	0.036	0.143	Aquatic plants	0.1	0.004	0.014	75	10.8	Overall average for all bird species	3.86E-03	0.036	0.23
				Benthic invertebrates	0.9	0.032	0.129	75					
Mallard (Lake Ontario)	1.082[a]	0.063	0.25[a]	Benthic invertebrates	1	0.063	0.250	75	3.3	Mallard	2.06E-03	0.06	0.43
Mallard (Polygon AB)	1.082[a]	0.063	0.25[a]	Aquatic plants	0.25	0.016	0.063	75	3.3	Mallard	2.06E-03	0.06	0.43
				Benthic invertebrates	0.75	0.047	0.188	75					
Muskrat	1.18	0.088	0.353	Aquatic plants	1[h]	0.088	0.353	75	3.3	Mallard	2.91E-03	0.114	0.621
American Robin	0.077[a]	0.012	0.093	Fruit (Berries)	0.6	0.0056	0.056	90	9.9	Average of the American Woodcock	1.18E-03	0.01	0.06
				Soil Invertebrates (Earthworms)	0.4	0.0063	0.037	83[i]		and Wild Turkey			
Bank Swallow	0.015[a]	0.004	0.022	Invertebrates (Caterpillar)	1	0.004	0.022	83[i]	5.0	For non-soil-dwelling birds	1.89E-04	0.02	0.004
Song Sparrow	0.021	0.005	0.047	Grains and seeds (Berries)	0.9	0.0042	0.042	90	5.0	For non-soil-dwelling birds	2.35E-04	0.004	0.02
				Invertebrates (Caterpillar)	0.1	0.0008	0.0047	83[i]					
Yellow Warbler	0.01[a]	0.003	0.018	Fruit (Berries)	0.1	0.00018	0.0018	90	5.0	For non-soil-dwelling birds	1.45E-04	0.003	0.012
				Invertebrates (Caterpillar)	0.9	0.0028	0.016	83[j]					
Eastern Cottontail	1.22[a]	0.081	0.404	Terrestrial Vegetation (Grass)	1	0.081	0.404	80	6.3	Black-tailed jackrabbit	5.08E-03	0.12	0.63
Meadow Vole	0.034[h]	0.002	0.010	Terrestrial Vegetation (Grass)	1	0.002	0.010	80	2.4	Meadow Vole	5.02E-05	0.005	0.036
White-tailed Deer	110[a]	3.27	16.37	Terrestrial Vegetation (Grass and/or Sugar Maple)	1	3.27	16.4	80	2.0	White-tailed deer	6.55E-02	6.8	23
Common (Masked) Shrew	0.0041[j]	0.001	0.008	Invertebrates (Caterpillar)	1	0.001	0.008	83[i]	2.0[j]	Default Rate	2.75E-05	0.0007	0.0067
Raccoon (Polygon AB)	5.7	0.287	1.68	Benthic invertebrates	0.1	0.042	0.17	75	9.4	Raccoon	2.70E-02	0.47	2.32
				Fruit (Berries)	0.15	0.025	0.25	90					
				Terrestrial Vegetation (Grass)	0.25	0.084	0.42	80					
				Small Mammals (Meadow Vole)	0.1	0.050	0.17	70					
				Invertebrates (Caterpillar)	0.4	0.11	0.67	83[i]					
Raccoon (Polygon C)*	5.7	0.287	1.73	Fruit (Berries)	0.15	0.026	0.26	90	9.4	Raccoon	2.70E-02	0.47	2.32
				Terrestrial Vegetation (Grass)	0.25	0.087	0.43	80					
				Small Mammals (Meadow Vole)	0.1	0.052	0.17	70					
				Invertebrates (Caterpillar)	0.5	0.15	0.87	83[i]					
Raccoon (Polygon D, E)*	5.7	0.287	1.73	Fruit (Berries)	0.15	0.026	0.26	90	9.4	Raccoon	2.70E-02	0.47	2.32
				Terrestrial Vegetation (Grass)	0.125	0.043	0.22	80					
				Terrestrial Vegetation (Sugar Maple)	0.125	0.043	0.22	80					
				Small Mammals (Meadow Vole)	0.1	0.052	0.17	70					

Receptor	Body weight	Total Feed Intake[b]		Dietary Components[a]	Feed Type Fraction[a]	Feed Intake		Moisture[e]	Intake of Soil/ Sediment[f]	Basis of the Soil and Sediment Intake Value	Total Soil/ Sediment[g]	Water Intake	Inhalation
	kg	kg/d dw	kg/d fw			kg/d dw[c]	kg/d fw[d]	%	%		kg DW/d	L/d	m^3/d
				Invertebrates (Caterpillar or Earthworm)	0.5	0.15	0.87	83[j]					
Red Fox (Polygon AB)	4.54	0.088	0.313	Small Mammals (Meadow Vole)	0.2	0.019	0.063	70	2.8	Red Fox	2.45E-03	0.39	1.83
				Small Mammals (Eastern Cottontail)	0.3	0.028	0.094	70					
				Riparian Birds (Bufflehead)	0.15	0.014	0.047	70					
				Riparian Birds (Mallard)	0.15	0.014	0.047	70					
				Terrestrial Vegetation (Grass)	0.2	0.013	0.063	80					
Red Fox (Polygon C, D, E)*	4.54	0.088	0.313	Small Mammals (Meadow Vole)	0.32	0.030	0.10	70	2.8	Red Fox	2.45E-03	0.39	1.83
				Small Mammals (Eastern Cottontail)	0.48	0.045	0.15	70					
				Terrestrial Vegetation (Grass)	0.2	0.013	0.063	80					
Short-tailed Weasel	0.18[a]	0.017	0.056	Small Mammals (Meadow Vole)	1	0.017	0.056	70	5.0	Average of small mammals	8.39E-04	0.02	0.14

Notes:

U.S. EPA (1993), unless otherwise indicated

[a] SENES (2009a); Common Shrew was not assessed in SENES (2009). The feed type fraction was assumed to be on a wet weight basis

[b] Total feed intake on a dry weight basis was estimated from the total feed intake on a fresh weight basis, or vice versa, using the approach in Sample et al, 1997

[c] Calculated by multiplying the feed type fraction by the total feed intake on a fresh weight basis and by the dry weight fraction of each food

[d] Calculated by multiplying the feedtype fraction by the total feed intake on a fresh weight basis

[e] CSA, 2014

[f-e] Beyer *et al.*, 1994

[g] Calculated by multiplying the Total Feed Type by the fraction of the Intake of Soil/Sediment

[h-g] SENES (2000)

[i-h] Beresford et al., 2008

[j-i] FCSAP, 2012

[*] Fraction of diet was assumed

4.2.4.1.2 Occupancy Factors

With the exception of riparian and terrestrial birds, the fraction of time a receptor resides in the different DN areas (e.g. Lake Ontario, Polygon AB (which includes Coots Pond), C, D (which includes Treefrog, Dragonfly and Polliwog ponds) is assumed to be one. For the Bufflehead, Mallard, American Robin, Bank Swallow and Yellow Warbler the fraction of time these birds reside in the DN area(s) is assumed to be 0.5, whereas the fraction of time the Song Sparrow resides in the DN areas is assumed to be 0.8. These fractions of time for these birds are consistent with assumptions in the previous new nuclear ERA (SENES, 2009a).

An occupancy factor is defined as the fraction of time the receptor species spends in or on various media. 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 **Error! Reference source not found.**.

Table 4-9: Receptor Occupancy Factors

Aquatic and Riparian Biota	OF_s	OF_{ss}	OF_w	Terrestrial Biota	OF_s	OF_{ss}
Northern Redbelly Dace		0.5	0.5	Earthworm	1	
Round White Fish		0.5	0.5	American Robin		1
White Sucker		0.5	0.5	Bank Swallow		0.5
Alewife			1	Song Sparrow		1
Lake Trout			1	Yellow Warbler		0.5
American Eel		0.5	0.5	Terrestrial Plants (Grass and Sugar maple)		1
Turtles		0.5	0.5	Eastern Cottontail		1
Frogs		0.5	0.5	Meadow Vole		1
Aquatic Plants			1	White-tailed Deer		1
Benthic Invertebrates	1			Common Shrew		1
Bufflehead		0.5		Raccoon		1
Mallard		0.5		Red Fox	0.2	0.8
Muskrat		0.5		Short-tailed Weasel		1

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

4.2.4.1.3 Bioaccumulation Factors

Bioaccumulation factors relate the COPCs in the environmental media to the concentration in the receptor. In cases where tissue concentrations were not available for the receptors at the DN site, BAFs were used to calculate COPC concentrations in plant, invertebrate and fish tissues. These factors vary throughout the literature. For the exposure assessment, BAFs were taken from CSA (2014), IAEA (2010) and literature sources, including those suggested in CSA N288.6 (2012). The BAFs used in the assessment are presented in **Error! Reference source not found.** and **Error! Reference source not found.**. Bioaccumulation factors for tritium and carbon-14 are calculated using the specific activity model in IMPACT™. As discussed in Section 3.2.6.1.2 of the HHRA, the fish BAF for hydrazine and morpholine is based on a QSAR model by Meylan et al. 1999 (as cited in European Commission, 2006). There are no other hydrazine and morpholine BAFs available for other aquatic biota. No BAF is presented for TRC as chlorine as it does not bioaccumulate in plants or animals (ATSDR, 2010). No BAF is presented for nitrate as there were no available data.

No BAFs are presented in **Error! Reference source not found.** and **Error! Reference source not found.** for ammonia, calcium, iron, magnesium, phosphorus, and potassium because these COPCs will be qualitatively assessed for mammals and birds in the risk assessment.

With the exception of those items listed above, BAFs are presented in **Error! Reference source not found.** and **Error! Reference source not found.** for those COPCs where tissue concentrations are needed and were not measured in the tissue of interest.

To estimate fruit concentrations, the measured or estimated terrestrial plant concentrations on a dry weight basis are adjusted to a wet weight basis using a moisture content of 90% for generic fruits and vegetables reported in CSA (2014).

Table 4-10: Bioaccumulation Factors (BAFs) for Fish, Turtles and Frogs, Aquatic Plants, and Benthic Invertebrates (L/kg fw)

COPC	Fish	Turtle and Frog	Aquatic Plant	Benthic Invertebrate
Cobalt-60	5.40E+01[1]	5.40E+01[1]	7.90E+02[1]	1.10E+02[1]
Cesium-134	3.50E+03[1]	3.50E+03[1]	2.20E+02[1]	9.90E+01[1]
Cesium-137	3.50E+03[1]	3.50E+03[1]	2.20E+02[1]	9.90E+01[1]
Iodine-131	6.00E+00[1]	6.00E+00[1]	7.10E+01[1]	9.60E+00[1]
Hydrazine	3.16E+00[2]	nd	nd	nd
Morpholine	3.16E+00[2]	nd	nd	nd
Aluminum	NA	NA	8.33E+02[3]	3.40E+03[4]
Barium	NA	NA	6.30E+01[1]	1.80E+02[1]
Boron	NA	NA	NA	NA
Cobalt	NA	NA	7.90E+02[1]	1.10E+02[1]
Copper	NA	NA	3.00E+03[4]	4.20E+01[4]
Lead	NA	NA	1.90E+03[4]	2.20E+01[4]
Manganese	NA	NA	4.40E+03[1]	6.90E+02[1]
Strontium	NA	NA	3.70E+02[1]	2.70E+02[4]
Vanadium	NA	NA	1.60E+02[5]	3.90E+02[4]

Notes:

nd = no data available
NA= BAF for non-radionuclides are only needed for an ecological receptor that will be consumed by another ecological receptor.
[1] CSA, 2014
[2] European Commission, 2006
[3] Abu Baker et al., 2013
[4] IAEA, 2010
[5] Sheppard, 2009

Table 4-11: Bioaccumulation Factors (BAFs) for Soil Invertebrates and Terrestrial Plants (kg-dw soil/kg-fw)

COPC	Soil Invertebrate (Earthworm and Caterpillar)	Terrestrial Plant[2] (Grass and Sugar Maple)	Terrestrial Plant[2] (Fruit)
Cobalt-60	6.08E-03[1]	9.40E-03	4.70E-03
Cesium-134	8.94E-02[1]	1.06E-02	5.30E-03
Cesium-137	8.94E-02[1]	1.06E-02	5.30E-03
Iodine-131	1.56E-01[1]	1.00E-02	5.00E-03
Aluminum	5.30E-02[3]	8.00E-04[4]	4.00E-04[4]
Barium	1.60E-01[3]	5.60E-03	2.80E-03
Copper	4.68E-01[3]	1.60E-01[5]	8.00E-02[5]
Strontium	2.78E-01[3]	1.74E-01	8.70E-02

Notes:
[1] Beresford, 2008
[2] CSA, 2014, using a dry fresh weight ratio of 0.2 for forage and 0.1 for generic fruits and vegetables
[3] Sample *et al*., 1998
[4] Baes *et al*., 1984
[5] IAEA, 2010

4.2.4.1.4 Transfer Factors

Transfer factors represent the fraction of daily COPC intake transferred to the tissue of birds and mammals. Ingestion transfer factors are COPC and biota-specific. Transfer factors from feed to tissue for agricultural livestock are available in CSA (2014). The transfer factors for rabbit and deer reported in CSA (2014) were applied directly to the Eastern cottontail and white-tailed deer, respectively. An allometric equation (transfer factor proportional to a -3/4 power of body weight) (CSA, 2012), was applied to transfer factors available for beef and poultry, to estimate the transfer factors for mammal and bird receptors, respectively. The derived transfer factors are presented in **Error! Reference source not found.** and **Error! Reference source not found.**. The transfer factors for tritium and carbon-14 were derived using specific activity methods in IMPACT™.

Transfer factors are not presented in **Error! Reference source not found.** and **Error! Reference source not found.** for ammonia, calcium, iron, magnesium, phosphorus, and potassium because these COPCs will be qualitatively assessed for mammals and birds.

Transfer factors are not present for boron, chromium, nickel, and zirconium in **Error! Reference source not found.** because these COPCs were identified as surface water (boron and zirconium) or sediment COPCs (chromium and nickel) for Treefrog Pond, located at Polygon D, and the Bufflehead, Mallard and muskrat were not identified as VECs for this Polygon.

Transfer factors are not present for chromium and nickel in **Error! Reference source not found.** because these COPCs were identified as sediment COPCs for Treefrog Pond, at Polygon D, and the VECs identified for Polygon D were not considered to be exposed to the sediment exposure pathway.

Table 4-12: Transfer Factors for Riparian Birds and Muskrat (d/kg fw)

COPC	Bufflehead	Mallard	Muskrat
Cobalt-60	2.86E+00	1.54E+00	4.60E-02
Cesium-134	7.96E+00	4.28E+00	2.36E+00
Cesium-137	7.96E+00	4.28E+00	2.36E+00
Iodine-131	2.57E-02	1.38E-02	7.17E-01
Aluminum	4.75E+01	2.55E+01	NA
Barium	5.60E-02	3.01E-02	NA
Cobalt	2.86E+00	1.54E+00	NA
Copper	8.26E-01	4.44E-01	NA
Lead	1.15E+00	6.18E-01	NA
Manganese	5.60E-03	3.01E-03	NA
Strontium	5.90E-02	3.17E-02	NA
Vanadium	8.26E-02	4.44E-02	NA

Notes:
There were no data available to determine transfer factors for hydrazine and morpholine
Radionuclide transfer factors were derived from beef and poultry transfer factors from CSA (2014), with the exception of aluminum, copper and vanadium.
Aluminum transfer factor for poultry was derived from beef transfer factor (ATSDR, 2008) times 100 (Zach and Sheppard, 1992)
Copper, lead, and vanadium transfer factors for poultry are from Sheppard (2009).
N/A indicates not applicable. Transfer factors for non-radionuclides are only needed for an ecological receptor that will be consumed by another ecological receptor.

Table 4-13: Transfer Factors for Terrestrial Birds and Mammals (d/kg fw)

COPC	American Robin	Bank Swallow	Song Sparrow	Yellow Warbler
Cobalt-60	1.12E+01	3.81E+01	2.96E+01	5.16E+01
Cesium-134	3.11E+01	1.06E+02	8.23E+01	1.44E+02
Cesium-137	3.11E+01	1.06E+02	8.23E+01	1.44E+02
Iodine-131	1.00E-01	3.41E-01	2.65E-01	4.63E-01
Aluminum	NA	NA	NA	NA
Barium	NA	NA	NA	NA
Lead	NA	NA	NA	NA
Strontium	NA	NA	NA	NA
Tin	NA	NA	NA	NA

COPC	Eastern Cottontail	Meadow Vole	White-tailed Deer	Common Shrew	Raccoon	Red fox	Short-tailed Weasel
Cobalt-60	1.80E-01	6.58E-01	1.20E-02	3.22E+00	1.41E-02	1.68E-02	1.89E-01
Cesium-134	1.10E+02	3.37E+01	1.50E-01	1.65E+02	7.23E-01	8.58E-01	9.65E+00
Cesium-137	1.10E+02	3.37E+01	1.50E-01	1.65E+02	7.23E-01	8.58E-01	9.65E+00
Iodine-131	4.60E-01	1.03E+01	3.20E-02	5.01E+01	2.20E-01	2.61E-01	2.94E+00
Aluminum	1.69E+01	2.47E+02	NA	NA	NA	NA	NA
Barium	1.47E-02	2.14E-01	NA	NA	NA	NA	NA
Boron	8.38E-02	1.22E+00	NA	NA	NA	NA	NA
Cobalt	4.50E-02	6.58E-01	NA	NA	NA	NA	NA
Copper	7.64E-01	1.12E+01	NA	NA	NA	NA	NA
Lead	7.33E-02	1.07E+00	NA	NA	NA	NA	NA
Manganese	6.28E-02	9.19E-01	NA	NA	NA	NA	NA
Strontium	1.36E-01	1.99E+00	NA	NA	NA	NA	NA
Tin	1.15E+00	1.68E+01	NA	NA	NA	NA	NA
Vanadium	1.47E-01	2.14E+00	NA	NA	NA	NA	NA
Zirconium	1.26E-04	1.84E-03	NA	NA	NA	NA	NA

Notes:
Transfer factors for non-radionuclides were not required for the American Robin, Bank Swallow, Song Sparrow, Yellow Warbler, white-tailed deer, common shrew, raccoon, red fox and short-tailed weasel because tissue concentrations were not required for the exposure calculation.
Radionuclide and non-radionuclide transfer factors were derived from beef, rabbit, deer, and poultry transfer factors from CSA (2014), with the following exceptions: the beef transfer factor for aluminum was obtained from ATSDR (2008); the beef transfer factor for boron was obtained from Baes et al. (1984); the beef transfer factors for copper and vanadium were obtained from Sheppard (2009), and the beef transfer factor for lead was obtained from IAEA, 2010.
NA indicates not applicable. Transfer factors for non-radionuclides are only needed for an ecological receptor that will be consumed by another ecological receptor (e.g., the meadow vole is consumed by the red fox)

4.2.4.1.5 Dose Coefficients

Radiation dose coefficients (DCs) used for terrestrial and aquatic biota are shown in **Error! Reference source not found.**. These DCs were taken from ICRP (2008) and the ERICA Tool 1.2.1 (2016; Brown *et al*., 2008). The surrogate organisms from these sources were selected to represent the VECs in this ERA, considering similarities in body size and likely external exposure media. The DC values for tritium in both sources (ICRP, 2008 and ERICA Tool 1.2.1, 2016; Brown *et al*., 2008) do not incorporate radiation quality factors for relative biological effectiveness (RBE). Therefore, the “low beta” components of the DCs were multiplied by 2 (as per CSA N288.6-12) in order to represent its greater relative effectiveness.

Table 4-14: Dose Coefficients of Surrogate Receptors Used for Radiological Exposure Calculations

Radionuclide	Earthworm		Grass		Pine Tree		Insect Larvae	
	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (in soil) (µGy/hr)/(Bq/kg dw)	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (µGy/hr)/(Bq/m²)	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (µGy/hr)/(Bq/m²)	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (µGy/hr)/(Bq/kg)
Carbon-14	2.83E-05	0.00E+00	2.83E-05	0.00E+00	2.83E-05	0.00E+00	2.80E-05	8.20E-07
Cobalt-60	7.50E-05	1.29E-03	7.50E-05	1.79E-05	7.50E-04	5.42E-06	5.20E-05	1.40E-03
Cesium-134	1.08E-04	8.33E-04	1.04E-04	1.21E-05	5.83E-04	3.58E-06	7.20E-05	9.20E-04
Cesium-137	1.42E-04	3.04E-04	1.42E-04	4.58E-06	3.25E-04	1.29E-06	9.80E-05	3.70E-04
Tritium	5.76E-06	0.00E+00	5.76E-06	0.00E+00	5.76E-06	0.00E+00	5.78E-06	2.40E-13
Iodine-131	1.13E-04	1.92E-04	1.08E-04	3.08E-06	2.46E-04	9.17E-07	8.70E-05	2.40E-04
Radionuclide	**Seaweed**		**Trout**		**Tadpole**		**Duck**	
	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (µGy/hr)/(Bq/kg ww)	Internal DC (µGy/hr)/(Bq/kg)	External DC (in water) (µGy/hr)/(Bq/kg)	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (in water) (µGy/hr)/(Bq/kg)	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (on soil) (µGy/hr)/(Bq/m²)
Carbon-14	2.83E-05	2.17E-07	2.83E-05	1.79E-08	2.83E-05	2.29E-07	2.83E-05	0.00E+00
Cobalt-60	8.75E-05	1.42E-03	2.13E-04	1.29E-03	6.25E-05	1.42E-03	2.38E-04	7.50E-06
Cesium-134	1.13E-04	8.75E-04	2.04E-04	7.92E-04	9.58E-05	9.17E-04	2.21E-04	5.00E-06
Cesium-137	1.38E-04	3.29E-04	1.83E-04	2.83E-04	1.33E-04	5.42E-07	1.88E-04	1.79E-06
Tritium	5.76E-06	2.33E-09	5.76E-06	3.54E-13	5.76E-06	1.33E-11	5.76E-06	0.00E+00
Iodine-131	1.13E-04	2.21E-04	1.38E-04	1.92E-04	1.04E-04	2.25E-04	1.42E-04	1.21E-06

Radionuclide	Rat		
	Internal DC (µGy/hr)/(Bq/kg fw)	External DC (on soil) (µGy/hr)/(Bq/m²)	External DC (in soil) (µGy/hr)/(Bq/kg dw)
Carbon-14	2.83E-05	0.00E+00	0.00E+00
Cobalt-60	1.67E-04	7.92E-06	1.21E-03
Cesium-134	1.71E-04	5.00E-06	7.92E-04
Cesium-137	1.71E-04	1.88E-06	2.83E-03
Tritium	5.76E-06	0.00E+00	0.00E+00
Iodine-131	1.29E-04	1.29E-06	1.79E-04

Notes:
Earthworm, grass, pine tree, seaweed, rat, trout, tadpole and duck DCs from ICRP (2008)
Insect larvae DCs from ERICA Assessment Tool 1.2.1. (2016; Brown *et al*., 2008)
Earthworm is the surrogate for earthworms and caterpillars; grass is the surrogate for grass, pine tree is the surrogate for fruits and sugar maple, insect larvae is the surrogate for aquatic invertebrates, seaweed is the surrogate for aquatic plants, trout is the surrogate for all fish, tadpole is the surrogate for frogs and turtles, rat is the surrogate for all mammals, and duck is the surrogate for all birds.

4.2.4.1.6 Specific Activity Model for Tritium

IMPACT™ was used to estimate tritium and C-14 tissue concentrations using specific activity models as outlined in CSA (2014) and as recommended in Clause 7.3.4.3.7 of CSA (2012).

Aquatic BAFs 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. BAFs are used to calculate tritium concentrations in plant, invertebrate and fish tissues. Therefore the BAF (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)

All aquatic HTO BAFs, which are derived from a specific activity model, are summarized in **Error! Reference source not found.**.

Table 4-15: Summary of BAFs for Tritium and Carbon-14

Receptor	Units	Tritium	Carbon-14	References
Fish	L/kg fw	7.50E-01	5.70E+03	CSA, 2014
Turtles and Frogs	L/kg fw	7.50E-01	5.70E+03	CSA, 2014 using fish as a surrogate
Aquatic Plants	L/kg fw	7.50E-01	5.90E+03	CSA, 2014
Benthic Invertebrates	L/kg fw	7.50E-01	5.20E+03	CSA, 2014

BAFs for terrestrial plants and soil invertebrates are not required for modelling tritium but are handled through the transfer from air as outlined in Clause 6.4.6.2 CSA (2014).

Because IMPACT™ and CSA (2014) do not consider the transfer of HTO to soil invertebrates, and because measured HTO soil invertebrate concentrations are not available for Polygon E, soil invertebrate concentrations are estimated for this polygon using modelled HTO air concentrations from IMPACT™ and the specific activity model (outside IMPACT™) as outlined in Clause 6.4.6.2 of CSA (2014) for plants. IMPACT™ was used to estimate the HTO concentration in air in Polygon E based on HTO emissions from 2011 to 2015. Emissions are modelled conservatively as a ground level release. Uncertainties in the model are discussion in

Section 4.2.7. Soil invertebrate HTO concentrations were estimated according to the equation below. These estimated soil invertebrate concentrations were then dictated in IMPACT^{TM} for the earthworm, which is also representative of the caterpillar. Clause 6.4.6.2 is considered appropriate to estimate the transfer of HTO to soil invertebrates through air.

Soil invertebrate HTO concentrations ($[SI]_{\_HTO}$) for polygon E are estimated as follows (Bq/kg-fw):

$$[SI]_{\_HTO} = [Air]_{HTO} \cdot P_{HTOair\_SI}$$

where,

$[Air]_{HTO}$ = air concentration of HTO (Bq/m^3),
P_{HTOair_SI} = transfer of HTO to soil invertebrates through air (m^3/kg-fw).

P_{HTOair_SI} is calculated as follows:

$$P_{HTOair\_SI} = RF_p \cdot (1\text{-}DW_{SI})/H_a$$

where,

RF_p = reduction factor that accounts for the effect of soil water tritium concentrations that are lower than air moisture tritium concentrations (unitless) (0.68 from CSA, 2014)
DW_{SI} = dry/fresh weight ratio for soil invertebrates (kg dw /kg–fw) (0.17 from Beresford et al., 2008)
$1\text{-}DW_{SI}$ = water content of the soil invertebrate (L water /kg-fw soil invertebrate)
H_a = atmospheric absolute humidity (L/m^3) (0.011 from CSA, 2014)

For HTO, the majority of the tritium taken into the animal is from water ingestion and food consumption. The soil ingestion pathway is negligible for HTO. Consistent with the CSA (2014) equations, IMPACT^{TM} was used to determine the transfer of HTO to animals ($P_{HTOwater\_animal}$, L/kg-fw) through water ingestion 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
DW_a = dry/fresh weight ratio for animal products (kg-dw/kg-fw) (0.3 from CSA, 2014)

The transfer of HTO to animals through food ingestion ($P_{HTOfood\_animal}$, unitless) was also determined in IMPACT™ using the specific activity model from CSA (2014), and is calculated as follows:

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

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 OBT as a result of HTO ingestion
$1-DW_a$	=	water content of the animal product (L water/kg-fw)
$1-DW_p$	=	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 red fox's diet at Polygon AB consists of 50% small mammals, 30% waterfowl and 20% vegetation. The combined DW_p for the red fox was the weighted average of the dry weight fraction for small mammals, waterfowl, and vegetation.

A summary of the input parameters is provided in **Error! Reference source not found.**.

Table 4-16: 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)
Bufflehead	0.22	0.65	0.121	0.10	0.25	244	111[1], 112[2]
Mallard	0.22	0.65	0.121	0.10	0.25	244	111[1], 115[2]
Muskrat	0.413	0.509	0.071	0.11	0.25	201	201
American Robin	0.22	0.65	0.121	0.10	0.128	244	74.4
Bank Swallow	0.22	0.65	0.121	0.10	0.17	244	111
Song Sparrow	0.22	0.65	0.121	0.10	0.107	244	56.1
Yellow Warbler	0.22	0.65	0.121	0.10	0.163	244	105
Eastern Cottontail	0.413	0.509	0.071	0.11	0.20	201	100
Meadow Vole	0.413	0.509	0.071	0.11	0.20	201	100
White-tailed Deer	0.33	0.582	0.081	0.11	0.20	201	100
Common Shrew	0.413	0.509	0.071	0.11	0.17	201	111
Raccoon	0.413	0.509	0.071	0.11	0.188[1], 0.180[2]	201	108
Red fox	0.413	0.509	0.071	0.11	0.28	201	194[1], 181[2]

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)
Short-tailed Weasel	0.413	0.509	0.071	0.11	0.30	201	201

Notes:
f_{w_w}, f_{w_pw}, f_{w_dw}, and f_{OBT} are from Table 16 and 17 in CSA (2014).
S_a are the beef and poultry values from Table 18 in CSA (2014)
[1] Polygon AB
[2] Polygon C, D,and E

4.2.4.1.7 Specific Activity Model for Carbon-14

Aquatic BAFs for C-14 assume that the C-14 to stable carbon ratio in aquatic animals is equal to the ratio in dissolved inorganic carbon in the water. Therefore the BAF (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)

Consistent with CSA (2014), S_w is 0.0213 gC/L. The stable carbon content for fish of 121.75 gC/kg-fw was used (CSA, 2014). The fish stable carbon content was considered appropriate for frogs and turtles. For freshwater invertebrates the stable carbon content for marine crustaceans of 111 gC/kg-fw was considered appropriate. For aquatic plants the stable carbon content for terrestrial plants of 500 gC/kg-dw or 125 gC/kg-fw was considered appropriate (CSA, 2014).

The stable carbon concentrations for terrestrial plants, fruits and terrestrial invertebrates are presented in **Error! Reference source not found.**.

Table 4-17: Stable Carbon Content for Food Types

Food Type	Stable Carbon Content (gC/kg-fw)	Reference
Aquatic plants	125	CSA, 2014
Benthic invertebrates	111	CSA, 2014
Bufflehead	244	CSA, 2014
Mallard	244	CSA, 2014
Earthworms/caterpillars	111	CSA, 2014
Grass/Sugar maple	100	CSA, 2014
Fruit	50	CSA, 2014
Eastern Cottontail	201	CSA, 2014
Meadow Vole	201	CSA, 2014

BAFs for terrestrial plants and soil invertebrates are not required for modelling tritium and C-14 but are handled through the transfer from air as outlined in Clause 6.4.9.2 CSA (2014).

Because IMPACT™ and CSA (2014) do not consider the transfer of C-14 to soil invertebrates, and because measured C-14 concentrations for soil invertebrates are not available for Polygon E, soil invertebrates concentrations are estimated for this polygon using modelled C-14 air concentrations from IMPACT™ and the specific activity model (outside IMPACT™) as outlined in Clause 6.4.9.2 of CSA (2014) for plants. IMPACT™ was used to estimate the C-14 concentration in air in Polygon E based on C-14 emissions from 2011 to 2015. Emissions are modelled conservatively as a ground level release. Uncertainties in the model are discussion in Section 4.2.7. Soil invertebrate C-14 concentrations were estimated according to the equation below. These estimated soil invertebrate concentrations were then dictated in IMPACT™ for the earthworm, which is also representative of the caterpillar. Clause 6.4.9.2 is considered appropriate to estimate the transfer of C-14 to soil invertebrates through air.

Soil invertebrate C-14 ($[SI]_{\_C\text{-}14}$) concentrations for polygon E are estimated as follows (Bq/kg-fw):

$$[SI]_{\_C\text{-}14} = [Air]_{C\text{-}14} \cdot P_{C\text{-}14air\_SI}$$

where,

$[Air]_{C\text{-}14}$ = air concentration of C-14 (Bq/m3)
P_{C14air_SI} = transfer of C-14 to soil invertebrates through air (m^3/kg-fw).

$P_{C\text{-}14air\_SI}$ is calculated as follows:

$$P_{C\text{-}14air\_SI} = f_{c\_air} \cdot S_{SI}/X_{1\_C}$$

where,

f_{c_air} = fraction of soil invertebrate stable carbon derived from air (unitless) (assumed to be 1)
S_{SI} = stable carbon content in the soil invertebrate (gC/kg-fw) (111 from CSA, 2014)
X_{1_C} = concentration of stable carbon in air (gC/m^3) (0.21 from CSA, 2014)

For C-14, food consumption contributes to the majority of the carbon ingested by the animal, compared to inhalation, water and soil ingestion. Consistent with CSA (2014), the specific activity model in IMPACT™ was used to determine the transfer of C-14 from food to animals, as follows:

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

where,

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

The stable carbon content in the animal was obtained from CSA (2014). The beef value was applied for all mammals and the poultry value was applied for all birds. This is reasonable since the stable carbon values presented by IAEA (TRS 472) for various domestic species within each category are all very close to each other, and since values are not available for wild species. N288.1 has noted this, and has used poultry values for wild waterfowl.

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 **Error! Reference source not found.**.

4.2.5 Dispersion Models

HTO concentrations were not measured in soil for Polygon C, D and E. IMPACT™ version 5.5.1 was used to estimate HTO concentrations in pore water based on atmospheric emissions of HTO and elemental tritium from 2011 to 2015, based on a maximum monthly emissions and average monthly emission. Emissions are modelled conservatively as a ground level release. Uncertainties in the model are discussed in Section 4.2.7.

4.2.6 Exposure Point Concentrations and Doses

4.2.6.1 Exposure Point Concentrations

The measured concentrations used for the exposure evaluation for the different polygons are listed in **Error! Reference source not found.** through **Error! Reference source not found.**. In cases where a measured concentration is not provided, the concentration is modelled using exposure factors discussed in Section 4.2.4. The emissions used for modelling are provided in Table 4.23. Modelled concentrations are presented in Appendix C.

As indicated in Section 4.2.1, media-specific concentrations were available for surface water, sediment, soil, fish, frogs, aquatic plants, benthic invertebrates, soil invertebrates, insects and terrestrial vegetation, for the different waters (e.g. Lake Ontario, Coots Pond and Treefrog Pond) and for different land polygons (AB, C, D, and E). Most of this data was obtained from the SENES (2009a) ERA, and supplemented with soil and terrestrial data from the SENES (2011c) ERA of the southwest corner, and surface water, sediment and fish monitoring data from the OPG Annual EMP reports for 2011 to 2015. In cases where data were available in the OPG Annual EMP report and in SENES (2009a) and SENES (2011c) for the same media or biota, the OPG EMP results were only used because these results represented more recent data.

Where applicable, effluent concentrations reported as part of the ECA/MISA monitoring programs (2011 to 2015), or the 2016 effluent characterization were used to estimate concentrations at the Outfall, with an appropriate 7-fold dilution factor.

Consistent with guidance from CSA N288.6-12 (CSA, 2012), in instances where there were non-detects in the dataset and they were not predominant (<15%), they were replaced with a one-half MDL value, and an arithmetic mean value was determined. However, when more than 50% of the dataset was comprised of non-detects, there is no method to provide a reliable estimate of the mean (CSA, 2012). For this assessment, to be conservative, in those instances the detection limit was considered to be a measured value and was used in the dataset to calculate the mean, likely overestimating the concentrations found at the location.

In some cases a mean could not be estimated using the available dataset because only the minimum and maximum results were provided. In these cases the mean of the minimum and maximum results were used to estimate a midpoint value of the dataset. This midpoint value was used to represent the mean exposure point concentration.

For Polygon D, although chromium, copper, nickel, phosphorus, and vanadium were identified as sediment COPCs for Treefrog Pond, located at Polygon D, the VECs identified for Polygon D do not consume food exposed to sediment or ingest sediment from Treefrog Pond; therefore, the exposure pathway for sediment is incomplete. As such, sediment exposure point concentrations for Polygon D have been excluded from **Error! Reference source not found.**.

Table 4-18: Exposure Point Concentrations for Lake Ontario

	Surface Water[1]		Sediment[2]		Round Whitefish[3]		White Sucker[4]		Alewife[5]		Mussels[6]	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Radionuclides												
Unit	Bq/L	Bq/L	Bq/kg(dw)	Bq/kg(dw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)
Carbon-14	2.20E-03	1.25E-04	9.84E-01	9.84E-01	3.40E+01	3.06E+01	3.37E+01	2.95E+01	3.46E+01	3.03E+01	3.51E+01	3.51E+01
Cobalt-60	<1.00E+00	<1.00E+00	2.00E-01	1.75E-01	<1.00E-01	<1.00E-01	<1.00E-01	<1.00E-01	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Cesium-134	<1.00E+00	<1.00E+00	2.00E-01	1.25E-01	<1.00E-01	<1.00E-01	<1.00E-01	<1.00E-01	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Cesium-137	5.68E-03	1.34E-03	1.30E+00	8.50E-01	3.00E-01	2.13E-01	2.00E-01	1.35E-01	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Tritium	2.87E+01	6.13E+00	<1.50E+01	<1.50E+01	3.75E+00	3.24E+00	6.30E+00	3.65E+00	2.30E+01	1.11E+01	1.00E+01	1.00E+01
Iodine-131	4.00E+00	2.07E+00	<2.00E+00	<2.00E+00	8.00E+00	7.00E+00	3.00E+00	3.00E+00	1.30E+01	7.46E+00	1.08E+02	8.88E+01
Non-Radionuclides												
Unit	mg/L	mg/L	mg/kg(dw)	mg/kg(dw)	-	-	-	-	-	-	mg/kg (ww)	mg/kg (ww)
Aluminum	2.14E-02	3.86E-03	3.49E+04	7.80E+03	-	-	-	-	-	-	2.12E+02	2.12E+02
Copper	4.00E-03	1.00E-03	4.46E+01	5.40E+00	-	-	-	-	-	-	2.12E+00	2.12E+00
Nitrate	8.97E+01	2.80E+00	-	-	-	-	-	-	-	-	-	-
Chlorine (TRC)	<1.20E-03	<1.20E-03	-	-	-	-	-	-	-	-	-	-
Hydrazine	1.14E-03	4.57E-04	-	-	-	-	-	-	-	-	-	-
Morpholine	1.14E-03	2.14E-04	-	-	-	-	-	-	-	-	-	-

Notes:
[1]SENES, 2009a (Co-60, Cs-134, I-131, copper, nitrate); Effluent concentrations from routine effluent data, MISA/ECA and effluent characterization program (2011 to 2016: C-14, Cs-137, HTO, aluminum, hydrazine, morpholine. all concentrations adjusted by a dilution factor of 7); EcoMetrix, 2015 (Chlorine (TRC)).
[2]SENES, 2009a (HTO, I-131, aluminum, copper); EMP 2011 (C-14, Co-60, Cs-134, Cs-137). C-14 was converted from Bg/kg-C using a total organic carbon of 5100 ppm
[3]SENES, 2009a (I-131); EMP 2011 (C-14, Co-60, Cs-134, Cs-137, HTO). C-14 was converted from Bg/kg-C using a freshwater fish tissue of 121.75 gC/kg FW (CSA, 2014)
[4]SENES, 2009a (I-131); EMP 2011-2015 (C-14, Co-60, Cs-134, Cs-137, HTO). C-14 was converted from Bg/kg-C using a freshwater fish tissue of 121.75 gC/kg FW (CSA, 2014)
[5]SENES, 2009a. C-14 was converted from Bg/kg-C using a freshwater fish tissue of 121.75 gC/kg FW (CSA, 2014)
[6]SENES, 2009a; mussels used to represent benthic invertebrates. C-14 was converted from Bg/kg-C using a benthic invertebrate carbon concentration in tissue of 111 gC/kg FW (CSA, 2014)
"-" indicates notapplicable
In cases where values were not detected, the maximum and mean values were both set to the full method detection limit. Similarly, if the sample size was equal to 1, the maximum and mean values were set to the single measured concentration.

Table 4-19: Exposure Point Concentrations for Polygon AB

	Surface Water		Sediment[1]		Northern Redbelly Dace[2]		Aquatic Plants[3]		Soil[1, 4,5]		Earthworm[6]		Caterpillar[6]		Terrestrial Vegetation[7]		Fruit[8]	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Radionuclides																		
Unit	Bq/L	Bq/L	Bq/kg(dw)	Bq/kg(dw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(dw)	Bq/kg(dw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)
Carbon-14	<5.00E-01	<5.00E-01	1.09E+01	9.23E+00	3.49E+01	3.18E+01	3.89E+01	3.46E+01	1.45E+01	1.09E+01	3.06E+01	2.93E+01	3.09E+01	2.68E+01	4.70E+01	2.87E+01	1.18E+01	1.18E+01
Cobalt-60	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.11E+00	<1.11E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Cesium-134	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.11E+00	<1.11E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Cesium-137	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	8.44E+00	3.29E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Tritium	7.80E+01	5.10E+01	2.98E+02	2.41E+02	7.70E+01	7.25E+01	4.30E+01	3.76E+01	2.01E+02	6.04E+01	<1.50E+01	<1.50E+01	5.30E+01	5.15E+01	4.95E+02	1.23E+02	8.60E+01	8.60E+01
Iodine-131	<4.00E+00	2.12E+00	<2.00E+00	<2.00E+00	3.18E+02	2.72E+02	<2.00E+00	<2.00E+00	8.89E+00	1.89E+00	1.00E+01	9.00E+00	6.00E+00	5.00E+00	1.70E+01	7.54E+00	<2.00E+00	<2.00E+00
Non-Radionuclides																		
Unit	mg/L	mg/L	-	-	-	-	-	-	mg/kg (dw)	mg/kg (dw)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)
Aluminum	2.94E+00	7.00E-01	2.87E+04	2.63E+04	-	-	-	-	2.52E+04	1.64E+04	4.01E+03	3.33E=03	1.88E+01	1.24E+01	2.20E+02	2.92E+01	1.10E+02	1.46E+01
Ammonia (un-ionized; as NH_3)	5.00E-02	1.00E-02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Barium	1.00E-01	5.00E-02	3.42E+02	3.37E+02	-	-	-	-	4.09E+02	2.56E+02	3.12E+01	2.24E+01	3.50E+00	2.75E+00	3.14E+01	6.82E+00	1.57E+01	3.41E+00
Boron (HWS)	-	-	-	-	-	-	-	-	1.98E+00	3.76E-01	-	-	-	-	-	-	-	-
Calcium	8.60E+01	4.90E+01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cobalt	4.00E-03	1.00E-03	9.90E+00	9.30E+00	-	-	-	-	1.45E+01	6.40E+00	3.02E+00	2.70E+00	<5.00E-02	<5.00E-02-	1.82E-01	3.60E-02	9.10E-02-	1.80E-02
Copper	1.50E-03	1.00E-03	2.69E+01	2.40E+01	-	-	-	-	2.92E+01	1.28E+01	7.84E+00	7.00E+00	5.72E+00	4.09E+00	3.64E+00	1.48E+00	1.82E+00	7.38E-01
Iron	1.30E+00	4.00E-01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lead	1.00E-03	3.00E-04	1.90E+01-	1.67E+01-	-	-	-	-	5.41E+01	2.34E+01	3.22E+00	2.84E+00	5.90E-02	5.45E-02	4.20E-01	8.73E-02	2.10E-01	4.37E-02
Magnesium	3.80E+01	3.20E+01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese	7.00E-02	4.00E-02	5.03E+02	4.61E+02	-	-	-	-	6.80E+02	4.76E+02	1.51E+02	1.24E+02	3.80E+00	3.80E+00	1.35E+01	6.78E+00	6.73E+00	3.39E+00
Phosphorus	-	-	6.73E+02	6.51E+02	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium	1.20E+01	7.70E+00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium	7.30E-01	5.10E-01	7.02E+02-	6.08E+02-	-	-	-	-	2.93E+02	1.49E+02	1.04E+02	7.86E+01	1.84E+01	1.07E+01	3.12E+01	1.38E+01	1.56E+01	6.89E+00
Vanadium	1.70E-03	7.00E-04	4.09E+01	3.81E+01	-	-	-	-	6.09E+01	4.26E+01	1.01E+01	8.20E+00	<5.00E-02	<5.00E-02	6.40E-01	1.11E-01	3.20E-01	5.55E-02

Notes:

All data obtained from SENES, 2009a, unless otherwise indicated

[1]C-14 was converted from Bg/kg-C assuming a carbon content of 5%

[2]C-14 was converted from Bg/kg-C using a freshwater fish tissue of 121.75 gC/kg FW (CSA, 2014)

[3]C-14 was converted from Bg/kg-C using an aquatic plant tissue of 125 gC/kg FW (CSA, 2014)

[4]Data obtained from SENES, 2009a and 2011c. Soil data on a wet weight basis was converted to a dry weight basis using an average water content of 10% (Geological and Hydrogeological Environment Existing Environmental Conditions TSD

[5]HTO value is presented in Bq/L. HTO in Bq/kg (dw) was converted to Bq/L using a dry bulk density of 1.3 kg (dw)/L dry soil and a water content of 10% (CSA, 2014)

[6]C-14 was converted from Bg/kg-C using a benthic invertebrate tissue of 111 gC/kg FW (CSA, 2014)

[7]C-14 was converted from Bg/kg-C using a terrestrial vegetation tissue (forage) of 100 gC/kg FW (CSA, 2014). A dry to fresh weight ratio of 0.2 was used to convert non-radionuclide terrestrial vegetation concentrations reported on a dry weight to a wet weight basis (CSA, 2014).
[8]C-14 was converted from Bg/kg-C using a terrestrial vegetation tissue (fruit) of 50 gC/kg FW (CSA, 2014). Non-radionuclide fruit concentrations were not measured. Fruit concentrations were estimated using measured terrestrial vegetation concentrations on a dry weight basis and a dry fresh weight ratio of 0.1 for fruit (CSA, 2014)
"-" indicates not applicable for the exposure pathway analysis. For aquatic plants "-" indicates not measured.
In cases where values were not detected, the maximum and mean values were both set to the full method detection limit. Similarly, if the sample size was equal to 1, the maximum and mean values were set to the single measured concentration.

Table 4-20: Exposure Point Concentrations for Polygon C

	Soil[1, 2,5]		Earthworm[3]		Caterpillar[3]		Terrestrial Vegetation[4]		Fruit[5]	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Radionuclides										
Unit	Bq/kg(dw)	Bq/kg(dw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)
Carbon-14	1.14E+01	9.45E+00	3.51E+01	3.51E+01	4.83E+01	4.83E+01	5.77E+01	4.95E+01	1.27E+01	1.27E+01
Cobalt-60	<1.11E+00	<1.11E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Cesium-134	<1.11E+00	<1.11E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Cesium-137	9.22E+00	4.89E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Tritium	-	-	3.70E+01	3.70E+01	1.85E+02	1.85E+02	2.66E+02	2.22E+02	1.51E+02	1.51E+02
Iodine-131	8.89E+00	5.28E+00	9.00E+00	9.00E+00	8.00E+00	8.00E+00	1.40E+01	1.03E+01	<2.00E+00	<2.00E+00
Non-Radionuclides										
Unit	mg/kg (dw)	mg/kg (dw)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)
Barium	4.28E+02	4.03E+02	1.08E+01	1.08E+01	1.70E+00	1.70E+00	3.88E+00	2.58E+00	1.94E+00	1.29E+00
Strontium	1.80E+02	1.66E+02	2.60E+01	2.60E+01	2.00E+00	2.00E+00	1.04E+01	9.28E+00	5.21E+00	4.64E+00
Tin	1.54E+01	9.16E+00	<5.00E-02	<5.00E-02	<5.00E-02	<5.00E-02	1.76E-02	1.34E-02	8.80E-03	6.70E-03

Notes:
All data obtained from SENES, 2009a, unless otherwise indicated
[1]C-14 was converted from Bg/kg-C assuming a carbon content of 5%
[2]Soil data on a wet weight basis was converted to a dry weight basis using an average water content of 10% (Geological and Hydrogeological Environment Existing Environmental Conditions TSD)
[3]C-14 was converted from Bg/kg-C using a benthic invertebrate tissue of 111 gC/kg FW (CSA, 2014)
[4]C-14 was converted from Bg/kg-C using a terrestrial vegetation tissue (forage) of 100 gC/kg FW (CSA, 2014). A dry to fresh weight ratio of 0.2 was used to convert non-radionuclide terrestrial vegetation concentrations reported on a dry weight to a wet weight basis (CSA, 2014)
[5]C-14 was converted from Bg/kg-C using a terrestrial vegetation tissue (fruit) of 50 gC/kg FW (CSA, 2014). Non-radionuclide fruit concentrations were not measured. Fruit concentrations were estimated using measured terrestrial vegetation concentrations on a dry weight basis and a dry fresh weight ratio of 0.1 for fruit (CSA, 2014)
"-" not measured
In cases where values were not detected, the maximum and mean values were both set to the full method detection limit. Similarly, if the sample size was equal to 1, the maximum and mean values were set to the single measured concentration.

Table 4-21: Exposure Point Concentrations for Polygon D

	Surface Water		Sediment[1]		Frogs[2]		Aquatic Plants[3]		Soil[1, 4]		Earthworm[5]		Caterpillar[5]		Terrestrial Vegetation[6]		Fruit[7]	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Radionuclides																		
Unit	Bq/L	Bq/L	Bq/kg(dw)	Bq/kg(dw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(dw)	Bq/kg(dw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)	Bq/kg(fw)
Carbon-14	<5.00E-01	<5.00E-01	1.15E+01	9.70E+00	3.39E+01	3.39E+01	5.75E+01	5.50E+01	8.35E+00	7.38E+00	3.55E+01	3.55E+01	3.26E+01	3.26E+01	5.68E+01	4.87E+01	1.46E+01	1.42E+01
Cobalt-60	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.11E+00	<1.11E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Cesium-134	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.11E+00	<1.11E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Cesium-137	<1.00E+00	<1.00E+00	<1.00E+00	6.00E-01	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	5.11E+00	3.53E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00	<1.00E+00
Tritium	1.58E+02	8.29E+01	2.42E+02	1.94E+02	3.80E+01	3.80E+01	5.80E+01	5.26E+01	-	-	1.90E+01	1.90E+01	9.20E+01	9.20E+01	5.50E+01	4.30E+01	9.30E+01	8.80E+01
Iodine-131	5.00E+00	2.14E+00	<2.00E+00	<2.00E+00	2.20E+01	2.20E+01	3.00E+00	2.20E+00	5.56E+00	4.44E+00	1.20E+01	7.00E+00	<4.00E+00	<4.00E+00	2.30E+01	1.90E+01	<2.00E+00	<2.00E+00
Non-Radionuclides																		
Unit	mg/L	mg/L	‘-	‘-	-	-	-	-	mg/kg (dw)	mg/kg (dw)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)	mg/kg (ww)
Barium	4.00E-01	1.00E-01	-	-	-	-	-	-	5.25E+02	3.93E+02	7.13E+01	4.68E+01	1.50E+00	1.50E+00	8.48E+00	5.74E+00	4.24E+00	2.87E+00
Boron	2.60E+00	4.00E-01	-	-	-	-	-	-	3.59E+01	2.32E+01	6.51E+00	4.12E+00	2.47E+00	2.47E+00	8.94E+00	8.64E+00	4.47E+00	4.32E+00
Calcium	9.30E+01	7.27E+01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cobalt	5.00E-03	1.00E-03	-	-	-	-	-	-	8.09E+00	7.57E+00	3.38E+00	3.19E+00	<5.00E-02	<5.00E-02	8.94E+00	8.64E+00	1.40E-02	1.17E-02
Iron	3.90E+00	1.00E+00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Magnesium	1.12E+01	8.70E+00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese	7.50E-01	3.00E-01	-	-	-	-	-	-	5.59E+02	5.12E+02	1.13E+02	1.07E+02	3.10E+00	3.10E+00	7.90E+00	5.80E+00	3.95E+00	2.90E+00
Nitrate	1.50E+01	9.00E-01			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium	1.18E+01	5.10E+00			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium	3.00E-01	2.00E-01	-	-	-	-	-	-	3.04E+02	2.21E+02	5.58E+01	3.46E+01	7.60E+00	7.60E+00	1.66E+01	1.11E+01	8.30E+00	5.53E+00
Tin	<1.00E-04	<1.00E-04	-	-	-	-	-	-	1.09E+01	7.82E+00	3.47E-01	2.15E-01	<5.00E-02	<5.00E-02	1.39E+00	7.18E-01	6.97E-01	3.59E-01
Zirconium	2.00E-02	4.00E-03	-	-	-	-	-	-	7.87E+01	5.97E+01	1.64E+01	9.47E+00	<5.00E-02	<5.00E-02	5.90E-02	4.51E-02	2.95E-02	2.26E-02

Notes:

All data obtained from SENES, 2009a, unless otherwise indicated

[1]C-14 was converted from Bg/kg-C assuming a carbon content of 5%

[2]C-14 was converted from Bg/kg-C using a freshwater fish tissue of 121.75 gC/kg FW (CSA, 2014)

[3]C-14 was converted from Bg/kg-C using an aquatic plant tissue of 125 gC/kg FW (CSA, 2014)

[4]Soil data presented on a wet weight basis was converted to a dry weight basis based on an average water content of 10% (Geological and Hydrogeological Environment Existing Environmental Conditions TSD)

[5]C-14 was converted from Bg/kg-C using a benthic invertebrate tissue of 111 gC/kg FW (CSA, 2014)

[6]C-14 was converted from Bg/kg-C using a terrestrial vegetation tissue (forage) of 100 gC/kg FW (CSA, 2014). A dry to fresh weight ratio of 0.2 was used to convert non-radionuclide terrestrial vegetation concentrations reported on a dry weight to a wet weight basis (CSA, 2014)

[7]C-14 was converted from Bg/kg-C using a terrestrial vegetation tissue (fruit) of 50 gC/kg FW (CSA, 2014). Non-radionuclide fruit concentrations were not measured. Fruit concentrations were estimated using measured terrestrial vegetation concentrations on a dry weight basis and a dry fresh weight ratio of 0.1 for fruit (CSA, 2014)

"-" indicates not measured in the case of soil for radionuclides, and not applicable for exposure pathway for mammal and bird VECs for non-radionuclides.

In cases where values were not detected, the maximum and mean values were both set to the full method detection limit. Similarly, if the sample size was equal to 1, the maximum and mean values were set to the single measured concentration.

Chromium, copper, nickel, phosphorus, and vanadium were identified as COPCs in the sediment, but not the surface water for Treefrog Pond located within Polygon D. Because the VECs assessed in this Polygon do not have a direct connection to the sediment pathway, exposure and risks to these COPCs via the sediment pathway were not considered for this Polygon D. Although, turtle, frogs and aquatic plants may have a sediment connection, the surface water connection was the only exposure pathway considered for these VECs for non-radionuclides.

Table 4-22: Exposure Point Concentrations for Polygon E

	Surface Water[1]		Soil[2]		Fruit[3]	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Radionuclides						
Unit	Bq/L	Bq/L	Bq/kg(dw)	Bq/kg(dw)	Bq/kg(fw)	Bq/kg(fw)
Carbon-14	2.20E-03	1.25E-04	1.51E+01	1.30E+01	1.49E+01	1.49E+01
Cobalt-60	<1.00E+00	<1.00E+00	<1.11E+00	<1.11E+00	<1.00E+00	<1.00E+00
Cesium-134	<1.00E+00	<1.00E+00	<1.11E+00	<1.11E+00	<1.00E+00	<1.00E+00
Cesium-137	5.68E-03	1.34E-03	9.20E+00	7.20E+00	<1.00E+00	<1.00E+00
Tritium	2.87E+01	6.13E+00	-	-	1.86E+02	1.86E+02
Iodine-131	<4.00E+00	2.07E+00	7.78E+00	5.56E+00	<2.00E+00	<2.00E+00
Non-Radionuclides						
Unit	mg/L	mg/L	mg/kg (dw)	mg/kg (dw)	mg/kg (ww)	mg/kg (ww)
Barium	6.00E-01	4.00E-02	4.49E+02	4.21E+02	-	-
Strontium	2.20E-01	2.00E-01	1.69E+02	1.60E+02	-	-

Notes:
All data obtained from SENES, 2009a, unless otherwise indicated
[1] Lake Ontario Water; SENES, 2009a (C-14, Co-60, Cs-134, I-131, aluminum, copper); Outfall concentration modelled from emission (Cs-137 and HTO)
[2]C-14 was converted from Bg/kg-C assuming a carbon content of 5%
"-" indicates not measured
In cases where values were not detected, the maximum and mean values were both set to the full method detection limit. Similarly, if the sample size was equal to 1, the maximum and mean values were set to the single measured concentration.

Table 4-23: Emissions to Air used to Model Exposure Point Concentrations

	Air[1]	
	Maximum	Mean
Radionuclides		
Unit	Bq/s	Bq/s
Carbon-14	7.04E+04	3.60E+04
Cobalt-60	2.20E+00	1.06E+00
Cesium-134	*	*
Cesium-137	*	*
Tritium	1.47E+07	6.40E+06
Iodine-131	7.05E+00	4.62E+00

Notes:

[1] Air Emissions (2011 to 2015)

* The particulate (gross beta-gamma) emission was modelled as Co-60.

4.2.6.2 Exposure Doses

The exposure concentrations in Section 4.2.6.1, along with the exposure factors in Section 4.2.4, were applied to the equations in Section 4.2.3 to estimate the radiological dose to all biota and non-radiological dose to birds and mammals. The estimated radiological doses are presented in **Error! Reference source not found.** to **Error! Reference source not found.**. The estimated non-radiological doses are presented in **Error! Reference source not found.** to **Error! Reference source not found.**.

Table 4-24: Estimated Radiation Doses for Aquatic Biota for Lake Ontario (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Round Whitefish	2.31E-05	2.08E-05	8.20E-07	7.81E-07	6.80E-07	6.09E-07	1.76E-06	1.22E-06	5.18E-07	4.48E-07	2.69E-05	2.36E-05	5.43E-05	4.76E-05
White Sucker	2.29E-05	2.00E-05	8.20E-07	7.81E-07	6.80E-07	6.09E-07	1.32E-06	8.83E-07	8.71E-07	5.04E-07	1.04E-05	1.04E-05	3.75E-05	3.33E-05
Alewife	2.35E-05	2.06E-05	5.10E-06	5.10E-06	4.90E-06	4.90E-06	4.40E-06	4.40E-06	3.18E-06	1.53E-06	4.29E-05	2.46E-05	8.45E-05	6.13E-05
Lake Trout	8.53E-06	4.86E-07	3.06E-04	3.06E-04	1.72E-02	1.72E-02	8.76E-05	2.07E-05	2.98E-06	6.36E-07	9.76E-05	5.05E-05	1.77E-02	1.75E-02
American Eel	8.53E-06	4.86E-07	2.99E-04	2.99E-04	1.72E-02	1.72E-02	8.80E-05	2.10E-05	2.98E-06	6.36E-07	9.35E-05	4.86E-05	1.77E-02	1.75E-02
Benthic Invertebrates	2.36E-05	2.36E-05	2.59E-06	2.42E-06	2.61E-06	2.28E-06	4.66E-06	3.86E-06	1.39E-06	1.39E-06	2.28E-04	1.88E-04	2.64E-04	2.21E-04
Bufflehead	2.62E-05	2.62E-05	1.65E-06	1.62E-06	3.91E-06	3.86E-06	2.93E-06	2.80E-06	1.99E-06	9.95E-07	9.71E-07	8.47E-07	3.78E-05	3.64E-05
Mallard	2.62E-05	2.62E-05	1.54E-06	1.52E-06	3.64E-06	3.59E-06	2.72E-06	2.61E-06	1.99E-06	9.95E-07	9.30E-07	8.13E-07	3.72E-05	3.58E-05

Table 4-25: Estimated Radiation Doses for VECs for Polygon AB (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Northern Redbelly Dace	2.38E-05	2.16E-05	6.65E-06	6.65E-06	5.85E-06	5.85E-06	4.74E-06	4.74E-06	1.06E-05	1.00E-05	1.05E-03	8.97E-04	1.10E-03	9.47E-04
Turtles	1.94E-03	1.94E-03	1.08E-04	1.08E-04	8.07E-03	8.07E-03	1.12E-02	1.12E-02	8.09E-06	5.29E-06	7.68E-05	4.08E-05	2.14E-02	2.14E-02
Frogs	1.94E-03	1.94E-03	1.08E-04	1.08E-04	8.07E-03	8.07E-03	1.12E-02	1.12E-02	8.09E-06	5.29E-06	7.68E-05	4.08E-05	2.14E-02	2.14E-02
Aquatic Plants	2.64E-05	2.35E-05	2.10E-06	2.10E-06	2.70E-06	2.70E-06	3.30E-06	3.30E-06	5.94E-06	5.20E-06	5.40E-06	5.40E-06	4.71E-05	4.30E-05
Benthic Invertebrates	1.75E-03	1.75E-03	1.44E-04	1.44E-04	1.75E-04	1.75E-04	2.35E-04	2.35E-04	8.11E-06	5.30E-06	8.25E-05	4.47E-05	2.39E-03	2.35E-03
Bufflehead	1.76E-03	1.75E-03	1.17E-04	1.17E-04	2.71E-04	2.71E-04	2.29E-04	2.29E-04	3.61E-06	2.28E-06	5.13E-07	4.09E-07	2.38E-03	2.37E-03
Mallard	1.47E-03	1.47E-03	9.18E-05	9.18E-05	2.13E-04	2.13E-04	1.80E-04	1.80E-04	3.46E-06	2.24E-06	4.67E-07	3.85E-07	1.96E-03	1.96E-03
Muskrat	1.06E-04	9.46E-05	1.99E-06	1.99E-06	5.74E-06	5.74E-06	4.99E-06	4.99E-06	6.05E-06	4.29E-06	3.22E-06	2.74E-06	1.29E-04	1.15E-04
Earthworm	2.08E-05	1.99E-05	1.80E-06	1.80E-06	2.60E-06	2.60E-06	3.40E-06	3.40E-06	2.07E-06	2.07E-06	2.70E-05	2.43E-05	5.77E-05	5.41E-05
American Robin	2.09E-05	2.05E-05	2.93E-05	2.93E-05	2.59E-05	2.59E-05	5.51E-05	2.59E-05	3.28E-06	2.74E-06	3.36E-05	7.20E-06	1.68E-04	1.12E-04
Bank Swallow	2.31E-05	2.00E-05	1.58E-05	1.58E-05	1.60E-05	1.60E-05	3.02E-05	1.55E-05	3.26E-06	2.66E-06	1.68E-05	3.63E-06	1.05E-04	7.38E-05
Song Sparrow	3.19E-05	3.14E-05	4.85E-05	4.85E-05	4.56E-05	4.56E-05	9.12E-05	4.48E-05	6.64E-06	5.76E-06	5.37E-05	1.15E-05	2.78E-04	1.88E-04
Yellow Warbler	2.27E-05	2.00E-05	1.61E-05	1.61E-05	1.67E-05	1.67E-05	3.08E-05	1.61E-05	3.36E-06	2.76E-06	1.68E-05	3.63E-06	1.07E-04	7.54E-05
Terrestrial Plants (Grass)	3.20E-05	1.95E-05	1.80E-06	1.80E-06	2.50E-06	2.50E-06	3.40E-06	3.40E-06	6.84E-05	1.70E-05	4.42E-05	1.96E-05	1.52E-04	6.38E-05
Eastern Cottontail	6.42E-05	3.92E-05	5.52E-05	5.52E-05	2.73E-04	2.73E-04	3.54E-04	2.82E-04	3.30E-05	9.59E-06	8.14E-05	1.96E-05	8.63E-04	6.79E-04
Meadow Vole	6.42E-05	3.92E-05	5.49E-05	5.49E-05	3.68E-05	3.68E-05	1.01E-04	4.07E-05	3.30E-05	9.59E-06	7.78E-05	1.80E-05	3.70E-04	2.00E-04
White-tailed Deer	6.42E-05	3.92E-05	3.36E-05	3.36E-05	6.98E-05	6.98E-05	7.74E-05	4.76E-05	3.66E-05	1.02E-05	8.90E-05	3.19E-05	3.72E-04	2.33E-04
Common Shrew	3.80E-05	3.30E-05	5.49E-05	5.49E-05	4.05E-05	4.05E-05	1.05E-04	4.44E-05	6.81E-06	5.25E-06	7.96E-05	2.17E-05	3.25E-04	2.00E-04
Raccoon	3.63E-04	3.52E-04	5.49E-05	5.49E-05	3.97E-05	3.97E-05	1.04E-04	4.38E-05	1.19E-05	4.65E-06	7.99E-05	2.03E-05	6.54E-04	5.15E-04
Red Fox	4.44E-04	4.26E-04	5.05E-05	5.05E-05	6.78E-05	6.78E-05	2.31E-04	1.12E-04	1.82E-05	6.44E-06	6.74E-05	1.50E-05	8.80E-04	6.78E-04
Short-tailed Weasel	6.42E-05	3.92E-05	5.49E-05	5.49E-05	3.67E-05	3.67E-05	1.01E-04	4.06E-05	1.99E-05	7.00E-06	7.35E-05	1.61E-05	3.51E-04	1.95E-04

Table 4-26: Estimated Radiation Doses for VECs for Polygon C (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Earthworm	2.39E-05	2.39E-05	1.80E-06	1.80E-06	2.60E-06	2.60E-06	3.40E-06	3.40E-06	5.11E-06	5.11E-06	2.43E-05	2.43E-05	6.11E-05	6.11E-05
American Robin	2.31E-05	2.31E-05	2.90E-05	2.90E-05	2.51E-05	2.51E-05	5.88E-05	3.43E-05	6.45E-06	4.82E-06	3.36E-05	2.00E-05	1.76E-04	1.36E-04
Song Sparrow	3.60E-05	3.60E-05	4.79E-05	4.79E-05	4.42E-05	4.42E-05	9.71E-05	5.80E-05	1.31E-05	1.04E-05	5.37E-05	3.19E-05	2.93E-04	2.29E-04
Yellow Warbler	3.46E-05	3.46E-05	1.57E-05	1.57E-05	1.56E-05	1.56E-05	3.20E-05	1.97E-05	9.54E-06	7.90E-06	1.69E-05	1.01E-05	1.25E-04	1.04E-04
Terrestrial Plants (Grass)	3.92E-05	3.37E-05	1.80E-06	1.80E-06	2.50E-06	2.50E-06	3.40E-06	3.40E-06	3.68E-05	3.07E-05	3.64E-05	2.67E-05	1.20E-04	9.87E-05
Eastern Cottontail	7.89E-05	6.77E-05	5.51E-05	5.51E-05	2.19E-04	2.19E-04	3.12E-04	2.51E-04	2.53E-05	1.70E-05	7.92E-05	4.81E-05	7.72E-04	6.59E-04
Meadow Vole	1.58E-04	1.35E-04	5.49E-05	5.49E-05	3.62E-05	3.62E-05	1.09E-04	5.88E-05	3.77E-05	2.53E-05	7.63E-05	4.59E-05	4.74E-04	3.58E-04
White-tailed Deer	7.89E-05	6.77E-05	3.19E-05	3.19E-05	5.46E-05	5.46E-05	7.38E-05	4.86E-05	2.57E-05	1.82E-05	7.57E-05	5.06E-05	3.42E-04	2.73E-04
Common Shrew	5.95E-05	5.95E-05	5.49E-05	5.49E-05	4.01E-05	4.01E-05	1.13E-04	6.27E-05	2.01E-05	1.44E-05	8.17E-05	5.26E-05	3.71E-04	2.85E-04
Raccoon	7.04E-05	6.54E-05	5.49E-05	5.49E-05	4.03E-05	4.03E-05	1.14E-04	6.32E-05	2.18E-05	1.49E-05	8.13E-05	5.10E-05	3.84E-04	2.90E-04
Red Fox	1.04E-04	8.94E-05	5.03E-05	5.03E-05	5.61E-05	5.61E-05	2.38E-04	1.38E-04	2.46E-05	1.45E-05	6.62E-05	3.95E-05	5.41E-04	3.88E-04
Short-tailed Weasel	1.58E-04	1.35E-04	5.48E-05	5.48E-05	3.55E-05	3.55E-05	1.09E-04	5.82E-05	2.80E-05	1.63E-05	7.26E-05	4.32E-05	4.59E-04	3.44E-04

Table 4-27: Estimated Radiation Doses for VECs for Polygon D (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Turtles	1.94E-03	1.94E-03	1.08E-04	1.08E-04	8.07E-03	8.07E-03	1.12E-02	1.12E-02	1.64E-05	8.60E-06	9.58E-05	4.13E-05	2.14E-02	2.14E-02
Frogs	2.30E-05	2.30E-05	3.20E-06	3.20E-06	3.40E-06	3.40E-06	3.60E-06	3.44E-06	5.25E-06	5.25E-06	5.56E-05	5.56E-05	9.71E-05	9.55E-05
Aquatic Plants	3.91E-05	3.74E-05	2.10E-06	2.10E-06	2.70E-06	2.70E-06	3.30E-06	3.30E-06	8.02E-06	7.27E-06	8.10E-06	5.94E-06	6.57E-05	6.00E-05
Earthworm	2.42E-05	2.42E-05	1.80E-06	1.80E-06	2.60E-06	2.60E-06	3.40E-06	3.40E-06	2.63E-06	2.63E-06	3.24E-05	1.89E-05	6.70E-05	5.35E-05
American Robin	2.51E-05	2.48E-05	2.93E-05	2.93E-05	2.59E-05	2.59E-05	3.62E-05	2.72E-05	4.69E-06	3.32E-06	2.11E-05	1.68E-05	1.43E-04	1.28E-04
Song Sparrow	3.87E-05	3.78E-05	4.85E-05	4.85E-05	4.56E-05	4.56E-05	6.12E-05	4.69E-05	9.15E-06	6.87E-06	3.36E-05	2.69E-05	2.37E-04	2.13E-04
Yellow Warbler	2.44E-05	2.43E-05	1.61E-05	1.61E-05	1.67E-05	1.67E-05	2.13E-05	1.68E-05	5.90E-06	4.62E-06	1.05E-05	8.43E-06	9.52E-05	8.71E-05
Terrestrial Plants (Grass)	3.86E-05	3.31E-05	1.80E-06	1.80E-06	2.50E-06	2.50E-06	3.40E-06	3.40E-06	7.60E-06	5.94E-06	5.98E-05	4.94E-05	1.14E-04	9.62E-05
Terrestrial Plants (Sugar Maple)	3.86E-05	3.31E-05	1.80E-05	1.80E-05	1.40E-05	1.40E-05	7.80E-06	7.80E-06	7.60E-06	5.94E-06	1.36E-04	1.12E-04	2.30E-04	1.94E-04
Eastern Cottontail	7.76E-05	6.66E-05	5.52E-05	5.52E-05	2.73E-04	2.73E-04	3.08E-04	2.85E-04	1.08E-05	6.35E-06	5.79E-05	4.62E-05	7.83E-04	7.33E-04
Meadow Vole	7.76E-05	6.66E-05	5.49E-05	5.49E-05	3.68E-05	3.68E-05	6.20E-05	4.35E-05	1.08E-05	6.35E-06	5.30E-05	4.22E-05	2.96E-04	2.51E-04
White-tailed Deer	7.76E-05	6.66E-05	3.36E-05	3.36E-05	6.98E-05	6.98E-05	5.81E-05	4.90E-05	9.98E-06	6.05E-06	9.45E-05	7.49E-05	3.45E-04	3.00E-04
Common Shrew	4.02E-05	4.02E-05	5.49E-05	5.49E-05	4.05E-05	4.05E-05	6.58E-05	4.72E-05	1.28E-05	9.05E-06	5.04E-05	4.10E-05	2.65E-04	2.33E-04
Raccoon	5.32E-05	4.92E-05	5.50E-05	5.50E-05	4.18E-05	4.18E-05	6.73E-05	4.86E-05	1.22E-05	8.07E-06	5.61E-05	4.50E-05	2.87E-04	2.48E-04
Red Fox	7.76E-05	6.66E-05	5.03E-05	5.03E-05	6.44E-05	6.44E-05	1.51E-04	1.14E-04	1.24E-05	6.80E-06	4.40E-05	3.46E-05	4.01E-04	3.38E-04
Short-tailed Weasel	7.76E-05	6.66E-05	5.49E-05	5.49E-05	3.67E-05	3.67E-05	6.20E-05	4.34E-05	1.28E-05	6.91E-06	4.71E-05	3.73E-05	2.92E-04	2.46E-04

Table 4-28: Estimated Radiation Doses for VECs for Polygon E (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Earthworm	5.06E-05	2.59E-05	3.44E-05	3.44E-05	2.25E-05	2.25E-05	7.00E-05	5.48E-05	2.26E-04	9.17E-05	3.91E-05	2.79E-05	4.42E-04	2.57E-04
American Robin	3.70E-05	2.61E-05	2.81E-05	2.81E-05	2.31E-05	2.31E-05	5.82E-05	4.64E-05	3.09E-05	1.48E-05	2.94E-05	2.10E-05	2.07E-04	1.60E-04
Bank Swallow	5.56E-05	2.84E-05	1.35E-05	1.35E-05	1.05E-05	1.05E-05	3.05E-05	2.38E-05	6.39E-05	2.59E-05	1.47E-05	1.05E-05	1.89E-04	1.13E-04
Song Sparrow	4.44E-05	4.00E-05	4.78E-05	4.78E-05	4.41E-05	4.41E-05	9.66E-05	7.83E-05	2.30E-05	1.48E-05	4.70E-05	3.36E-05	3.04E-04	2.59E-04
Yellow Warbler	5.25E-05	2.80E-05	1.37E-05	1.37E-05	1.12E-05	1.12E-05	3.10E-05	2.44E-05	5.84E-05	2.40E-05	1.47E-05	1.05E-05	1.82E-04	1.12E-04
Terrestrial Plants (Grass)	4.56E-05	2.33E-05	1.24E-04	1.24E-04	8.37E-05	8.37E-05	2.63E-04	2.06E-04	2.32E-04	8.92E-05	1.50E-04	1.07E-04	8.99E-04	6.34E-04
Terrestrial Plants (Sugar maple)	4.56E-05	2.33E-05	3.78E-05	3.77E-05	2.50E-05	2.50E-05	7.49E-05	5.86E-05	2.32E-04	8.92E-05	4.60E-05	3.28E-05	4.84E-04	2.75E-04
Eastern Cottontail	9.17E-05	4.68E-05	5.49E-05	5.49E-05	9.34E-05	9.34E-05	1.47E-04	1.15E-04	1.04E-04	3.97E-05	6.36E-05	4.53E-05	5.59E-04	3.97E-04
Meadow Vole	9.17E-05	4.68E-05	5.49E-05	5.49E-05	3.53E-05	3.53E-05	1.08E-04	8.44E-05	1.04E-04	3.97E-05	6.35E-05	4.52E-05	4.62E-04	3.08E-04
White-tailed Deer	9.17E-05	4.68E-05	2.97E-05	2.97E-05	3.35E-05	3.35E-05	5.54E-05	4.33E-05	1.18E-04	4.51E-05	3.64E-05	2.49E-05	3.70E-04	2.26E-04
Common Shrew	9.17E-05	4.68E-05	5.48E-05	5.48E-05	3.57E-05	3.57E-05	1.12E-04	8.78E-05	9.74E-05	3.93E-05	6.47E-05	4.62E-05	4.57E-04	3.11E-04
Raccoon	8.40E-05	4.59E-05	5.49E-05	5.49E-05	3.80E-05	3.80E-05	1.12E-04	8.81E-05	8.23E-05	3.34E-05	6.56E-05	4.68E-05	4.39E-04	3.08E-04
Red Fox	9.17E-05	4.68E-05	5.03E-05	5.03E-05	4.09E-05	4.09E-05	2.16E-04	1.69E-04	6.47E-05	2.47E-05	5.82E-05	4.13E-05	5.24E-04	3.74E-04
Short-tailed Weasel	9.17E-05	4.68E-05	5.49E-05	5.49E-05	3.58E-05	3.58E-05	1.08E-04	8.46E-05	5.50E-05	2.10E-05	6.36E-05	4.53E-05	4.10E-04	2.89E-04

Table 4-29: Estimated Non-Radiological Doses for Riparian Birds at Lake Ontario (mg/kg·d)

COPC	Bufflehead		Mallard	
	Maximum	Mean	Maximum	Mean
Aluminum	1.74E+02	6.38E+01	5.77E+01	3.19E+01
Copper	5.02E-01	3.42E-01	2.88E-01	2.50E-01

Table 4-30: Estimated Non-Radiological Doses for Birds and Mammals at Polygon AB (mg/kg·d)

COPC	Bufflehead		Mallard		Muskrat		American Robin		Bank Swallow	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Aluminum	1.51E+03	4.40E+02	9.64E+02	2.48E+02	8.04E+02	2.39E+02	1.20E+03	9.36E+02	1.77E+02	1.13E+02
Barium	3.94E+00	2.65E+00	2.07E+00	1.19E+00	2.74E+00	1.78E+00	1.64E+01	8.61E+00	5.30E+00	3.72E+00
Cobalt	1.48E-01	6.48E-02	1.39E-01	4.12E-02	9.70E-01	2.59E-01	8.73E-01	7.08E-01	1.34E-01	7.87E-02
Copper	1.86E-01	1.49E-01	1.61E-01	1.13E-01	1.41E+00	9.57E-01	2.78E+00	2.06E+00	4.42E+00	3.11E+00
Lead	1.09E-01	7.76E-02	7.49E-02	3.30E-02	6.15E-01	2.12E-01	1.27E+00	8.80E-01	3.86E-01	1.88E-01
Manganese	1.33E+01	8.29E+00	1.36E+01	7.92E+00	9.34E+01	5.38E+01	4.40E+01	3.48E+01	7.19E+00	5.87E+00
Strontium	3.38E+01	2.41E+01	2.56E+01	1.80E+01	8.26E+01	5.80E+01	3.32E+01	2.27E+01	1.64E+01	9.54E+00
Vanadium	2.61E-01	1.94E-01	1.04E-01	6.32E-02	1.82E-01	1.28E-01	3.03E+00	2.33E+00	4.23E-01	3.06E-01

COPC	Song Sparrow		Yellow Warbler		Eastern Cottontail		Meadow Vole		White-tailed Deer	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Aluminum	4.00E+02	1.72E+02	2.09E+02	1.31E+02	1.79E+02	7.83E+01	1.05E+02	3.33E+01	4.79E+01	1.41E+01
Barium	2.85E+01	8.05E+00	7.30E+00	4.44E+00	1.21E+01	3.34E+00	1.03E+01	2.48E+00	4.92E+00	1.17E+00
Cobalt	2.80E-01	9.39E-02	1.56E-01	8.94E-02	1.21E-01	3.88E-02	7.80E-02	2.07E-02	3.60E-02	9.23E-03
Copper	4.06E+00	1.96E+00	5.08E+00	3.52E+00	1.33E+00	5.44E-01	1.16E+00	4.73E-01	5.59E-01	2.27E-01
Lead	8.20E-01	2.86E-01	4.60E-01	2.19E-01	3.66E-01	1.27E-01	2.09E-01	6.15E-02	9.48E-02	2.69E-02
Manganese	1.72E+01	1.02E+01	8.69E+00	6.90E+00	7.32E+00	4.25E+00	5.16E+00	2.80E+00	2.41E+00	1.30E+00
Strontium	3.00E+01	1.39E+01	1.89E+01	1.07E+01	1.16E+01	5.25E+00	1.01E+01	4.53E+00	4.86E+00	2.17E+00
Vanadium	1.05E+00	4.76E-01	5.13E-01	3.55E-01	4.67E-01	2.15E-01	2.87E-01	9.72E-02	1.32E-01	4.19E-02

COPC	Common Shrew		Raccoon		Red Fox		Short-tailed Weasel	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Aluminum	2.07E+02	1.35E+02	4.63E+02	1.60E+02	7.27E+02	2.16E+02	2.00E+02	1.02E+02
Barium	9.67E+00	7.16E+00	5.89E+00	2.46E+00	6.00E-01	1.97E-01	1.92E+00	1.20E+00
Cobalt	1.97E-01	1.42E-01	1.05E-01	4.30E-02	1.28E-02	8.62E-03	6.82E-02	3.00E-02
Copper	1.15E+01	8.16E+00	1.17E+00	6.90E-01	9.42E-02	3.87E-02	1.78E-01	7.64E-02
Lead	4.80E-01	2.65E-01	3.04E-01	1.26E-01	2.73E-02	1.04E-02	2.53E-01	1.09E-01
Manganese	1.21E+01	1.07E+01	6.39E+00	4.17E+00	4.56E-01	2.80E-01	3.19E+00	2.23E+00
Strontium	3.84E+01	2.22E+01	1.24E+01	7.38E+00	6.68E-01	3.17E-01	1.51E+00	7.79E-01
Vanadium	5.08E-01	3.85E-01	3.76E-01	2.27E-01	3.35E-02	1.82E-02	2.86E-01	1.99E-01

Table 4-31: Estimated Non-Radiological Dose for Birds and Mammals at Polygon C (mg/kg·d)

COPC	American Robin		Song Sparrow		Yellow Warbler	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Barium	6.59E+00	6.16E+00	7.12E+00	5.89E+00	4.68E+00	4.44E+00
Strontium	9.55E+00	9.23E+00	1.00E+01	9.01E+00	3.42E+00	3.27E+00
Tin	1.33E-01	8.46E-02	1.60E-01	1.01E-01	1.54E-01	1.08E-01

COPC	Eastern Cottontail		Meadow Vole		White-tailed Deer	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Barium	3.08E+00	2.54E+00	1.83E+00	1.39E+00	8.32E-01	6.24E-01
Strontium	4.21E+00	3.77E+00	3.47E+00	3.10E+00	1.66E+00	1.48E+00
Tin	7.02E-02	4.27E-02	2.82E-02	1.76E-02	1.18E-02	7.45E-03

COPC	Common Shrew		Raccoon		Red Fox		Short-tailed Weasel	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Barium	6.23E+00	6.06E+00	2.67E+00	2.42E+00	2.87E-01	2.55E-01	2.00E+00	1.88E+00
Strontium	5.16E+00	5.06E+00	2.19E+00	2.01E+00	2.69E-01	2.43E-01	8.61E-01	7.94E-01
Tin	2.02E-01	1.60E-01	8.28E-02	5.26E-02	1.22E-02	7.34E-03	7.33E-02	4.36E-02

Table 4-32: Estimated Non-Radiological Doses for Birds and Mammals at Polygon D (mg/kg·d)

COPC	American Robin		Song Sparrow		Yellow Warbler	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Aluminum	1.27E+03	1.05E+03	3.15E+02	2.00E+02	2.48E+02	1.59E+02
Barium	2.28E+01	1.54E+01	1.16E+01	8.23E+00	5.55E+00	4.38E+00
Boron	3.81E+00	2.79E+00	8.15E+00	7.39E+00	3.48E+00	2.71E+00
Cobalt	8.84E-01	8.32E-01	1.04E-01	9.46E-02	1.03E-01	9.74E-02
Manganese	3.30E+01	3.08E+01	1.18E+01	9.66E+00	7.19E+00	6.62E+00
Nitrate	1.95E+00	1.17E-01	2.86E+00	1.71E-01	4.50E+00	2.70E-01
Strontium	1.89E+01	1.21E+01	1.69E+01	1.19E+01	9.30E+00	8.41E+00
Tin	4.19E-01	2.42E-01	1.18E+00	6.34E-01	1.83E-01	1.31E-01
Zirconium	4.57E+00	2.75E+00	7.63E-01	5.79E-01	6.21E-01	4.77E-01
COPC	**Eastern Cottontail**		**Meadow Vole**		**White-tailed Deer**	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Aluminum	1.45E+02	9.18E+01	5.77E+01	3.70E+01	2.40E+01	1.55E+01
Barium	5.05E+00	3.56E+00	3.44E+00	2.36E+00	1.60E+00	1.09E+00
Boron	3.37E+00	3.00E+00	3.19E+00	2.75E+00	1.51E+00	1.32E+00
Cobalt	4.36E-02	3.95E-02	2.13E-02	1.85E-02	9.29E-03	8.04E-03
Manganese	5.03E+00	4.09E+00	3.37E+00	2.58E+00	1.55E+00	1.19E+00
Nitrate	1.48E+00	8.88E-02	2.21E+00	1.32E-01	9.27E-01	5.56E-02
Strontium	6.81E+00	4.61E+00	5.60E+00	3.76E+00	2.67E+00	1.79E+00
Tin	5.08E-01	2.71E-01	4.45E-01	2.32E-01	2.14E-01	1.12E-01
Zirconium	3.51E-01	2.65E-01	1.37E-01	1.03E-01	5.69E-02	4.25E-02
COPC	**Common Shrew**		**Raccoon**		**Red Fox**	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Aluminum	2.45E+02	1.63E+02	1.73E+02	1.09E+02	1.27E+02	8.02E+01
Barium	6.55E+00	5.62E+00	3.59E+00	2.67E+00	4.39E-01	3.03E-01
Boron	5.56E+00	5.10E+00	1.65E+00	1.37E+00	3.79E-01	1.79E-01
Cobalt	1.54E-01	1.50E-01	4.91E-02	4.59E-02	5.28E-03	4.58E-03
Manganese	1.00E+01	9.61E+00	3.96E+00	3.50E+00	4.90E-01	3.95E-01
Nitrate	2.56E+00	1.54E-01	1.24E+00	7.42E-02	1.29E+00	7.73E-02
Strontium	1.71E+01	1.65E+01	4.27E+00	3.32E+00	4.64E-01	3.20E-01
Tin	1.72E-01	1.51E-01	2.04E-01	1.20E-01	5.43E-02	2.96E-02
Zirconium	6.30E-01	5.00E-01	3.88E-01	2.95E-01	4.51E-02	3.32E-02

Notes:
The exposure dose for nitrate is only for the surface water pathway. Nitrate is not expected to biomagnify along the foodchain.

Table 4-33: Estimated Non-Radiological Doses for Birds and Mammals at Polygon E (mg/kg·d)

COPC	American Robin		Bank Swallow		Song Sparrow		Yellow Warbler	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Barium	6.92E+00	6.42E+00	1.27E+01	1.12E+01	8.18E+00	7.57E+00	1.36E+01	1.26E+01
Strontium	8.58E+00	8.10E+00	7.27E+00	6.86E+00	2.57E+01	2.42E+01	9.20E+00	8.68E+00
COPC	**Eastern Cottontail**		**Meadow Vole**		**White-tailed Deer**			
	Maximum	Mean	Maximum	Mean	Maximum	Mean		
Barium	2.77E+00	2.55E+00	1.52E+00	1.35E+00	6.79E-01	6.04E-01		
Strontium	1.05E+01	9.90E+00	9.33E+00	8.81E+00	4.49E+00	4.24E+00		
COPC	**Common Shrew**		**Raccoon**		**Red Fox**		**Short-tailed Weasel**	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Barium	2.72E+01	2.55E+01	4.28E+00	3.97E+00	3.31E-01	2.65E-01	2.16E+00	1.97E+00
Strontium	1.69E+01	1.60E+01	4.95E+00	4.68E+00	5.87E-01	5.54E-01	8.71E-01	8.22E-01

4.2.6.2.1 Darlington Waste Management Facility

The dose rate for ecological receptors in close proximity to the DWMF (approximately 5 m from any wall) could be up to 1 µGy/h (0.024 mGy/d), assuming full capacity of the DWMF.

The dose rate to any ecological VEC at the DWMF property boundary could be up to 0.5 µGy/h (0.012 mGy/d), assuming full capacity of the DWMF. Based on measured dose rates at the DWMF property boundary from 2011 to 2014 the average dose rate was 0.08 µGy/h (0.002 mGy/d).

The above assessment is conservative as it assumes the receptor is always located at the DWMF and does not incorporate an occupancy factor based on the fraction of time a receptor is likely to be in close proximity to the DWMF. Based on expected radiological dose rates to ecological receptors in Polygon E (**Error! Reference source not found.**) located on the DN site, the dose from the DWMF at full capacity, would be the largest contributor to total dose.

4.2.7 Uncertainties in Exposure Assessment

Uncertainties in the exposure assessment include the representativeness of media concentrations used in the assessment at each location. Mean concentrations of COPCs were used for each location and media, where possible, and are considered to be representative for all mobile receptors. Maximum concentrations found in various sources were also used as an upper bound on exposure. These values are, by definition, not representative for mobile organisms that can move around the site, effectively averaging their exposure concentrations. Maximum values are representative for exposures of any sessile organisms that reside at the location of the maximum value.

Although the majority of data comes from measured values, BAFs were used to calculate uptake into tissues. In some cases, BAFs for a species of interest were unavailable, and surrogate values were used, e.g., fish values used for frog. The BAFs used for the exposure assessment were not site-specific, and were taken from reputable sources and are considered to be representative of the conditions found at the site.

Wildlife exposure factors, such as intake rates and diets, are a potential source of uncertainty. Reputable sources are used for these factors and are considered to be representative of the organisms assessed.

Dose coefficients were obtained from reputable sources for reference organisms, but have not been derived specifically for all the organisms assessed. Dose coefficients for surrogate organisms were often used. They were selected with attention to similar body size and exposure habits, and are believed to adequately represent the organism assessed. Dose coefficients for each receptor were not adjusted for body size and dimensions.

Radiation doses were calculated from measured concentrations of radionuclides such as cobalt-60, cesium-134, and cesium-137 in water. The majority of samples resulted in concentrations below the detection limit. Doses were calculated assuming these concentrations were at the detection limit. This is likely a conservative assumption and doses resulting from these radionuclides are likely lower than presented.

Uncertainty in the HTO air and soil pore water predictions arises from inherent uncertainty in the air model in IMPACT. The model reports an average concentration, and typically over-predicts this concentration by a factor of 1.5 (Hart, 2008). Uncertainty in the predictions arises from the following assumptions made in the air model:

- 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.
- 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.

The main uncertainties associated with the exposure assessment are summarized in **Error! Reference source not found.**.

Table 4-34: Summary of Major Uncertainties in the Ecological Exposure Assessment

Risk Assessment Assumption	Justification	Over/Under Estimate Risk?
HTO concentrations in pore water were estimated based on modelling from atmospheric emissions data in IMPACT	Measured data were not always available. The model is conservative.	Overestimate
BAFs, intake rates, etc. are from literature when measured information as not available	Reputable literature sources were used	Neither (value is best estimate)
BAF (fish) for hydrazine is based on QSAR model and not measured bioaccumulation data.	Limited information exists on bioaccumulation of hydrazine, although it is expected to be low. Only one study (Slonim and Gisclard, 1976) exists on hydrazine bioaccumulation, and there is large uncertainty surrounding the methods and results.	Neither (value is best estimate)
BAF (fish) for morpholine is based on QSAR model and not measured bioaccumulation data.	No information in literature regarding morpholine BAF, although it is not expected to bioaccumulate.	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)

4.3 Effects Assessment

The potential for ecological effects from COPC exposure at each location (Section 4.2) was assessed by comparing the exposure levels to toxicological, radiation, and thermal benchmarks. These benchmarks values (BVs) are taken from literature and are compared to the exposure values (EVs) to determine the potential for adverse ecological effects. The assessment and measurement endpoints used for the effects assessment for the listed VECs are described in Section 4.1.3**Error! Reference source not found.**.

4.3.1 Toxicological Benchmarks

For hydrazine, the aquatic toxicity benchmark values were taken from the Federal Environmental Quality Guidelines (EC, 2013a). Morpholine aquatic toxicity benchmark values were taken from WHO (1996). Benchmarks listed by EC for hydrazine (for fish and benthic invertebrates) and those listed by WHO for morpholine are acute. To evaluate long-term risk to VECS, these acute benchmarks were converted to chronic benchmarks by dividing by a factor of 10 (CCME, 1999a; Suter *et al.*, 1993).

All aquatic benchmarks for fish, aquatic plants and benthic invertebrates are summarized in **Error! Reference source not found.**. The benchmarks were obtained from Suter and Tsao (1996), CCME (1999, 2003, 2009, 2012), Fargasova et al., (1999), Borgmann et al. (2005), BC MOE (2008), MOE (2011), EC (2013a), WHO (1996, 2001), and the U.S. EPA ECOTOX AQUIRE database. In cases where a chronic benchmark was not found and an acute benchmark was available, the acute benchmark was converted to a chronic benchmark by dividing by a factor of 10.

Consistent with CSA (2012) and FCSAP (2012) guidance, assessment of benthic invertebrates, toxicity benchmarks have been presented as water concentrations. Considering that benthic invertebrates also reside in sediment, sediment toxicity benchmarks are presented for COPCs with MOECC Lowest Effect Levels (LELs) for assessment of benthic invertebrates (MOEE, 1993; MOE, 2011). In the absence of these objectives and guidelines, sediment screening benchmarks were obtained from Jones et al. (1997) for aluminum and Thompson et al. (2005) for vanadium. These benchmarks are summarized in **Error! Reference source not found.**.

Chromium, iron and nickel were identified as COPCs in the sediment, but not the surface water for Treefrog Pond located at Polygon D. Because the benthic invertebrates are not considered VECs for this Polygon, exposure and risks from these COPCs via the sediment was not considered for Treefrog Pond.

Table 4-35: Toxicological Benchmarks for Aquatic Receptors

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
Aluminum	Fish and Frog	3.29E+00	LCV	*Pimephales promelas* (28-day embryo-larval tests)	Kimball, n.d. (cited in Suter and Tsao, 1996)
	Aquatic Plants	4.60E-01	LCV	*Selenastrum capricornutum*	EPA, 1988 (cited in Suter and Tsao, 1996)
	Benthic Invertebrate	1.90E+00	LCV	*Daphnia magna*	McCauley *et al*., 1986 (cited in Suter and Tsao, 1996
Ammonia (un-ionized, as NH_3)	Fish and Frog	1.70E-03	LCV	Pink Salmon (*Oncorhynchus gorbuscha*)	Rice and Bailey, 1980 (cited in Suter and Tsao, 1996)

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
	Aquatic Plants	2.40E+00	LCV	*Chlorella vulgaris*	EPA, 1985 (cited in Suter and Tsao, 1996)
	Benthic Invertebrate	6.3E-01	LCV	Daphnia magna	EPA, 1985 (cited in Suter and Tsao, 1996)
Barium	Fish and Frog	5.00E+01	acute LC_{50} converted to a chronic value	Sheepshead minnow (*Cyprinodon variegatus*)	Heitmuller *et al*., 1981 (cited in WHO, 2001)
	Aquatic Plants	2.30E+00	91.3 day LOEL (growth)	*Chlorella vulgaris*	(De Jong 1985 (cited in MOE, 2011)
	Benthic Invertebrate	3.15E-01	1 week (acute) LC_{50}/10 to convert to chronic	*Hyalella azteca*	Borgmann *et al*., 2005
Boron	Fish and Frog	1.50E+00	'-	-	Water quality guideline, because lowest chronic effect value was lower than the water quality guideline.
	Aquatic Plants	3.50E+00	LOEC	duckweed *(Spirodella polyrrhiza)*	Davis *et al*., 2002 (cited in CCME, 2009)
	Benthic Invertebrate	8.83E+00	LCV	*Daphnia magna*	Lewis and Valentine, 1981 (cited in Suter and Tsao, 1996)
Calcium	Fish and Frog	nd	-	-	-
	Aquatic Plants	nd	-	-	-
	Benthic Invertebrate	1.16E+02	LCV	*Daphnia magna*	Biesinger and Christensen (cited in Suter and Tsao, 1996)
Cobalt	Fish and Frog	2.90E-01	LCV	Embryo-larval tests with *Pimephales promelas*	Kimball, n.d. (cited in Suter and Tsao, 1996)
	Aquatic Plants	9.70E-02	7-day EC_{20} (wet weight)	Lemna minor	(Naumann et al., 2007) from ECOTOX AQUIRE Database
	Benthic Invertebrate	5.10E-03	LCV	*Daphnia magna*	Kimball, n.d. (cited in Suter and Tsao, 1996)
Copper	Fish and Frog	3.80E-03	LCV	*Salvelinus fontinalis* (Early life stage)	Sauter *et al.*, 1976 (cited in Suter and Tsao, 1996)
	Aquatic Plants	NA	NA	NA	NA
	Benthic Invertebrate	6.07E-03	LCV	*Gammarus pseudolimnaeus*	Arthur and Leonard, 1970, (cited in Suter and Tsao, 1996)
Iron	Fish and Frog	1.30E+00	LCV	Rainbow trout (*Oncorhynchus mykiss*)	Amelung, 1981 (cited in Suter and Tsao, 1996)
	Aquatic Plants	1.49E+00	EC_{50} converted to EC_{20}	*Lemna minor*	Wang, 1986 (cited in BC MOE, 2008)
	Benthic Invertebrate	3.00E-01	-	-	Water quality guideline, because lowest chronic effect value was lower than the water quality guideline.
Magnesium	Fish and Frog	1.36E+03	28-day LC_{50}	Rainbow trout (*Oncorhynchus mykiss*)	(Birge *et al*., 1980) ECOTOX AQUIRE Database

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
	Aquatic Plants	6.80E+01	4-day IC50 (population)	Lesser duckweed (*Lemna aequinoctialis*)	(Van Dam *et al*., 2010) from the ECOTOX AQUIRE Database.
	Benthic Invertebrate	8.20E+01	LCV	*Daphnia magna*	Biesinger and Christensen (cited in Suter and Tsao, 1996)
Manganese	Fish and Frog	1.78E+00	LCV	Fathead minnows (*Pimephales promelas*)	Kimball, n.d. (cited in Suter and Tsao, 1996)
	Aquatic Plants	4.98E+00	acute value converted to chronic	12-day population effects on the green algae (*Scenedesmus quadricauda*)	Fargasova *et al*., 1999
	Benthic Invertebrate	1.10E+00	LCV	*Daphnia magna*	Kimball, n.d. (cited in Suter and Tsao, 1996)
Nitrate	Fish and Frog	2.80E+01	LOEC (149 day hatching or developmental delay of swim-up fry)	*Salvelinus namaycush*	McGurk et al., 2006 (cited in CCME, 2003, update 2012).
	Aquatic Plants	nd	-	-	-
	Benthic Invertebrate	5.70E+01	IC_{25} (14 day, growth)	*Hyalella azteca*	Elphick, 2011 (cited in CCME, 2003, update 2012).
Potassium	Fish and Frog	5.00E+02	7-day LOEC (growth)	Fathead minnow (*Pimephales promelas*)	(Pickering *et al*., 1996) ECOTOX AQUIRE Databas
	Aquatic Plants	6.70E+02	LOEC (population growth)	Green algae (*Chlorella vulgaris*)	(De Jong, 1965) from the ECOTOX AQUIRE Database
	Benthic Invertebrate	5.30E+01	LCV	*Daphnia magna*	Biesinger and Christensen (cited in Suter and Tsao, 1996)
Zirconium	Fish and Frog	5.48E-01	LCV	Fathead minnow (*Pimephales promelas*)	Cushman *et al*., 1977 (estimated) (cited in Suter and Tsao, 1996).
	Aquatic Plants	2.60E+00	96h EC50 (growth)	Green algae (*Pseudokirchneriella subcapitata*)	(Couture *et al*., 1989) from the ECOTOX AQUIRE Database
	Benthic Invertebrate	3.15E-01	1 week-(acute) LC_{50}/10 to convert to chronic	*Hyalella azteca*	Borgmann *et al*., 2005
Chlorine (TRC)	Fish and Frog	5.90E-03	LC_{50} (96 hour) converted to EC_{20}	*Oncorhynchus* mykiss	Fisher *et al.*,1999 (cited in CCME, 1999)
	Aquatic Plants	NA	NA	NA	NA
	Benthic Invertebrate	3.20E-03	LC_{50} (48 hour) converted to EC_{20}	*Daphnia magna*	Fisher *et al.*,1999 (cited in CCME, 1999)
Hydrazine	Fish and Frog	6.1E-02	LC_{50} (96 hour) converted to chronic	*Lebistes rericulatus*	Slonim, 1977 (cited in EC, 2013a)

COPC	Receptor	Water TRV (mg/L)	Endpoint	Test Species	Reference
	Aquatic Plants	NA	NA	NA	NA
	Benthic Invertebrate	4.00E-03	LC_{50} (48 hour) converted to chronic	*Hyalella azteca*	Fisher *et al.*,1980, (cited in EC, 2013a)
Morpholine	Fish and Frog	1.80E+01	LC_{50} (96 hour) converted to chronic	*Oncorhynchus mykiss* (low hardness)	WHO,1996
	Aquatic Plants	NA	NA	NA	NA
	Benthic Invertebrate	1.00E+01	EC_{50} (24 hour) converted to chronic	*Daphnia magna*	WHO,1996

Notes:
nd-no data
-indicates not applicable
NA-indicates that the COPC was not identified in a Polygon where aquatic plants were present.

Table 4-36: Toxicological Benchmarks for Benthic Invertebrates

COPC	Benthic Invertebrate (mg/kg dw)	Reference
Aluminum	5.80E+04	Probable Effects Concentration (Jones *et. al,* 1997)
Copper	1.60E+01	Sediment LEL (MOE, 2011)
Manganese	4.60E+02	Sediment LEL (MOEE, 1993)
Nitrate	NA	Not expected to partition into sediment (EC, 2003).
Phosphorus	6.00E+02	Sediment LEL (MOEE, 1993)
Vanadium	3.52E+01	Sediment LEL (Thompson et al., 2005)
Chlorine (TRC)	NA	Not expected to partition into sediment (ATSDR, 2010).
Hydrazine	NA	Not expected to partition into sediment (EC/HC, 2011).
Morpholine	NA	Not expected to partition into sediment (Lewis et al. 1995 as cited in Poupin *et al.*, 1998).

Note:
NA- Not Applicable

Terrestrial plant and soil invertebrate benchmarks are based on soil concentrations. The values are Canadian soil quality guidelines (industrial soil contact values) (CCME, 1999), provincial soil quality guidelines (industrial plant and soil organism values) (MOE, 2011) or Lowest Observable Effect Concentration (LOEC) soil concentrations from Effroymson et al. (1997a,b). The Effroymson values are specific to either earthworms (1997a) or plants (1997b) and are conservative values.

Because boron, as hot water soluble (HWS) boron, affects mostly plants, a soil invertebrate benchmark for boron HWS is not applicable. The available benchmark for boron (HWS) was obtained from the provincial soil quality guidelines (industrial plant and soil organism values) (MOE, 2011).

There are no guidelines available for strontium, and no values are provided by Effroymson (1997a,b). A WHO (2010) report on strontium cites an effect level for invertebrates of 10,600 mg/kg. This effect level is used as a benchmark for soil invertebrates. A benchmark for strontium for terrestrial plants was estimated from the study of Hara et al. (1977) that found symptoms of injury to cabbage plants exposed to strontium in culture water at a water concentration of 25 mg/L (LOEC). In order to estimate a LOEC for strontium soil concentrations, the strontium LOEC of 25 mg/L was multiplied by the K_d of 69 L/kg dw for loam soils reported in CSA (2014). This estimated LOEC soil concentration of 1725 mg/kg dw was used as the benchmark for terrestrial plants.

There are no guidelines available for tin, and no values reported in Effroymson (1997b) for soil invertebrates. As such, a soil invertebrate benchmark for tin is not selected. However, Effroymson (1997b) reports a LOEC of 50 mg/kg for plants. This LOEC is used as a benchmark for terrestrial plants.

The terrestrial plant and soil invertebrate benchmarks are summarized in **Error! Reference source not found.**.

Table 4-37: Toxicological Benchmarks for Soil for Terrestrial Invertebrates and Plants

COPC	Soil Invertebrate (mg/kg)	Reference	Terrestrial Plant (mg/kg)	Reference
Boron (hot water soluble)	NA	-	1.50E+00	MOE, 2011
Strontium	1.06E+04	WHO, 2010	1.73E+03	Hara *et al*., 1977-
Tin	nd	-	5.00E+01	Kabata-Pendias and Pendias, 1984 (cited in Efroymson *et al*., 1997)

Notes

NA-Not Applicable as boron does not affect soil invertebrates.

nd- no data

The mammal and bird benchmarks used are summarized in **Error! Reference source not found.** and **Error! Reference source not found.**, respectively.

The benchmark values for birds and mammals (riparian and terrestrial) are based on doses. The benchmark doses used are the LOAEL values from Sample *et al.* (1996) for mammals and birds, the U.S. EPA (2005) for barium and cobalt for mammals, and the U.S. EPA (2005) for cobalt for birds. There were no data available for the toxicity of strontium, nitrate, TRC, hydrazine and morpholine for birds. Hydrazine and morpholine are concerns in the aquatic environment, but due to their rapid degradation in the aquatic system and low octanol-water partition coefficient, the bioaccumulation of hydrazine and morpholine in the food chain is unlikely (EC/HC, 2011). TRC is unlikely to bioaccumulate in the food chain because it does not bioaccumulate in plants or animals (ATSDR, 2010).

Major ions (Ca, Mg, K) were considered to be essentially non-toxic for birds and mammals. They are effectively regulated in the body and have not been associated with adverse effects in birds and mammals at environmental concentrations. There is no evidence of adverse health effects from these major ions in drinking water (HC, 2012).

Phosphorus was considered to be essentially non-toxic and not directly bioavailable for mammals and birds. Phosphorus is an essential nutrient for normal muscle growth in animals and egg formation in birds and is important for the transfer and utilization of energy (Li et al., 2016). Exposure to bioavailable forms of phosphorus for birds and mammals is through the food chain. Phosphorus is actively regulated in birds and mammals with excess phosphorus being excreted in urine and feces.

Adverse health effects for birds and mammals are not expected from elevated levels of iron in surface water. Iron is generally present in surface water as salts in its trivalent form (Fe_3^+) when the pH is above 7 (HC, 1978). Most of the iron salts are insoluble and settle to or become bound to the sediments. Therefore, most iron in surface water is associated with particulate matter and is not bioavailable. Absorption of iron in the body (mammals and birds) is regulated, and very little is metabolised. Iron ingested from drinking water is efficiently expelled from the body in faeces (HC, 1978).

Additionally, adverse health effects for birds and mammals are not expected from ammonia in surface water. When ammonia is dissolved in water, it exists in two forms simultaneously: the non-ionized form (NH_3) and the ammonium cation (NH_4^+). The equilibrium between the two species is governed in large part by pH and temperature. The sum of the two forms is known as total ammonia (HC, 2013). Ammonia is produced in the body and efficiently metabolized in healthy individuals (HC, 2013). The odour threshold for ammonia in water is 1.5 mg/L (HC, 2013). Concentrations above 1.5 mg/L may provoke avoidance behaviours for mammals and birds and thereby limit ingestion of surface water with elevated levels of ammonia, because of undesirable odour and taste in the water.

Overall, TRVs for birds and mammals for the major ions, phosphorus, iron, and ammonia (un-ionized) are not warranted.

Because mammals were not identified as VECs for the Lake Ontario Polygon, mammal benchmarks for, nitrate, chlorine as TRC, hydrazine, and morpholine are not listed in **Error! Reference source not found.**.

Table 4-38: Selected Toxicity Reference Values for Mammals (Riparian and Terrestrial)

COPC	Mammal LOAEL (mg/kg-d)	Test Species	Endpoint	Test Duration	Reference
Aluminum	1.93E+01	mouse	reproduction	3 generations	Ondreicka *et al.,* 1966 (cited in Sample *et al*., 1996)
Barium	1.21E+02	rat	growth, mortality	92 days	Dietz *et al*., 1992 (cited in U.S. EPA, 2005a)
Boron	9.36E+01	rat	reproduction	3 generations	Weir and Fisher, 1972 (cited in Sample *et al*., 1996)
Cobalt	8.76E+00	mouse	growth	16 week	Haga *et al*., 1996 (cited in the U.S. EPA 2005b)
Copper	1.51E+01	mink	growth	357 days	Aulerich *et al*., 1982 (cited in Sample *et al*., 1996)
Lead	8.00E+01	rat	reproduction	3 generations	Azar *et al*., 1973 (cited in Sample *et al.*, 1996)
Manganese	2.84E+02	rat	reproduction	224 days	Laskey *et al*., 1982 (cited in Sample *et al*., 1996)
Nitrate	1.13E+03	guinea pig-	guinea pig	143-204 days	Sleight and Atallah, 1968 (cited in Sample *et al*., 1996)
Strontium	2.63E+02	rat	body weight and bone changes	3 years	Skoryna, 1981 (cited in Sample *et al*., 1996)
Tin	3.50E+01	mouse	reproduction	days 6-15 of gestation	Davis et al., 1987 (cited in Sample *et al*., 1996)
Vanadium	2.10E+00	rat	reproduction	60 days prior to gestation, during gestation, delivery and lactation	Domingo *et al*., 1986 (cited in Sample *et al*., 1996)
Zirconium	1.74E+00	mouse	Lifespan, longeviity	> 1 year	Schroeder *et al*., 1968 (cited in Sample *et al*., 1996)

Note:
nd = no data available
The strontium and zirconium TRVs areNOAELs because LOAELs are not available

Table 4-39: Selected Toxicity Reference Values for Birds

COPC	Bird LOAEL (mg/kg bw-d)	Test Species	Endpoint	Test Duration	Reference
Aluminum	1.10E+02	Ringed Dove	reproduction	4 months	Carriere *et al*., 1986 (cited in Sample *et al.*, 1996)
Barium	4.17E+01	1-day old chicks	mortality	4 weeks	Johnson *et al*. 1960 (cited in Sample *et al*., 1996)
Boron	1.00E+02	Mallard	reproduction	9 weeks	Smith and Anders, 1989 (cited in Sample *et al*., 1996)
Cobalt	7.80E+00	Chicken	growth	5 week	Hill, 1979 as cited in the U.S. EPA, 2005

COPC	Bird LOAEL (mg/kg bw-d)	Test Species	Endpoint	Test Duration	Reference
Copper	6.17E+01	1 day old chicks	growth, mortality	10 weeks	Mehring *et al.*, 1960 (cited in Sample *et al.*, 1996)
Lead	1.13E+01	Japanese Quail	reproduction	12 weeks	Edens *et al.,* 1976 (cited in Sample *et al.*, 1996)
Manganese	9.77E+02	Japanese Quail	growth, aggressive behaviour	75 days	Laskey and Edens, 1985 (cited in Sample *et al*., 1996).
Nitrate	nd	-	-	-	-
Strontium	nd	-	-	-	-
Tin	1.69E+01	Japanese Quail	reproduction	6 weeks	Schlatterer *et al*., 1993 (cited in Sample *et al*., 1996)
Vanadium	1.14E+01	Mallard	mortality, body weight, blood chemistry	12 weeks	White and Dieter, 1978 (cited in Sample *et al*., 1996)
Zirconium	nd	-	-	-	-
Chlorine (TRC)	nd	-	-	-	-
Hydrazine	nd	-	-	-	-
Morpholine	nd	-	-	-	-

Note:
nd = no data available
The aluminum, manganese, and vanadium TRVs are NOAELs because LOAELs are not available.
The barium and cobalt TRVs are sub-chronicvalues divided by 10 to convert to chronic.

4.3.2 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 DN 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 NCRP (1991) and was recommended by the 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) (1996, 2008) have supported this recommendation.

The aquatic biota considered by UNSCEAR are organisms such as fish and benthic invertebrates that reside in water. Birds and mammals with riparian habits 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 (1992) and UNSCEAR (1996). More recently, 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 (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 significant 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 invertebrates, and 3 mGy/d for mammals and terrestrial plants (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 International Commission on Radiological Protection (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) (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively. These benchmarks were recommended in CSA N288.6 (2012), and are appropriate for this assessment.

4.3.3 Thermal Benchmarks

Golder (2012) cited an optimal temperature range of 1ºC to 5ºC for round whitefish embryos (Wismer and Christie, 1987) and a continuous ΔT of 3.5ºC or a periodic (6h/day) ΔT of 5ºC (Griffiths, 1980) as being consistent with adequate embryonic survival over the winter embryo development period. More recent studies of round whitefish embryo survival (Patrick et al., 2014) found that a reduction to 90% survival required a ΔT of 3.7ºC as an average over the embryonic period. These benchmarks were used in assessment of potential for thermal effects on round whitefish embryos in the vicinity of the DN thermal discharge.

Senes (2011a) and Golder (2010) considered maximum weekly average temperatures (MWATs) in the vicinity of the DN thermal discharge, and compared these to MWAT criteria for other fish species known to occur in the area, including emerald shiner, alewife, white sucker and lake trout. The MWAT criteria are species-specific values below which thermal conditions are considered suitable, either for growth of juveniles and adults, or for embryonic development (U.S. EPA, 1977). The relevant MWAT criteria are shown in **Error! Reference source not found.**.

Table 4-40: Maximum Weekly Average Temperature Criteria (US EPA, 1977)

Fish Species	MWAT Criteria for Growth (ºC)	MWAT Criteria for Embryos (ºC)	Embryonic Period
Emerald shiner	30	24	June-August
Alewife	N/A[1]	22	April-July
White sucker	28	N/A[2]	N/A
Lake trout	N/A[1]	9	Dec-April

[1] Alewife and Lake trout move offshore soon after hatching; conditions near DN not relevant to their growth.
[2] White suckers spawn in tributaries; conditions near DN discharge not relevant to their embryonic period.

4.3.4 Uncertainties in the Effects Assessment

Toxicological benchmarks used in the risk assessment were selected from sources recommended in the CSA N288.6 (2012) standard, and other reputable sources. These BVs represent the low end of threshold effect levels in literature for each receptor category. BVs for the test species were not adjusted for body weight and were considered directly applicable to the wildlife species. The BVs are considered to be conservatively representative of the effect threshold for the COPC 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.

Also, toxicological benchmarks are not available for certain COPCs (e.g., strontium for terrestrial birds and terrestrial plants or tin for soil organisms), therefore no quantitative assessment could be carried out. Without the benchmark value, it is difficult to determine potential quantitative effects for these biota; however, in these cases a qualitative assessment was carried out.

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 (2008) and CSA N288.6-12 (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 vary among literature sources and have varied somewhat among studies of thermal effects at Darlington. .

4.4 Risk Characterization

4.4.1 Risk Estimation

Ecological risk is estimated by dividing the EV (Section 4.2.6) by the BV (Section 4.3) for a given COPC and receptor species, yielding a HQ. When the EV for an organism at a site exceeds the BV (HQ > 1), a potential for adverse ecological effects is inferred. A summary of the radiation doses to each receptor by COPC and polygon is presented in **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**, with bolded/shaded values indicating benchmark exceedances. A summary of non-radiological HQs for each receptor by COPC and polygon is presented in **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, and

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Table 4-41: Summary of Radiation Dose Estimates for Biota for Lake Ontario (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Round Whitefish	2.31E-05	2.08E-05	8.20E-07	7.81E-07	6.80E-07	6.09E-07	1.76E-06	1.22E-06	5.18E-07	4.48E-07	2.69E-05	2.36E-05	5.43E-05	4.76E-05
White Sucker	2.29E-05	2.00E-05	8.20E-07	7.81E-07	6.80E-07	6.09E-07	1.32E-06	8.83E-07	8.71E-07	5.04E-07	1.04E-05	1.04E-05	3.75E-05	3.33E-05
Alewife	2.35E-05	2.06E-05	5.10E-06	5.10E-06	4.90E-06	4.90E-06	4.40E-06	4.40E-06	3.18E-06	1.53E-06	4.29E-05	2.46E-05	8.45E-05	6.13E-05
Lake Trout	8.53E-06	4.86E-07	3.06E-04	3.06E-04	1.72E-02	1.72E-02	8.76E-05	2.07E-05	2.98E-06	6.36E-07	9.76E-05	5.05E-05	1.77E-02	1.75E-02
American Eel	8.53E-06	4.86E-07	2.99E-04	2.99E-04	1.72E-02	1.72E-02	8.80E-05	2.10E-05	2.98E-06	6.36E-07	9.35E-05	4.86E-05	1.77E-02	1.75E-02
Benthic Invertebrates	2.36E-05	2.36E-05	2.59E-06	2.42E-06	2.61E-06	2.28E-06	4.66E-06	3.86E-06	1.39E-06	1.39E-06	2.28E-04	1.88E-04	2.64E-04	2.21E-04
Bufflehead	2.62E-05	2.62E-05	1.65E-06	1.62E-06	3.91E-06	3.86E-06	2.93E-06	2.80E-06	1.99E-06	9.95E-07	9.71E-07	8.47E-07	3.78E-05	3.64E-05
Mallard	2.62E-05	2.62E-05	1.54E-06	1.52E-06	3.64E-06	3.59E-06	2.72E-06	2.61E-06	1.99E-06	9.95E-07	9.30E-07	8.13E-07	3.72E-05	3.58E-05

Notes:

Bold and shaded values exceed the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d

Table 4-42: Summary of Radiation Dose Estimates for Biota for Polygon AB (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Northern Redbelly Dace	2.38E-05	2.16E-05	6.65E-06	6.65E-06	5.85E-06	5.85E-06	4.74E-06	4.74E-06	1.06E-05	1.00E-05	1.05E-03	8.97E-04	1.10E-03	9.47E-04
Turtles	1.94E-03	1.94E-03	1.08E-04	1.08E-04	8.07E-03	8.07E-03	1.12E-02	1.12E-02	8.09E-06	5.29E-06	7.68E-05	4.08E-05	2.14E-02	2.14E-02
Frogs	1.94E-03	1.94E-03	1.08E-04	1.08E-04	8.07E-03	8.07E-03	1.12E-02	1.12E-02	8.09E-06	5.29E-06	7.68E-05	4.08E-05	2.14E-02	2.14E-02
Aquatic Plants	2.64E-05	2.35E-05	2.10E-06	2.10E-06	2.70E-06	2.70E-06	3.30E-06	3.30E-06	5.94E-06	5.20E-06	5.40E-06	5.40E-06	4.71E-05	4.30E-05
Benthic Invertebrates	1.75E-03	1.75E-03	1.44E-04	1.44E-04	1.75E-04	1.75E-04	2.35E-04	2.35E-04	8.11E-06	5.30E-06	8.25E-05	4.47E-05	2.39E-03	2.35E-03
Bufflehead	1.76E-03	1.75E-03	1.17E-04	1.17E-04	2.71E-04	2.71E-04	2.29E-04	2.29E-04	3.61E-06	2.28E-06	5.13E-07	4.09E-07	2.38E-03	2.37E-03
Mallard	1.47E-03	1.47E-03	9.18E-05	9.18E-05	2.13E-04	2.13E-04	1.80E-04	1.80E-04	3.46E-06	2.24E-06	4.67E-07	3.85E-07	1.96E-03	1.96E-03
Muskrat	1.06E-04	9.46E-05	1.99E-06	1.99E-06	5.74E-06	5.74E-06	4.99E-06	4.99E-06	6.05E-06	4.29E-06	3.22E-06	2.74E-06	1.29E-04	1.15E-04
Earthworm	2.08E-05	1.99E-05	1.80E-06	1.80E-06	2.60E-06	2.60E-06	3.40E-06	3.40E-06	2.07E-06	2.07E-06	2.70E-05	2.43E-05	5.77E-05	5.41E-05
American Robin	2.09E-05	2.05E-05	2.93E-05	2.93E-05	2.59E-05	2.59E-05	5.51E-05	2.59E-05	3.28E-06	2.74E-06	3.36E-05	7.20E-06	1.68E-04	1.12E-04
Bank Swallow	2.31E-05	2.00E-05	1.58E-05	1.58E-05	1.60E-05	1.60E-05	3.02E-05	1.55E-05	3.26E-06	2.66E-06	1.68E-05	3.63E-06	1.05E-04	7.38E-05
Song Sparrow	3.19E-05	3.14E-05	4.85E-05	4.85E-05	4.56E-05	4.56E-05	9.12E-05	4.48E-05	6.64E-06	5.76E-06	5.37E-05	1.15E-05	2.78E-04	1.88E-04
Yellow Warbler	2.27E-05	2.00E-05	1.61E-05	1.61E-05	1.67E-05	1.67E-05	3.08E-05	1.61E-05	3.36E-06	2.76E-06	1.68E-05	3.63E-06	1.07E-04	7.54E-05
Terrestrial Plants (Grass)	3.20E-05	1.95E-05	1.80E-06	1.80E-06	2.50E-06	2.50E-06	3.40E-06	3.40E-06	6.84E-05	1.70E-05	4.42E-05	1.96E-05	1.52E-04	6.38E-05
Eastern Cottontail	6.42E-05	3.92E-05	5.52E-05	5.52E-05	2.73E-04	2.73E-04	3.54E-04	2.82E-04	3.30E-05	9.59E-06	8.14E-05	1.96E-05	8.63E-04	6.79E-04
Meadow Vole	6.42E-05	3.92E-05	5.49E-05	5.49E-05	3.68E-05	3.68E-05	1.01E-04	4.07E-05	3.30E-05	9.59E-06	7.78E-05	1.80E-05	3.70E-04	2.00E-04
White-tailed Deer	6.42E-05	3.92E-05	3.36E-05	3.36E-05	6.98E-05	6.98E-05	7.74E-05	4.76E-05	3.66E-05	1.02E-05	8.90E-05	3.19E-05	3.72E-04	2.33E-04
Common Shrew	3.80E-05	3.30E-05	5.49E-05	5.49E-05	4.05E-05	4.05E-05	1.05E-04	4.44E-05	6.81E-06	5.25E-06	7.96E-05	2.17E-05	3.25E-04	2.00E-04
Raccoon	3.63E-04	3.52E-04	5.49E-05	5.49E-05	3.97E-05	3.97E-05	1.04E-04	4.38E-05	1.19E-05	4.65E-06	7.99E-05	2.03E-05	6.54E-04	5.15E-04
Red Fox	4.44E-04	4.26E-04	5.05E-05	5.05E-05	6.78E-05	6.78E-05	2.31E-04	1.12E-04	1.82E-05	6.44E-06	6.74E-05	1.50E-05	8.80E-04	6.78E-04
Short-tailed Weasel	6.42E-05	3.92E-05	5.49E-05	5.49E-05	3.67E-05	3.67E-05	1.01E-04	4.06E-05	1.99E-05	7.00E-06	7.35E-05	1.61E-05	3.51E-04	1.95E-04

Notes:

Bold and shaded values exceed the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d

Table 4-43: Summary of Radiation Dose Estimates for Biota for Polygon C (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Earthworm	2.39E-05	2.39E-05	1.80E-06	1.80E-06	2.60E-06	2.60E-06	3.40E-06	3.40E-06	5.11E-06	5.11E-06	2.43E-05	2.43E-05	6.11E-05	6.11E-05
American Robin	2.31E-05	2.31E-05	2.90E-05	2.90E-05	2.51E-05	2.51E-05	5.88E-05	3.43E-05	6.45E-06	4.82E-06	3.36E-05	2.00E-05	1.76E-04	1.36E-04
Song Sparrow	3.60E-05	3.60E-05	4.79E-05	4.79E-05	4.42E-05	4.42E-05	9.71E-05	5.80E-05	1.31E-05	1.04E-05	5.37E-05	3.19E-05	2.93E-04	2.29E-04
Yellow Warbler	3.46E-05	3.46E-05	1.57E-05	1.57E-05	1.56E-05	1.56E-05	3.20E-05	1.97E-05	9.54E-06	7.90E-06	1.69E-05	1.01E-05	1.25E-04	1.04E-04
Terrestrial Plants (Grass)	3.92E-05	3.37E-05	1.80E-06	1.80E-06	2.50E-06	2.50E-06	3.40E-06	3.40E-06	3.68E-05	3.07E-05	3.64E-05	2.67E-05	1.20E-04	9.87E-05
Eastern Cottontail	7.89E-05	6.77E-05	5.51E-05	5.51E-05	2.19E-04	2.19E-04	3.12E-04	2.51E-04	2.53E-05	1.70E-05	7.92E-05	4.81E-05	7.72E-04	6.59E-04
Meadow Vole	1.58E-04	1.35E-04	5.49E-05	5.49E-05	3.62E-05	3.62E-05	1.09E-04	5.88E-05	3.77E-05	2.53E-05	7.63E-05	4.59E-05	4.74E-04	3.58E-04
White-tailed Deer	7.89E-05	6.77E-05	3.19E-05	3.19E-05	5.46E-05	5.46E-05	7.38E-05	4.86E-05	2.57E-05	1.82E-05	7.57E-05	5.06E-05	3.42E-04	2.73E-04
Common Shrew	5.95E-05	5.95E-05	5.49E-05	5.49E-05	4.01E-05	4.01E-05	1.13E-04	6.27E-05	2.01E-05	1.44E-05	8.17E-05	5.26E-05	3.71E-04	2.85E-04
Raccoon	7.04E-05	6.54E-05	5.49E-05	5.49E-05	4.03E-05	4.03E-05	1.14E-04	6.32E-05	2.18E-05	1.49E-05	8.13E-05	5.10E-05	3.84E-04	2.90E-04
Red Fox	1.04E-04	8.94E-05	5.03E-05	5.03E-05	5.61E-05	5.61E-05	2.38E-04	1.38E-04	2.46E-05	1.45E-05	6.62E-05	3.95E-05	5.41E-04	3.88E-04
Short-tailed Weasel	1.58E-04	1.35E-04	5.48E-05	5.48E-05	3.55E-05	3.55E-05	1.09E-04	5.82E-05	2.80E-05	1.63E-05	7.26E-05	4.32E-05	4.59E-04	3.44E-04

Notes:
Bold and shaded values exceed the terrestrial benchmark of 2.4 mGy/d

Table 4-44: Summary of Radiation Dose Estimates for Biota for Polygon D (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Turtles	1.94E-03	1.94E-03	1.08E-04	1.08E-04	8.07E-03	8.07E-03	1.12E-02	1.12E-02	1.64E-05	8.60E-06	9.58E-05	4.13E-05	2.14E-02	2.14E-02
Frogs	2.30E-05	2.30E-05	3.20E-06	3.20E-06	3.40E-06	3.40E-06	3.60E-06	3.44E-06	5.25E-06	5.25E-06	5.56E-05	5.56E-05	9.71E-05	9.55E-05
Aquatic Plants	3.91E-05	3.74E-05	2.10E-06	2.10E-06	2.70E-06	2.70E-06	3.30E-06	3.30E-06	8.02E-06	7.27E-06	8.10E-06	5.94E-06	6.57E-05	6.00E-05
Earthworm	2.42E-05	2.42E-05	1.80E-06	1.80E-06	2.60E-06	2.60E-06	3.40E-06	3.40E-06	2.63E-06	2.63E-06	3.24E-05	1.89E-05	6.70E-05	5.35E-05
American Robin	2.51E-05	2.48E-05	2.93E-05	2.93E-05	2.59E-05	2.59E-05	3.62E-05	2.72E-05	4.69E-06	3.32E-06	2.11E-05	1.68E-05	1.43E-04	1.28E-04
Song Sparrow	3.87E-05	3.78E-05	4.85E-05	4.85E-05	4.56E-05	4.56E-05	6.12E-05	4.69E-05	9.15E-06	6.87E-06	3.36E-05	2.69E-05	2.37E-04	2.13E-04
Yellow Warbler	2.44E-05	2.43E-05	1.61E-05	1.61E-05	1.67E-05	1.67E-05	2.13E-05	1.68E-05	5.90E-06	4.62E-06	1.05E-05	8.43E-06	9.52E-05	8.71E-05
Terrestrial Plants (Grass)	3.86E-05	3.31E-05	1.80E-06	1.80E-06	2.50E-06	2.50E-06	3.40E-06	3.40E-06	7.60E-06	5.94E-06	5.98E-05	4.94E-05	1.14E-04	9.62E-05
Terrestrial Plants (Sugar Maple)	3.86E-05	3.31E-05	1.80E-05	1.80E-05	1.40E-05	1.40E-05	7.80E-06	7.80E-06	7.60E-06	5.94E-06	1.36E-04	1.12E-04	2.30E-04	1.94E-04
Eastern Cottontail	7.76E-05	6.66E-05	5.52E-05	5.52E-05	2.73E-04	2.73E-04	3.08E-04	2.85E-04	1.08E-05	6.35E-06	5.79E-05	4.62E-05	7.83E-04	7.33E-04
Meadow Vole	7.76E-05	6.66E-05	5.49E-05	5.49E-05	3.68E-05	3.68E-05	6.20E-05	4.35E-05	1.08E-05	6.35E-06	5.30E-05	4.22E-05	2.96E-04	2.51E-04
White-tailed Deer	7.76E-05	6.66E-05	3.36E-05	3.36E-05	6.98E-05	6.98E-05	5.81E-05	4.90E-05	9.98E-06	6.05E-06	9.45E-05	7.49E-05	3.45E-04	3.00E-04
Common Shrew	4.02E-05	4.02E-05	5.49E-05	5.49E-05	4.05E-05	4.05E-05	6.58E-05	4.72E-05	1.28E-05	9.05E-06	5.04E-05	4.10E-05	2.65E-04	2.33E-04
Raccoon	5.32E-05	4.92E-05	5.50E-05	5.50E-05	4.18E-05	4.18E-05	6.73E-05	4.86E-05	1.22E-05	8.07E-06	5.61E-05	4.50E-05	2.87E-04	2.48E-04
Red Fox	7.76E-05	6.66E-05	5.03E-05	5.03E-05	6.44E-05	6.44E-05	1.51E-04	1.14E-04	1.24E-05	6.80E-06	4.40E-05	3.46E-05	4.01E-04	3.38E-04
Short-tailed Weasel	7.76E-05	6.66E-05	5.49E-05	5.49E-05	3.67E-05	3.67E-05	6.20E-05	4.34E-05	1.28E-05	6.91E-06	4.71E-05	3.73E-05	2.92E-04	2.46E-04

Note:

Bold and shaded values exceed the aquatic benchmark of 9.6 mGy/d or the terrestrial benchmark of 2.4 mGy/d

Table 4-45: Summary of Radiation Dose Estimates for Biota for Polygon E (mGy/d)

Receptor	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131		Total Dose	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Earthworm	5.06E-05	2.59E-05	3.44E-05	3.44E-05	2.25E-05	2.25E-05	7.00E-05	5.48E-05	2.26E-04	9.17E-05	3.91E-05	2.79E-05	4.42E-04	2.57E-04
American Robin	3.70E-05	2.61E-05	2.81E-05	2.81E-05	2.31E-05	2.31E-05	5.82E-05	4.64E-05	3.09E-05	1.48E-05	2.94E-05	2.10E-05	2.07E-04	1.60E-04
Bank Swallow	5.56E-05	2.84E-05	1.35E-05	1.35E-05	1.05E-05	1.05E-05	3.05E-05	2.38E-05	6.39E-05	2.59E-05	1.47E-05	1.05E-05	1.89E-04	1.13E-04
Song Sparrow	4.44E-05	4.00E-05	4.78E-05	4.78E-05	4.41E-05	4.41E-05	9.66E-05	7.83E-05	2.30E-05	1.48E-05	4.70E-05	3.36E-05	3.04E-04	2.59E-04
Yellow Warbler	5.25E-05	2.80E-05	1.37E-05	1.37E-05	1.12E-05	1.12E-05	3.10E-05	2.44E-05	5.84E-05	2.40E-05	1.47E-05	1.05E-05	1.82E-04	1.12E-04
Terrestrial Plants (Grass)	4.56E-05	2.33E-05	1.24E-04	1.24E-04	8.37E-05	8.37E-05	2.63E-04	2.06E-04	2.32E-04	8.92E-05	1.50E-04	1.07E-04	8.99E-04	6.34E-04
Terrestrial Plants (Sugar maple)	4.56E-05	2.33E-05	3.78E-05	3.77E-05	2.50E-05	2.50E-05	7.49E-05	5.86E-05	2.32E-04	8.92E-05	4.60E-05	3.28E-05	4.84E-04	2.75E-04
Eastern Cottontail	9.17E-05	4.68E-05	5.49E-05	5.49E-05	9.34E-05	9.34E-05	1.47E-04	1.15E-04	1.04E-04	3.97E-05	6.36E-05	4.53E-05	5.59E-04	3.97E-04
Meadow Vole	9.17E-05	4.68E-05	5.49E-05	5.49E-05	3.53E-05	3.53E-05	1.08E-04	8.44E-05	1.04E-04	3.97E-05	6.35E-05	4.52E-05	4.62E-04	3.08E-04
White-tailed Deer	9.17E-05	4.68E-05	2.97E-05	2.97E-05	3.35E-05	3.35E-05	5.54E-05	4.33E-05	1.18E-04	4.51E-05	3.64E-05	2.49E-05	3.70E-04	2.26E-04
Common Shrew	9.17E-05	4.68E-05	5.48E-05	5.48E-05	3.57E-05	3.57E-05	1.12E-04	8.78E-05	9.74E-05	3.93E-05	6.47E-05	4.62E-05	4.57E-04	3.11E-04
Raccoon	8.40E-05	4.59E-05	5.49E-05	5.49E-05	3.80E-05	3.80E-05	1.12E-04	8.81E-05	8.23E-05	3.34E-05	6.56E-05	4.68E-05	4.39E-04	3.08E-04
Red Fox	9.17E-05	4.68E-05	5.03E-05	5.03E-05	4.09E-05	4.09E-05	2.16E-04	1.69E-04	6.47E-05	2.47E-05	5.82E-05	4.13E-05	5.24E-04	3.74E-04
Short-tailed Weasel	9.17E-05	4.68E-05	5.49E-05	5.49E-05	3.58E-05	3.58E-05	1.08E-04	8.46E-05	5.50E-05	2.10E-05	6.36E-05	4.53E-05	4.10E-04	2.89E-04

Notes:

Bold and shaded values exceed the terrestrial benchmark of 2.4 mGy/d

Table 4-46: Non-Radiological Hazard Quotients for Biota for Lake Ontario

Receptor	Aluminum		Copper		Nitrate		Chlorine (TRC)		Hydrazine		Morpholine	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Fish	6.5E-03	1.1E-03	**1.1E+00**	2.6E-01	**3.2E+00**	1.0E-01	2.0E-01	2.0E-01	1.9E-02	7.5E-03	6.3E-05	1.2E-05
Benthic Invertebrates (Water)	1.1E-02	2.0E-03	6.6E-01	1.6E-01	**1.6E+00**	4.9E-02	3.8E-01	3.8E-01	2.9E-01	1.1E-01	1.1E-04	2.1E-05
Benthic Invertebrates (Sediment)	6.0E-01	1.3E-01	**2.8E+00**	3.4E-01	-	-	-	-	-	-	-	-
Bufflehead	**1.6E+00**	5.8E-01	8.1E-03	5.5E-03	nd	nd	-	-	-	-	-	-
Mallard	5.3E-01	2.9E-01	4.7E-03	4.1E-03	nd	nd	-	-	-	-	-	-

Notes:

Bold and shaded values indicate a HQ > 1

"-" denotes that HQs were not calculated because COPC is not of toxicological concern to receptor

nd indicates that a HQ could not be estimated because there was no TRV selected

Table 4-47: Non-Radiological Hazard Quotients for Biota for Polygon AB

Receptor	Aluminum		Ammonia (un-ionized; as NH3)		Barium		Boron (HWS)		Calcium		Cobalt		Copper		Iron		Lead		Magnesium		Manganese		Phosphorus		Potassium		Strontium		Vanadium	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Northern Redbelly Dace	8.9E-01	1.1E-01	**2.9E+01**	**5.9E+00**	2.0E-03	1.0E-03	-	-	nd	nd	1.4E-02	3.4E-03	-	-	1.0E+00	3.1E-01	-	-	2.8E-02	2.4E-02	-	-	-	-	2.4E-02	1.5E-02	-	-	-	-
Turtles	8.9E-01	1.1E-01	**2.9E+01**	**5.9E+00**	2.0E-03	1.0E-03	-	-	nd	nd	1.4E-02	3.4E-03	-	-	1.0E+00	3.1E-01	-	-	2.8E-02	2.4E-02	-	-	-	-	2.4E-02	1.5E-02	-	-	-	-
Frogs	8.9E-01	1.1E-01	**2.9E+01**	**5.9E+00**	2.0E-03	1.0E-03	-	-	nd	nd	1.4E-02	3.4E-03	-	-	1.0E+00	3.1E-01	-	-	2.8E-02	2.4E-02	-	-	-	-	2.4E-02	1.5E-02	-	-	-	-
Aquatic Plants	**6.4E+00**	**1.5E+00**	2.1E-02	4.2E-03	4.3E-02	2.2E-02	-	-	nd	nd	4.1E-02	1.0E-02	-	-	8.7E-01	2.7E-01	-	-	5.6E-01	4.7E-01	-	-	-	-	1.8E-02	1.1E-02	-	-	-	-
Benthic Invertebrates (Water)	**1.5E+00**	3.7E-01	7.9E-02	1.6E-02	3.2E-01	1.6E-01	-	-	7.4E-01	4.2E-01	7.8E-01	2.0E-01	-	-	**4.3E+00**	**1.3E+00**	-	-	4.6E-01	3.9E-01	-	-	-	-	2.3E-01	1.5E-01	-	-	-	-
Benthic Invertebrates (Sediment)	-	-	-	-	-	-	-	-	-	-	-	-	**1.7E+00**	**1.5E+00**	-	-	-	-	-	-	**1.1E+00**	1.0E+00	**1.1E+00**	**1.1E+00**	-	-	-	-	**1.2E+00**	**1.1E+00**
Bufflehead	**1.4E+01**	**4.0E+00**	nd	nd	9.4E-02	6.3E-02	-	-	nd	nd	1.9E-02	8.3E-03	3.0E-03	2.4E-03	nd	nd	-	-	nd	nd	1.4E-02	8.5E-03	nd	nd	nd	nd	-	-	2.3E-02	1.7E-02
Mallard	**8.8E+00**	**2.3E+00**	nd	nd	5.0E-02	2.9E-02	-	-	nd	nd	1.8E-02	5.3E-03	2.6E-03	1.8E-03	nd	nd	-	-	nd	nd	1.4E-02	8.1E-03	nd	nd	nd	nd	-	-	9.2E-03	5.5E-03
Muskrat	**4.2E+01**	**1.2E+01**	nd	nd	2.3E-02	1.5E-02	-	-	nd	nd	1.1E-01	3.0E-02	9.3E-02	6.3E-02	nd	nd	-	-	nd	nd	3.3E-01	1.9E-01	nd	nd	nd	nd	-	-	8.7E-02	6.1E-02
Earthworm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.8E-02	1.4E-02	-	-
American Robin	**1.1E+01**	**8.5E+00**	nd	nd	3.9E-01	2.1E-01	-	-	nd	nd	1.1E-01	9.1E-02	-	-	nd	nd	1.1E-01	7.8E-02	nd	nd	-	-	-	-	nd	nd	nd	nd	-	-
Bank Swallow	**1.6E+00**	**1.0E+00**	nd	nd	1.3E-01	8.9E-02	-	-	nd	nd	1.7E-02	1.0E-02	-	-	nd	nd	3.4E-02	1.7E-02	nd	nd	-	-	-	-	nd	nd	nd	nd	-	-
Song Sparrow	**3.6E+00**	**1.6E+00**	nd	nd	6.8E-01	1.9E-01	-	-	nd	nd	3.6E-02	1.2E-02	-	-	nd	nd	7.3E-02	2.5E-02	nd	nd	-	-	-	-	nd	nd	nd	nd	-	-
Yellow Warbler	**1.9E+00**	**1.2E+00**	nd	nd	1.8E-01	1.1E-01	-	-	nd	nd	2.0E-02	1.1E-02	-	-	nd	nd	4.1E-02	1.9E-02	nd	nd	-	-	-	-	nd	nd	nd	nd	-	-
Terrestrial Plants	-	-	-	-	-	-	**1.3E+00**	2.5E-01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7E-01	8.6E-02	-	-
Eastern Cottontail	**9.3E+00**	**4.1E+00**	nd	nd	1.0E-01	2.8E-02	-	-	nd	nd	1.4E-02	4.4E-03	-	-	nd	nd	4.6E-03	1.6E-03	nd	nd	-	-	-	-	nd	nd	4.4E-02	2.0E-02	-	-
Meadow Vole	**5.5E+00**	**1.7E+00**	nd	nd	8.5E-02	2.1E-02	-	-	nd	nd	8.9E-03	2.4E-03	-	-	nd	nd	2.6E-03	7.7E-04	nd	nd	-	-	-	-	nd	nd	3.9E-02	1.7E-02	-	-
White-tailed Deer	**2.5E+00**	7.3E-01	nd	nd	4.1E-02	9.7E-03	-	-	nd	nd	4.1E-03	1.1E-03	-	-	nd	nd	1.2E-03	3.4E-04	nd	nd	-	-	-	-	nd	nd	1.8E-02	8.3E-03	-	-
Common Shrew	**1.1E+01**	**7.0E+00**	nd	nd	8.0E-02	5.9E-02	-	-	nd	nd	2.2E-02	1.6E-02	-	-	nd	nd	6.0E-03	3.3E-03	nd	nd	-	-	-	-	nd	nd	1.5E-01	8.4E-02	-	-
Raccoon	**2.4E+01**	**8.3E+00**	nd	nd	4.6E-02	1.9E-02	-	-	nd	nd	1.2E-02	4.9E-03	7.8E-02	4.6E-02	nd	nd	3.8E-03	1.6E-03	nd	nd	2.2E-02	1.5E-02	nd	nd	nd	nd	2.8E-02	1.4E-02	1.8E-01	1.1E-01
Red Fox	**3.8E+01**	**1.1E+01**	nd	nd	5.0E-03	1.6E-03	-	-	nd	nd	1.5E-03	9.8E-04	6.2E-03	2.6E-03	nd	nd	3.4E-04	1.3E-04	nd	nd	1.6E-03	9.9E-04	nd	nd	nd	nd	2.5E-03	1.2E-03	1.6E-02	8.7E-03
Short-tailed Weasel	**1.0E+01**	**5.3E+00**	nd	nd	1.6E-02	9.9E-03	-	-	nd	nd	7.8E-03	3.4E-03	-	-	nd	nd	3.2E-03	1.4E-03	nd	nd	-	-	-	-	nd	nd	5.7E-03	3.0E-03	-	-

Notes:

Bold and shaded values indicate a HQ > 1

"-" denotes that HQs were not calculated because COPC is not of toxicological concern to receptor

nd indicates that a HQ could not be estimated because there was no TRV selected

Copper, manganese, phosphorus, and vanadium were identified as COPCs in the sediment, but not the surface water. As such, VECs with no exposure link to the sediment exposure pathway for these COPCs were not assessed.

Table 4-48: Non-Radiological Hazard Quotients for Biota for Polygon C

Receptor	Barium		Strontium		Tin	
	Maximum	Mean	Maximum	Mean	Maximum	Mean
Earthworm	-	-	1.7E-02	1.6E-02	nd	nd
American Robin	1.6E-01	1.5E-01	nd	nd	7.9E-03	5.0E-03
Song Sparrow	1.7E-01	1.4E-01	nd	nd	9.5E-03	6.0E-03
Yellow Warbler	1.1E-01	1.1E-01	nd	nd	9.1E-03	6.4E-03
Terrestrial Plants	-	-	1.0E-01	9.6E-02	3.1E-01	1.8E-01
Eastern Cottontail	2.5E-02	2.1E-02	1.6E-02	1.4E-02	2.0E-03	1.2E-03
Meadow Vole	1.5E-02	1.1E-02	1.3E-02	1.2E-02	8.0E-04	5.0E-04
White-tailed Deer	6.9E-03	5.2E-03	6.3E-03	5.6E-03	3.4E-04	2.1E-04
Common Shrew	5.1E-02	5.0E-02	2.0E-02	1.9E-02	5.8E-03	4.6E-03
Raccoon	2.2E-02	2.0E-02	8.3E-03	7.7E-03	2.4E-03	1.5E-03
Red Fox	2.4E-03	2.1E-03	1.0E-03	9.2E-04	3.5E-04	2.1E-04
Short-tailed Weasel	1.7E-02	1.6E-02	3.3E-03	3.0E-03	2.1E-03	1.2E-03

Notes:

Bold and shaded values indicate a HQ > 1

"-" denotes that HQs were not calculated because COPC is not of toxicological concern to receptor

nd indicates that a HQ could not be estimated because there was no TRV selected

Table 4-49: Non-Radiological Hazard Quotients for Biota for Polygon D

Receptor	Barium		Boron		Calcium		Cobalt		Iron		Magnesium		Manganese		Nitrate		Potassium		Strontium		Tin		Zi
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximu
Turtles	8.0E-03	2.0E-03	**1.7E+00**	2.7E-01	nd	nd	1.7E-02	3.4E-03	**3.0E+00**	7.7E-01	8.3E-03	6.4E-03	4.2E-01	1.7E-01	5.4E-01	3.2E-02	2.4E-02	1.0E-02	-	-	-	-	3.6E-0
Frogs	8.0E-03	2.0E-03	**1.7E+00**	2.7E-01	nd	nd	1.7E-02	3.4E-03	**3.0E+00**	7.7E-01	8.3E-03	6.4E-03	4.2E-01	1.7E-01	5.4E-01	3.2E-02	2.4E-02	1.0E-02	-	-	-	-	3.6E-0
Aquatic Plants	1.7E-01	4.3E-02	7.4E-01	1.1E-01	nd	nd	5.2E-02	1.0E-02	**2.6E+00**	6.7E-01	1.6E-01	1.3E-01	1.5E-01	6.0E-02	nd	nd	1.8E-02	7.6E-03	-	-	-	-	7.7E-0
Earthworm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.9E-02	2.1E-02	nd	nd	-
American Robin	5.5E-01	3.7E-01	3.8E-02	2.8E-02	nd	nd	1.1E-01	1.1E-01	nd	nd	nd	nd	3.4E-02	3.2E-02	nd	nd	nd	nd	nd	nd	2.5E-02	1.4E-02	nd
Song Sparrow	2.8E-01	2.0E-01	8.2E-02	7.4E-02	nd	nd	1.3E-02	1.2E-02	nd	nd	nd	nd	1.2E-02	9.9E-03	nd	nd	nd	nd	nd	nd	7.0E-02	3.7E-02	nd
Yellow Warbler	1.3E-01	1.0E-01	3.5E-02	2.7E-02	nd	nd	1.3E-02	1.2E-02	nd	nd	nd	nd	7.4E-03	6.8E-03	nd	nd	nd	nd	nd	nd	1.1E-02	7.7E-03	nd
Terrestrial Plants	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	nd	nd	2.2E-01	1.6E-01	-
Eastern Cottontail	4.2E-02	2.9E-02	3.6E-02	3.2E-02	nd	nd	5.0E-03	4.5E-03	nd	nd	nd	nd	1.8E-02	1.4E-02	1.3E-03	7.9E-05	nd	nd	2.6E-02	1.8E-02	1.5E-02	7.7E-03	2.0E-0
Meadow Vole	2.8E-02	2.0E-02	3.4E-02	2.9E-02	nd	nd	2.4E-03	2.1E-03	nd	nd	nd	nd	1.2E-02	9.1E-03	2.0E-03	1.2E-04	nd	nd	2.1E-02	1.4E-02	1.3E-02	6.6E-03	7.9E-0
White-tailed Deer	1.3E-02	9.0E-03	1.6E-02	1.4E-02	nd	nd	1.1E-03	9.2E-04	nd	nd	nd	nd	5.5E-03	4.2E-03	8.2E-04	4.9E-05	nd	nd	1.0E-02	6.8E-03	6.1E-03	3.2E-03	3.3E-0
Common Shrew	5.4E-02	4.6E-02	5.9E-02	5.4E-02	nd	nd	1.8E-02	1.7E-02	nd	nd	nd	nd	3.5E-02	3.4E-02	2.3E-03	1.4E-04	nd	nd	6.5E-02	6.3E-02	4.9E-03	4.3E-03	3.6E-0
Raccoon	3.0E-02	2.2E-02	1.8E-02	1.5E-02	nd	nd	5.6E-03	5.2E-03	nd	nd	nd	nd	1.4E-02	1.2E-02	1.1E-03	6.6E-05	nd	nd	1.6E-02	1.3E-02	5.8E-03	3.4E-03	2.2E-0
Red Fox	3.6E-03	2.5E-03	4.1E-03	1.9E-03	nd	nd	6.0E-04	5.2E-04	nd	nd	nd	nd	1.7E-03	1.4E-03	1.1E-03	6.8E-05	nd	nd	1.8E-03	1.2E-03	1.6E-03	8.5E-04	2.6E-0
Short-tailed Weasel	2.1E-02	1.5E-02	5.0E-03	1.7E-03	nd	nd	4.4E-03	4.0E-03	nd	nd	nd	nd	9.5E-03	8.5E-03	1.5E-03	8.8E-05	nd	nd	5.6E-03	4.1E-03	2.1E-03	1.4E-03	2.1E-0

Notes:
Bold and shaded values indicate a HQ > 1
"-" denotes that HQs were not calculated because COPC is not of toxicological concern to receptor
nd indicates that a HQ could not be estimated because there was no TRV selected

Table 4-50: Non-Radiological Hazard Quotients for Biota for Polygon E

Receptor	Barium		Strontium	
	Maximum	Mean	Maximum	Mean
Earthworm	-	-	1.6E-02	1.5E-02
American Robin	1.7E-01	1.5E-01	nd	nd
Bank Swallow	3.0E-01	2.7E-01	nd	nd
Song Sparrow	2.0E-01	1.8E-01	nd	nd
Yellow Warbler	3.3E-01	3.0E-01	nd	nd
Terrestrial Plants	-	-	9.8E-02	9.3E-02
Eastern Cottontail	2.3E-02	2.1E-02	4.0E-02	3.8E-02
Meadow Vole	1.3E-02	1.1E-02	3.5E-02	3.3E-02
White-tailed Deer	5.6E-03	5.0E-03	1.7E-02	1.6E-02
Common Shrew	2.3E-01	2.1E-01	6.4E-02	6.1E-02
Raccoon	3.5E-02	3.3E-02	1.9E-02	1.8E-02
Red Fox	2.7E-03	2.2E-03	2.2E-03	2.1E-03
Short-tailed Weasel	1.8E-02	1.6E-02	3.3E-03	3.1E-03

Notes:

Bold and shaded values indicate a HQ > 1

"-" denotes that HQs were not calculated because COPC is not of toxicological concern to receptor.

nd indicates that a HQ could not be estimated because there was no TRV selected

4.4.2 Discussion of Chemical and Radiation Effects

4.4.2.1 Effects Monitoring Evidence

Data used for the problem formulations, screening and ecological risk assessment were taken from the most recent ERAs (SENES, 2009a and 2011c) and associated TSDs, annual EMP reports (from years 2011 to 2015), ECA reports (from years 2011 to 2015) prepared for the DN site, and the 2016 effluent characterization study. No additional data are available beyond what is presented at this time to clarify potential effects at the site.

4.4.2.2 Likelihood of Effects

4.4.2.2.1 Polygon Lake Ontario

Radiological

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota at the SSA in Lake Ontario, including fish and benthic invertebrates. The 2.4 mGy/d radiation benchmark has also not been exceeded for the Bufflehead and Mallard.

Non-Radiological

Maximum surface water concentrations for the SSA in Lake Ontario exceeded the target benchmarks for copper and nitrate for fish and the target benchmarks for nitrate for benthic invertebrates. Copper and nitrate were identified as potential risks to ecological receptors based on monitoring data collected to support the 2009 NND EA. Based on data collected from the 2016 effluent characterization study, the maximum copper and nitrate concentrations in the CCW were 0.0019 mg/L and 0.44 mg/L, respectively. Maximum measured surface water data from Lake Ontario in 2009 for copper and nitrate were 0.004 mg/L and 89.7 mg/L, respectively. Based on these concentrations, the facility contribution for copper and nitrate is low.

The mean surface water concentrations for Lake Ontario, however, did not exceed the target benchmarks for copper and nitrate for fish, or the target benchmarks for nitrate for benthic invertebrates.

Because fish are more mobile around a wider area, the HQs for mean water concentrations for copper and nitrate are more representative of fish exposure than maximum concentrations. As such, fish are likely not at toxicological risk from DN operations.

Mean nitrate surface water concentrations are more representative of chronic exposure to benthic invertebrates than maximum nitrate water concentrations because nitrate concentrations are not expected to remain at these high concentrations in the environment. As such, benthic invertebrates may not be at risk to nitrate exposure via water exposure on a long term basis. Additionally, although a few benthic invertebrates may be exposed to these maximum concentrations, the community as a whole is not expected to be affected.

Maximum sediment concentrations for Lake Ontario exceeded the sediment target benchmark for copper for benthic invertebrates. The mean sediment concentrations for Lake Ontario did not exceed the sediment benchmarks. However, there is uncertainty surrounding this risk because sediment in Lake Ontario is transient and the invertebrate community is mainly epifaunal. In other words, this suggests that the sediment exposure pathway is unlikely to be the primary exposure route for benthic invertebrates in Lake Ontario. Although, a few benthic invertebrates may be exposed to the maximum copper in sediment, the benthic community as a whole is not expected to be affected.

The HQ target of 1 was exceeded for aluminum for the Bufflehead. This HQ target of 1 was exceeded when Bufflehead were exposed to maximum water, sediment and benthic invertebrate concentrations. The HQ target of 1 was not exceeded when Bufflehead were exposed to mean water, sediment and benthic invertebrate concentrations, which is a more realistic exposure scenario.

The maximum and mean aluminum concentrations are based on measured effluent data collected in 2016 during the effluent characterization program at the effluent discharge point from the CCW discharge duct to the DN diffuser (with a dilution factor of 7 applied). The mean measured concentrations, rather than the measured maximum concentrations, are considered to be more representative of chronic exposure because it is unlikely that the Bufflehead will spend most of its time at the diffuser and effluent concentrations are not likely to remain at maximum concentrations for chronic exposure durations.

There were no data to determine nitrate benchmarks for birds. The Poultry Industry Council recommends a maximum water quality guideline of 10 mg/L nitrate as nitrogen for fowl (Weltzein 2002). This water quality guideline is equivalent to approximately 44 mg/L nitrate, is based on poultry “performance”. This guideline is not considered appropriate for assessing potential health risks to birds, as it is not based on a specific toxicological endpoint. As such, there is uncertainty around potential health risks to birds due to nitrate. The maximum analyzed concentration of nitrate in the CCW during the 2016 Effluent Characterization Program was 0.44 mg/L (see, for example, Table A.11a in Appendix A), and this concentration was measured before dilution in Lake Ontario. The maximum modeled concentration of nitrate in Lake Ontario based on storm water measurements from 2010 and 2011 was 0.0411 mg/L (see Table A.12 in Appendix A). The maximum analyzed concentration of nitrate in Lake Ontario water, however, was 89.7 mg/L (from SENES, 2009a). As such, station effluent and storm water are considered unlikely to be sources of elevated concentrations of nitrate in Lake Ontario, and any health risks incurred by birds are expected to be due to other, external sources of nitrate.

The American Eel is identified as a species at risk; therefore the assessment endpoint is the health of the individual. As discussed above, the fish benchmarks were exceeded for maximum water concentrations of copper and nitrate, but not for mean water concentrations. Since fish are more mobile around a wider area, the HQs for mean water concentrations are more representative than maximum concentrations. As such, the American Eel and other fish VECs are likely not at risk from DN operations.

4.4.2.2.2 Polygon AB

Radiological

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota in Coots Pond (Polygon AB). Aquatic biota include: Northern Redbelly Dace, turtles, frogs, aquatic plants and benthic invertebrates.

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial and riparian biota for Polygon AB. Terrestrial and riparian biota include: Bufflehead, Mallard and muskrat at Coots Pond, earthworms, terrestrial plants (grass), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern cottontail, meadow vole, white-tailed deer, common shrew, raccoon, red fox, and short-tailed weasel.

Although the radiation dose to all receptors located in Coots Pond (Polygon AB) was below the radiation dose benchmarks for aquatic and terrestrial receptors, there is uncertainty regarding the contribution of DN emissions to the tritium concentration measured in Coots Pond. Although Coots Pond receives runoff from the DN landfill it does not receive effluent from the DN site, other than through atmospheric deposition. The maximum tritium concentration measured in Coots Pond to support the 2009 NND EA was 78 Bq/L compared to 7.5 Bq/L in Lake Ontario in the vicinity of DN. Lake Ontario receives tritium emissions from DN, but has a much lower tritium concentration than Coots Pond.

Non-Radiological

A summary of the results of the aquatic assessment in Coots Pond (Polygon AB) is provided below:

- The HQ target of 1 was exceeded for aluminum for aquatic plants, benthic invertebrates, bufflehead, mallard, and muskrat, based on maximum and mean aluminum concentrations in water and sediment in Coots Pond. The HQ target of 1 was also exceeded for aluminum for terrestrial receptors at Polygon AB that are assumed to drink water or part of their diet from Coots Pond.

- Maximum and mean sediment concentrations in Coots Pond exceeded the sediment target benchmarks for copper, manganese (maximum only), phosphorus, and vanadium for benthic invertebrates.

- Maximum and mean iron concentrations in surface water in Coots Pond exceeded the benthic invertebrate benchmark for water, but not for sediment.

- Maximum and mean ammonia (un-ionized) concentrations in surface water in Coots Pond exceeded the fish and turtle/frog benchmarks.

The maximum pH observed in Coots Pond was 9.4, exceeding the MOECC water quality objective for pH of a range from 6.5 to 8.5. The MOE considers the PWQO for pH to be the range within which waters are the most productive (MOE, 1979). Surface water with pH above the upper limit of the PWQO may be less productive. Since the mean pH measured at Coots Pond was 8.5 and the aquatic environment is productive, no adverse effects from pH are expected at Coots Pond.

The productive nature of Coots Pond is evident from the descriptions by Golder and Senes (2009) and from recent biodiversity studies (Beacon, 2016a). Coots Pond is described as an open water wetland habitat, with mostly open water in the eastern portion of the pond, and emergent and submerged aquatic vegetation present along the edges of the pond and abundant in the western portion of the pond (Golder and SENES, 2009). In 2015, 80% of the pond was open water, while 20% of the pond was covered by cattails (*Typha*), common reed (*Phragmites australis*) and other grasses and desirable emergent vegetation; submerged vegetation, mostly algae (*Chara*) was also observed (Beacon, 2016a). Coots Pond supports aquatic invertebrates and an introduced population of Northern Redbelly Dace (Golder and SENES, 2009). Coots Pond also provides habitat and breeding areas for amphibians, turtles and migrant birds. In 2015, bats were observed foraging over Coots Pond, while bank swallows were found to be roosting in the reeds (Beacon, 2016a).

Calcium in surface water was not assessed quantitatively for fish, turtles and frogs, and aquatic plants, because of a lack of toxicity data. Calcium is an essential macro-nutrient for plants and aquatic animals, and for this reason, calcium is considered to be essentially non-toxic for these aquatic VECs.

Although potential risks were identified to aquatic and riparian receptors at Coots Pond from a number of COPCs, the source of these COPCs in Coots Pond is not the result of emissions from the DN site, but likely from construction debris placed in the landfill and subsequent stormwater runoff since the pond is designed to be a settling pond for stormwater runoff from the landfill. There is no pathway from DN liquid effluent to Coots Pond. There is potential for DN air emissions to deposit at the pond; however, the chemical signature in Coots Pond is characteristic of landfill runoff (mean concentrations above benchmark for iron, aluminum, ammonia in water, plus metals and phosphorus in sediment; Table 4.47). Treefrog Pond, which does not drain the landfill, does not show this signature (Table 4.49).

An assessment of the terrestrial environment was also performed for soil COPCs identified in Polygon AB. The HQ target of 1 was exceeded for boron (hot water soluble, HWS) for terrestrial plants exposed to maximum boron (HWS) soil concentrations, but not exposed to mean boron (HWS) soil concentrations. This suggests that soils on site that exceed the boron (HWS) maximum are localized on site, rather than deposition from atmospheric sources. Although individual plants may be affected, the plant population should not be affected.

Where data were available, the HQ target of 1 was not exceeded- for terrestrial biota for barium, strontium, and lead. There were no data to determine strontium benchmarks for birds. Strontium competes with calcium but it does not have a toxic effect on bone in chicks. A study (cited in Skoryna, 1981) found that there were no deleterious effects on chicks until very high doses were given. This dose is reported to be much higher than the benchmark value used to assess strontium effects on mammals. If the benchmark value for birds were set to the mammal benchmark, which could be interpreted as a NOAEL, there would be no exceedances.

4.4.2.2.3 Polygon C

Radiological

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial biota at Polygon C. Terrestrial biota include earthworms, terrestrial plants (grass), American Robin, Song Sparrow, Yellow Warbler, Eastern cottontail, meadow vole, white-tailed deer, common shrew, raccoon, red fox, and short-tailed weasel.

Non-Radiological

Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium, strontium, and tin. No risks were identified for terrestrial biota for polygon C.

There were no data to determine strontium benchmarks for birds. As discussed above, when strontium benchmark values for birds are set to strontium benchmarks for mammals, there are no exceedances for polygon C.

There were no data to determine tin benchmarks for soil invertebrates. As such, there are uncertainties associated with the effects assessment for soil invertebrates exposed to tin concentrations in soil. Borgmann et al. (2005) reported an acute one week LC_{50} of > 1 mg/L for epibenthic *Hyalella azteca* exposed to tin in water obtained from Lake Ontario. If an acute to chronic factor of 10 is applied to the acute value in order to adjust it to a chronic value, and then multiplied by a K_d of 1300 L/kg dw for freshwater sediments obtained from CSA (2014), this results in a sediment concentration of 130 mg/kg dw. If this sediment value is used as a surrogate for soil concentrations to investigate the effects of tin exposure to soil invertebrates, it is unlikely that there would be adverse effects to soil invertebrates due to tin exposure because the maximum tin soil concentration in Polygon C is 15 mg/kg dw, well below the surrogate soil concentration of 130 mg/kg dw.

4.4.2.2.4 Polygon D

Radiological

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota present at Treefrog Pond. Aquatic biota at Treefrog Pond include: turtles, frogs, and aquatic plants.

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial and riparian biota for Polygon AB. Terrestrial and riparian biota include: Bufflehead, Mallard and muskrat at Coots Pond, earthworms, terrestrial plants (grass and sugar maple), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern cottontail, meadow vole, white-tailed deer, common shrew, raccoon, red fox, and short-tailed weasel.

Because Dragonfly and Polliwog Ponds are known to dry up at different times of the year, the surface water and sediment concentrations at Treefrog Pond, along with the aquatic biota present at this pond, have been used to represent surface water and sediment concentrations along with the presence of potential aquatic biota at Dragonfly and Polliwog ponds.

Non-Radiological

The HQ target of 1 was exceeded for boron and iron for turtles and frogs based on maximum water concentrations, but not the mean water concentration at Treefrog Pond (Polygon D). Because turtles and frogs are mobile, the HQs for mean surface water concentrations for boron and iron are more representative of turtle and frogs exposure than maximum concentrations. As such, there are unlikely to be adverse effects for turtles and frogs exposed to boron and iron at Treefrog Pond.

The HQ target of 1 was exceeded for iron for aquatic plants based on the maximum surface water concentration, but not the mean surface water concentration at Treefrog Pond. Although some aquatic plants may be exposed to maximum iron surface water concentrations at Treefrog Pond, the aquatic plant community as a whole is not expected to be affected.

Calcium in surface water was not assessed quantitatively for fish, turtles and frogs, and aquatic plants, because of the lack of toxicity data. As noted above, calcium is an essential macro-nutrient for plants and aquatic animals, and for this reason, calcium is considered to be essentially non-toxic for these aquatic VECs.

Nitrate in surface water was not assessed quantitatively for aquatic plants, because of the lack of toxicity data. Considering that nitrate can serve as a source of nutrients for freshwater algae (BC MOE, 1985), nitrate is not considered to be toxic to aquatic plants. There were no data to determine nitrate benchmarks for birds. As such, there is uncertainty around potential health risks to birds due to nitrate. However, any potential health risks incurred by birds are not expected to be due to operations at DN because nitrate concentrations in station effluents and storm water (see 4.4.2.2.1) were well below the nitrate surface water quality guideline of 13 mg/L, and because station effluents and stormwater do not connect directly to Treefrog Pond.

An assessment of the terrestrial environment was also performed for soil COPCs identified in Polygon D. Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium, strontium, and tin. No risks were identified for terrestrial biota for polygon D.

There were no data to determine strontium benchmarks for birds. As discussed above and based on the study cited in Skoryna (1981) when the benchmark value for birds is set to the mammal benchmark, there are no exceedances for Polygon D.

There were also no data to determine zirconium benchmarks for birds. However, zirconium toxicity to animals is considered to be low due to zirconium's low solubility (IPCS INCHEM, 1998). If the zirconium benchmark for birds is set to the mammal benchmark, the HQ is greater than 1 for the American Robin based on the maximum and mean exposure doses for zirconium. However, there is uncertainty regarding this HQ due to the lack of avian toxicity data. ..

There were no data to determine tin benchmarks for soil invertebrates. As such, there are uncertainties associated with the effects assessment for soil invertebrates exposed to tin concentrations in soil. However it is unlikely that there would be adverse effects on soil invertebrates due to tin, because the maximum tin soil concentration in Polygon D is 11 mg/kg dw, well below the surrogate soil concentration of 130 mg/kg dw (as discussed above in Polygon C).

4.4.2.2.5 Polygon E

Radiological

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial biota at Polygon E. Terrestrial biota include: earthworms, terrestrial plants (grass and sugar maple), American robin, song sparrow, yellow warbler, Eastern cottontail, meadow vole, white-tailed deer, common shrew, raccoon, red fox, and short-tailed weasel.

Non-Radiological

Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium and strontium. No risks were identified for terrestrial biota for polygon E.

There were no data to determine strontium benchmarks for birds. As discussed above, when the strontium benchmark value for birds is set to the mammal benchmark, there would be no exceedances for Polygon E.

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The maximum dose rate to any ecological VEC residing in close proximity (5 m) to the DWMF could be up to 0.024 mGy/d, lower than the 2.4 mGy/d radiation benchmark for terrestrial biota. The dose also remains below the radiation benchmark if the maximum dose from the DWMF is combined with the dose to ecological VECs from being exposed to radionuclides through other existing DN operations (**Error! Reference source not found.**).

4.4.3 Thermal Effects

An assessment of thermal effects from the warm cooling water discharged by DN was conducted in 2011 and 2012 by Golder (2012b). In this study, continuous temperature data were obtained from temperature loggers installed at 31 locations in and around the discharge, and at reference (ambient) locations, over an eight month period from January through September, and from December to April. At 25 locations, the temperature loggers were installed at two or more depths.

The assessment focused on near surface temperatures. This is conservative during the warm water period (June – September) when some thermal stratification is evident. During the cold water period (January – May) there is generally less than 1ºC difference between surface and bottom temperatures.

Error! Reference source not found. illustrates the maximum extent of the thermal plume, based on the 95th percentile of temperature increase above ambient (ΔT). The extent of the ΔT of 1ºC was measured to extend up to 6.9 km to the west and up to 3.5 km to the east. The areal extent of the ΔT of 1ºC was usually small with a maximum area of 7.5 km^2. The ΔT of 2ºC did not extend beyond the turbulent mixing zone which has an area of approximately 1 km^2.

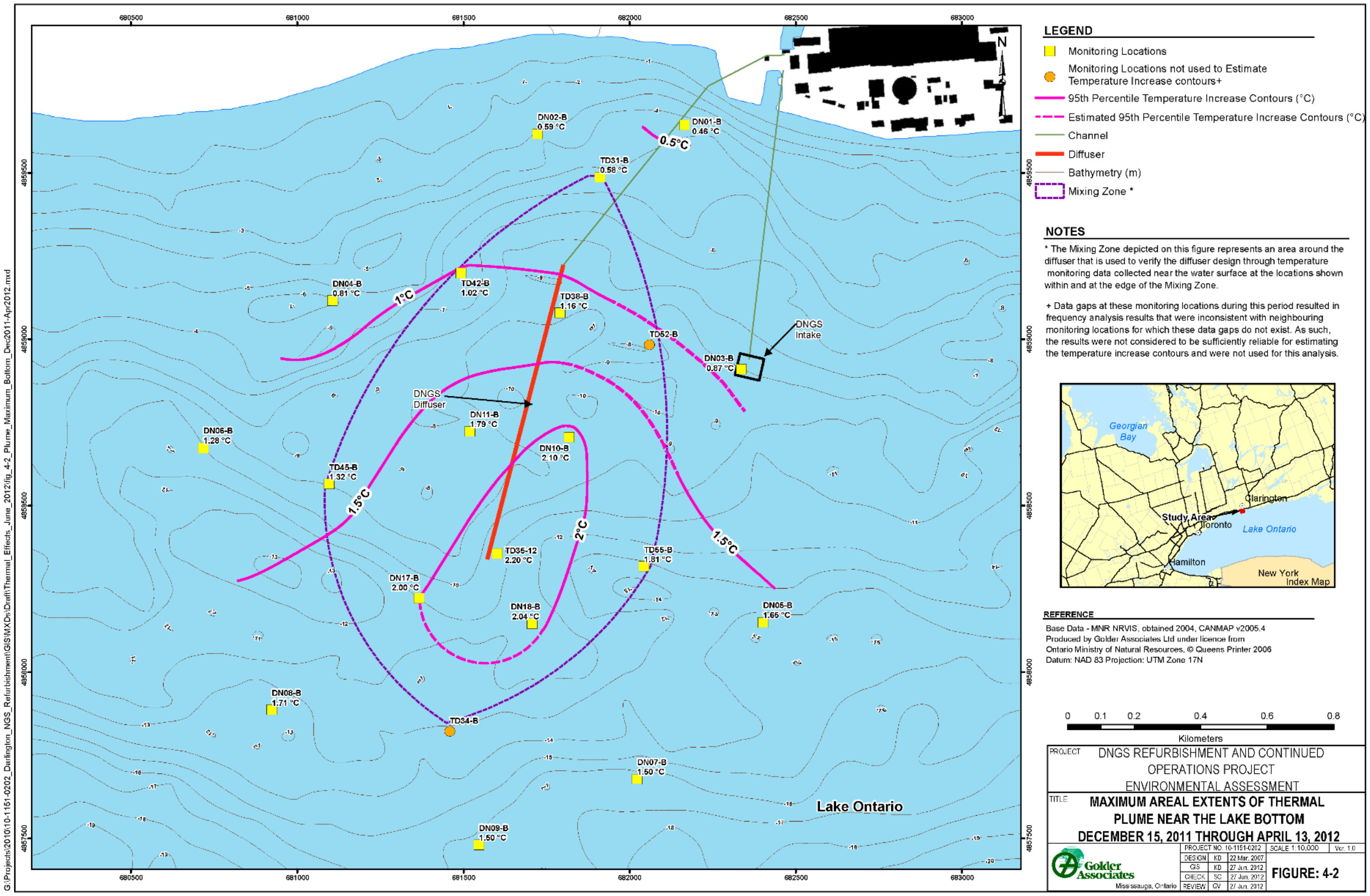

Figure 4-4: 2011-2012 Maximum Extent of Thermal Plume – Temperature above Ambient (Golder, 2012b)

Error! Reference source not found. shows the frequency of various ΔT values at individual locations either inside the turbulent mixing zone, at the edge of this zone, or outside this zone. These data indicate that a ΔT of 3°C is a rare occurrence within the mixing zone, and never occurs outside this zone.

Table 4-51: Frequency of Hourly Average Bottom Water Temperatures Increases Over Ambient - Period of December 15, 2011 through April 13, 2012 (Second Winter Period)

Location	Water Depth (m)	No. of Data Points	Increase Over Ambient							
			Average	75th Percentile	95th Percentile	Frequency of Exceedance				
						1°C	2°C	3°C	4°C	5°C
Inside Mixing Zone										
TD38-B	10	1,713	-0.11	0.36	1.16	7.4%	0.0%	0.0%	0.0%	0.0%
TD35-12	12	2,903	0.69	1.26	2.20	37%	6.8%	1.7%	0.7%	0.0%
DN10-B	11	2,122	1.11	1.56	2.10	57%	7.5%	0.0%	0.0%	0.0%
DN11-B	10	1,966	0.28	0.97	1.79	24%	2.8%	0.0%	0.0%	0.0%
DN17-B	12.5	2,904	0.45	1.15	2.00	30%	5.0%	0.0%	0.0%	0.0%
DN18-B	12.5	2,904	0.54	1.36	2.04	38%	5.8%	0.2%	0.0%	0.0%
Edge of Mixing Zone (Clockwise from Nearshore – starting at TD31)										
TD31-B	6	2,904	-0.20	0.08	0.58	0.3%	0.0%	0.0%	0.0%	0.0%
TD52-B	10	1,210	0.81	1.09	1.64	31%	1.2%	0.0%	0.0%	0.0%
TD55-B	15	2,904	0.21	1.00	1.81	25%	2.9%	0.0%	0.0%	0.0%
TD34-B	14	966	-0.34	0.56	1.53	11%	1.4%	0.0%	0.0%	0.0%
TD45-B	10	2,904	0.13	0.64	1.32	12%	0.4%	0.0%	0.0%	0.0%
TD42-B	8	1,875	0.04	0.47	1.02	5.7%	0.0%	0.0%	0.0%	0.0%
Outside Regulated Mixing Zone (Clockwise from Nearshore – starting at DN01)										
DN01-B	6	1,030	-0.27	0.12	0.46	0.2%	0.0%	0.0%	0.0%	0.0%
DN03-B	11	1,694	-0.43	0.23	0.87	2.7%	0.0%	0.0%	0.0%	0.0%
DN05-B	15	2,904	0.18	0.97	1.65	24%	2.0%	0.0%	0.0%	0.0%
DN07-B	18	2,904	0.15	0.94	1.50	22%	0.8%	0.0%	0.0%	0.0%
DN09-B	18	2,365	0.01	0.84	1.50	18%	0.3%	0.0%	0.0%	0.0%
DN08-B	14	2,904	0.30	0.95	1.71	23%	2.3%	0.0%	0.0%	0.0%
DN06-B	12	1,920	0.03	0.61	1.28	11%	0.2%	0.0%	0.0%	0.0%
DN04-B	7	1,921	-0.08	0.28	0.81	3.0%	0.0%	0.0%	0.0%	0.0%
DN02-B	5	2,901	-0.18	0.08	0.59	0.5%	0.0%	0.0%	0.0%	0.0%

Source: Golder, 2012b

The Golder (2012b) assessment of thermal effects focused on the round whitefish because its sensitive embryonic life stage is expected to be present in the diffuser area from January through March. Eggs are typically deposited sometime in December, at water depths of 5-10m, and hatch in late March or early April. After hatch, the larvae move inshore to feed over the summer, and then move offshore in the fall.

Golder cited an optimal temperature range of 1ºC to 5ºC for round whitefish embryos (Wismer and Christie, 1987) and a continuous ΔT of 3.5ºC or a periodic (6h/day) ΔT of 5ºC (Griffiths, 1980) as being consistent with adequate embryonic survival. Using 7 day average lake temperatures for comparison to the optimal range, and ΔT as shown in **Error! Reference source not found.**, it was concluded that no benchmarks for adverse effect are exceeded as a result of the DN thermal discharge, and that no adverse effects on round whitefish embryos are expected.

Since the studies by Griffiths used an unrealistic temperature regime (base temperature for 16 h/day followed by an abrupt shift to the increased temperature for 8h/day) and had relatively poor survival even at ambient temperature (88%), the CANDU Owners Group (COG) funded new studies of round whitefish embryo survival using a naturally varying base temperature. In these studies (Patrick et al., 2014), survival was 99% under the ambient temperature condition. The COG study found that a reduction to 90% survival required a temperature increase of 3.7ºC above ambient. The ΔT values around the DN diffuser are well below this level.

Various statistical models can be fit to the COG data, as described in Appendix B of the report, and used to predict round whitefish survival for any sequence of temperatures measured over the embryonic period. First the duration of the embryonic period must be predicted, since this also depends on the temperature regime. OPG (2014c) used a degree day model, fit to the COG data, to predict this duration at specific locations where temperature was continuously recorded, assumed three different fertilization dates in December, and then used a logistic quadratic model to predict survival at each location based on average temperature over the period. The results are shown in **Error! Reference source not found.**.

As seen in **Error! Reference source not found.**, the predicted survival over the winter of 2011-2012 was greater than 95%. The largest predicted survival loss (as compared to an average of Thickson Point and Bonnie Brae reference locations) was 1.1%, well below the 10% threshold used by the CNSC in the Darlington Refurbishment EA to demark a moderate risk.

Table 4-52: Predicted Egg Survival for Round Whitefish at DN and Farfield Locations for the Winter of 2011-2012 Based on the COG Model (Patrick et al., 2014)

	1-Dec-11				15-Dec-11				30-Dec-11			
Location	Predicted Hatch Date	Average Temp	Survival	Relative Survival Loss	Predicted Hatch Date	Average Temp	Survival	Relative Survival Loss	Predicted Hatch Date	Average Temp	Survival	Relative Survival Loss
ADCP	1-Mar-12	3.6	97.4%	0.1%	18-Mar-12	3.4	97.6%	0.0%	1-Apr-12	3.5	97.5%	0.3%
DN02-B	7-Mar-12	3.0	97.9%	-0.4%	21-Mar-12	3.0	97.9%	-0.3%	2-Apr-12	3.4	97.6%	0.2%
DN04-B	3-Mar-12	3.4	97.6%	-0.1%	19-Mar-12	3.3	97.7%	-0.1%	31-Mar-12	3.6	97.5%	0.4%
DN05-B	27-Feb-12	4.0	97.0%	0.5%	15-Mar-12	3.7	97.3%	0.3%	30-Mar-21	3.7	97.3%	0.6%
DN07-B	28-Feb-12	3.9	97.1%	0.4%	15-Mar-12	3.7	97.3%	0.3%	30-Mar-12	3.7	97.3%	0.5%
DN08-B	28-Feb-12	4.0	97.0%	0.5%	15-Mar-12	3.7	97.3%	0.3%	28-Mar-12	3.9	97.1%	0.7%
DN09-B	6-Mar-12	4.1	96.9%	0.6%					4-Apr-12	4.0	96.9%	0.9%
DN10-B	25-Feb-12	4.3	96.5%	1.0%	12-Mar-12	4.1	96.9%	0.7%				
DN13-B	28-Feb-12	3.9	97.1%	0.4%	16-Mar-12	3.6	97.4%	0.2%	30-Mar-12	3.7	97.3%	0.5%
DN15-5	4-Mar-12	3.4	97.6%	-0.1%	19-Mar-12	3.3	97.7%	-0.1%	31-Mar-12	3.6	97.5%	0.4%
DN16-B	1-Mar-12	3.7	97.3%	0.2%	17-Mar-12	3.5	97.6%	0.1%	31-Mar-12	3.6	97.4%	0.4%
DN17-B	26-Feb-12	4.1	96.9%	0.6%	14-Mar-12	3.8	97.2%	0.4%	27-Mar-12	4.0	97.0%	0.8%
DN18-B	25-Feb-12	4.2	96.7%	0.8%	12-Mar-12	4.0	97.0%	0.6%				
PG1-B	8-Mar-12	2.9	97.9%	-0.5%	23-Mar-12	2.9	98.0%	-0.4%	4-Apr-12	3.2	97.8%	0.0%
TD31-B	6-Mar-12	3.1	97.8%	-0.3%	21-Mar-12	3.1	97.9%	-0.2%	2-Apr-12	3.4	97.6%	0.2%
TD35-B	26-Feb-12	4.1	96.8%	0.7%	13-Mar-12	3.9	97.1%	0.6%	26-Mar-12	4.2	96.7%	1.1%
TD45-B	1-Mar-12	3.7	97.4%	0.1%	17-Mar-12	3.5	97.5%	0.1%	30-Mar-12	3.7	97.3%	0.5%
TD55-B	27-Feb-12	4.0	96.9%	0.6%	15-Mar-12	3.7	97.3%	0.3%	29-Mar-12	3.7	97.3%	0.6%
Totals	29-Feb-12	3.8	97.2%	0.3%	16-Mar-12	3.5	97.5%	0.2%	22-Oct-12	3.7	97.3%	0.5%

Note:
DN10 and TD35 are within the turbulent mixing zone; other stations are at the edge or outside this zone. Far-field locations are Port Darlington (ADCP) and Port Granby (PG1-B), 11 and 18 km east of DN, respectively

SENES (2011a) and Golder (2010) considered maximum weekly average temperatures (MWATs) in the vicinity of the DN thermal discharge, and compared these to MWAT criteria for other fish species known to occur in the area, including emerald shiner, alewife, white sucker and lake trout (**Error! Reference source not found.**). The measured weekly average temperatures were calculated from temperature records collected using dataloggers installed at 35 locations in and around the DN thermal discharge over the period 1993-1996 (Golder, 2011a, Appendix C). The measured MWATs did not exceed any of the relevant MWAT criteria. It was concluded that no effects are expected on local fishes due to the influence of the DN thermal discharge.

4.4.4 Impingement and Entrainment

4.4.4.1 Fish Impingement

Fish impingement sampling was conducted between May 2010 and April 2011 (SENES, 2011b). Each sample was collected from the travelling screens at one unit over a 24-hour period. Samples were collected at least weekly, and twice per week during May-July and

February-March. At least four samples were collected in each month, at one to four units in each month.

Daily impingement rates by species were calculated for each unit in each month. Based on the number of days operating and the number of pumps operating at each unit in each month, the daily rates were used to calculate monthly rates for the station when operating at full capacity.

The monthly impingement rates by species, and the estimated annual total, are shown in **Error! Reference source not found.**. Thirteen fish species were taken at DN, assuming that *Cottus* sp. is the slimy sculpin, with alewife and round goby representing 97% of the counts. The estimated annual total was 274,931 fish impinged.

The monthly fish biomass taken by species, and the estimated annual total, are shown in **Error! Reference source not found.**. Alewife and round goby represented 97% of the biomass taken. The estimated annual total was 2,362 kg of fish biomass.

Table 4-53: Estimates of Total Annual Impingement (Counts), May 2010 – April 2011 (SENES, 2011b)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
Alewife	3240	26	17	11	550	3926	8255	4280	2142	4176	1921	86950	115465	42.1
American eel	0	5	0	0	0	0	0	0	0	0	0	0	5	0.0
Brown bullhead	0	0	4	0	0	0	0	0	0	0	0	0	4	0.0
Emerald Shiner	0	5	21	0	0	0	0	0	0	0	0	60	86	0.0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rainbow smelt	180	31	27	43	1349	829	1150	872	10	94	339	933	5857	2.1
Round goby	21240	5238	8924	21410	23576	10920	24513	9216	728	3169	4317	18261	151510	55.1
Slimy sculpin	0	16	63	34	0	0	0	0	0	0	0	0	113	0.0
Smallmouth bass	0	0	0	0	0	0	0	8	0	0	0	0	8	0.0
Spoonhead sculpin	0	256	94	83	481	325	276	40					1555	0.6
Threespine stickleback	0	5	0	0	0	0	0	0	0	0	0	0	5	0.0
Cottus sp.	0	157	4	0	0	0	0	0	0	0	0	0	161	0.1
Sunfish (unident.)	0	5	0	0	0	0	0	0	0	0	0	0	5	0.0
White sucker	0	5	0	0	0	0	34	0	0	0	0	0	39	0.0
Yellow perch	0	5	0	6	0	0	0	0	0	0	0	0	11	0.0
Total	**24660**	**5755**	**9154**	**21587**	**25955**	**16000**	**34232**	**14416**	**2881**	**7439**	**6577**	**106276**	**274931**	**100**

Table 4-54: Estimates of Total Annual Impingement (Biomass) (kg), May 2010 – April 2011 (SENES, 2011b)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
Alewife	29.20	0.27	0.10	0.02	4.28	36.16	33.61	31.02	4.11	11.57	9.85	833.92	994	42.1
American eel	0	7.48	0	0	0	0	0	0	0	0	0	0	7.5	0.3
Brown bullhead	0	0	0.01	0	0	0	0	0	0	0	0	0	0.0	0.0
Emerald Shiner	0	0.01	0.04	0	0	0	0	0	0	0	0	0.27	0.3	0.0
Pumpkinseed	0	0	0	0	0	0	0.27	0	0	0	0	0.22	0.5	0.0
Rainbow smelt	1.50	0.22	0.12	0.47	8.97	4.21	5.99	5.06	0.10	1.22	1.56	3.98	33	1.4
Round goby	164.7	41.59	70.55	192.7	217.8	117.6	219.7	92.21	5.27	28.75	41.8	115.3	1308	55.4
Slimy sculpin	0	0.12	0.62	0.34	0	0	0	0	0	0	0	0	1.1	0.0
Smallmouth bass	0	0	0	0	0	0	0	0.08	0	0	0	0	0.0	0.0
Spoonhead sculpin	0	2.84	1.03	0.78	3.71	2.02	2.31	0.34					13	0.6
Threespine stickleback	0	0.01	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Cottus sp.	0	1.71	0.04	0	0	0	0	0	0	0	0	0	1.8	0.1
Sunfish (unident.)	0	0.04	0	0	0	0	0	0	0	0	0	0	0.0	0.0
White sucker	0	2.02	0	0	0	0	.34	0	0	0	0	0	2.4	0.1
Yellow perch	0	0.14	0	0.04	0	0	0	0	0	0	0	0	0.2	0.0
Total	195.4	56.45	72.52	194.3	234.7	160.0	262.2	128.7	9.49	41.55	53.2	953.7	2362	100

Both numbers and biomass of fish impinged in 2010-2011 were higher than the estimates made in 2006-2007 (26,024 fish, 893 kg, assuming all units impinged similar amounts as Unit 4). The greater impingement in 2010-11 is explained partly by population changes in round goby and alewife. The round goby is an invasive species which has likely increased in the area as it invades Lake Ontario. The alewife population has been increasing in Lake Ontario, following a previous decline. According to the MNR (2010), the alewife population (age 1 and over) was estimated at 1650 metric tonnes (MT) in 2006, and 5298 MT in 2009. The age 1 year class had particularly increased, with the 2010 age 1 year class being the third largest in the past 15 years (Walsh and Connerton, 2011). In addition, the sampling in 2010-11 was more intensive, likely providing more accurate estimates, and the new travelling screens installed in 2010 are likely more efficient. The large counts of alewife in December 2010 (75% of the annual counts) may have been associated with an upwelling event, as suggested by SENES (2011b).

4.4.4.1.1 Equivalent Loss Metrics

Various “equivalent loss” metrics can be calculated from the counts of fish impinged, as recommended in CSA N288.6-12. These metrics, including equivalent age 1, equivalent fishery yield, and production foregone, are more relevant to effect on the population than are the raw counts (Dey, 2002; U.S. EPA, 2002; EPRI, 2004), and facilitate comparison to fishery statistics. These metrics were calculated using the 2010-2011 fish impingement data (SENES, 2011b). The results are presented in **Error! Reference source not found.**.

Equivalent Age 1 values were calculated for most fish species, using standard life history parameters as described by SENES (2011b). The unidentified sculpin (*Cottus* sp.) were considered to be slimy sculpin. The unidentified sunfish were considered to be pumpkinseed. As calculated by SENES, the equivalent age 1 values can be greater than the annual counts if the fish taken at the station are mainly older than age 1. This was particularly evident for round goby because the individuals taken were mainly at 2+ and 3+ ages.

Production foregone values represent the loss of future biomass due to the foregone growth of the fish taken at the station. This metric is usually calculated for forage fish, since their ecological value is in the production of prey biomass. It was calculated by SENES (2011b) for most fish species. The production foregone over all species considered was 905 kg, mainly from alewife, round goby and rainbow smelt. Adding this to the biomass of fish lost at the time of impingement (2355 kg) a total biomass loss of 3260 kg was calculated.

Lost Fishery Yield was calculated only for species with commercial or recreational fisheries. This metric represents the loss of future fishery yield (expressed as biomass) that will not be harvested as a result of fish taken at the station. The Lost Fishery Yield was only 89 kg and consisted almost exclusively of rainbow smelt.

Table 4-55: Estimates of Annual Equivalent Loss from Impingement at the Darlington Nuclear Generating Station, May 2010 – April 2011 (SENES, 2011b)

Taxa	Number of Equivalent Age 1+	Total Annual Impingement Weight (kg)	Total Future Production Foregone (kg)	Total Biomass Lost (kg)	Lost Fishery Yield (kg)
Alewife	56,515	994.14	576.65	1,570.79	N/A
Brown bullhead	7	0.01	0.60	0.61	0.21
Emerald shiner	1,006	0.32	0.09	0.41	N/A
Pumpkinseed	132	0.49	2.59	3.09	0.75
Rainbow smelt	20,114	33.42	111.93	145.35	87.30
Round goby	3,860,403	1,307.85	207.27	1,515.12	N/A
Slimy sculpin	26,573	1.08	0.09	1.17	N/A
Smallmouth bass	0	0.08	0.04	0.12	0.01
Spoonhead sculpin	237,962	13.02	2.44	15.46	N/A
Threespine stickleback	20	0.01	0.00	0.01	N/A
Unidentified sculpin	39,281	1.75	0.13	1.88	N/A
Unidentified sunfish	8	0.04	0.14	0.18	0.04
White sucker	21	2.35	2.57	4.92	0.56
Yellow perch	10	0.18	0.93	1.11	0.35
Total	**4,242,050**	**2,354.75**	**905.47**	**3,260.22**	**89.22**

N/A = not applicable
Unidentified sculpin – likely slimy sculpin

4.4.4.1.2 Comparison to Fishery Statistics

The alewife population in Lake Ontario in 2009 was estimated at 134 million age 1 and older fish, with a biomass of 5298 metric tonnes (MNR, 2010). The take of alewife at DN in 2010-2011 was equivalent to 56,515 age 1 fish, or 0.04% of the population. The total biomass lost, including production foregone, was 1571 kg, or 0.03% of the population biomass. These losses are negligible.

The rainbow smelt population in Lake Ontario in 2009 was estimated at 311 million age 1 and older fish, with a biomass of 1714 metric tonnes (MNR, 2010). The take of rainbow smelt at DN in 2010-2011 was 5857 fish, or 0.002% of the population. The total biomass lost, including production foregone, was 145 kg, or 0.008% of the population biomass. These losses are negligible.

The invasive round goby has increased rapidly in Lake Ontario since appearing in 2002, with a concurrent decline in the native benthic prey species such as the slimy sculpin (NYDEC, 2014). Based on bottom trawl surveys on the U.S. side of the lake, round goby density is approximately 0.03/m^2, with a biomass of 0.2 g/m^2. For a lake area of

18,960 km^2, Lake Ontario may contain around 568 million round goby, and a biomass of around 3.8 million kg. These are very rough estimates. The take of round goby at DN in 2010-2011 was 151,510 fish, or 0.27% of the population. On a biomass basis, the total biomass lost, including production foregone, was 1515 kg, or 0.04% of the population. These losses are negligible.

The losses of other species due to impingement at DN are trivial. In no case could the loss of these fish have any plausible effect on their populations.

4.4.4.2 Entrainment

Studies of fish egg and larval entrainment at DN were conducted in 2004 (June – August) and 2006 (March – September) (Ager et al., 2005, 2006). Samples were collected using larval tows in the forebay. The 2004 samples were comprised mainly of rainbow smelt and alewife. The annualized estimates of entrainment were 15,631,833 eggs, and 1,201,943 larvae, representing 1,318 age-1 equivalent fish. The production foregone was estimated at 46.2 kg. The 2006 samples were comprised mainly of alewife, common carp and freshwater drum. The annualized estimates of entrainment were 605,059 eggs and 6,996,246 larvae, representing 11,548 age-1 equivalent fish.

Limited sampling was conducted in the forebay in April and July, 2010 (SENES, 2011a). Both fish and aquatic invertebrates were enumerated in these samples. Fish in the samples included larvae of round goby, round whitefish and alewife. Invertebrates included two species of freshwater shrimp (*Mysis relicta*, and the invasive *Hemimysis anomala*). The sampling effort was considered insufficient to support calculation of annualized losses or equivalent loss metrics.

As a follow-up program to the environmental assessment for DN refurbishment and continued operation, more intensive studies of fish (eggs and larvae) and macro benthic invertebrate entrainment are being completed in 2015/2016 (OPG, 2015d). Entrainment sampling was proposed in the DN forebay from December 2015 to November 2016, for a total of 62 sampling events. Sampling has focused on continuous 24-hr collections and each sampling event has a day time and night time sample, approximately 12-hrs each depending on daylight hours. Sample frequency was approximately weekly in December, biweekly in January and February, weekly in March, twice weekly from April through July, weekly for August and September, and biweekly for October and November. In addition, larval tows occurred in the area of the DN intake, and in two reference areas (vicinity of Bond Head and Thickson Point), over three epifauna sampling events (May, late June, and late August). Infauna sampling occurred in late August/early September. In each event, in each area, sampling occurred at three water depths (approximately 5 m, 10 m and 15 m).

The lake sampling will indicate whether entrained samples are similar to lake samples, and whether entrainment could be inferred from intake flows and lake sampling data. It will also enable comparison of the intake area with reference areas to determine if there is any measureable effect of DN operations on benthic invertebrate communities. Results from the 2015/2016 entrainment and benthic invertebrate community sampling program are still in progress and will be reported to the CNSC under a separate report.

4.4.5 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, dose coefficients and averaging assumptions (discussed in Section 4.2), as well as benchmark values used to determine risk of potential effects (discussed in Section 4.3).

Overall, considering uncertainties in the exposure assessments and the benchmark values, it is reasonable to consider that HQs above 1 for a COPC, receptor and location are indicative of a potential for adverse effects. However it does not necessarily imply adverse effects. In some cases, field studies may be appropriate to clarify whether effects are occurring.

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 (2012), a qualitative or semi-quantitative evaluation of uncertainty is considered sufficient for evaluation of uncertainty.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Conclusions of Human Health Risk Assessment (HHRA)

5.1.1.1 Non-Radiological HHRA

Potential risks to human receptors were characterized quantitatively in terms of Hazard Quotients (HQs) for non-carcinogens (morpholine, nitrate) and Incremental Lifetime Cancer Risks (ILCRs) for potential carcinogens (hydrazine). The target risk threshold is 0.2 for non-cancer risk (HQ) and a target cancer risk of 10^{-6} (ILCR). The results of the qualitative HHRA are as follows.

- No increased risk to human receptors is expected resulting from exposure to morpholine.
- The target risk for non-cancer risk was exceeded for the Oshawa/Courtice and Bowmanville Urban Residents due to exposure to maximum nitrate in drinking water, based on surface water data collected in 2009. Mean water concentrations of nitrate did not exceed the target risk. Additionally, based on the 2016 effluent characterization study, all measured nitrate concentrations in the effluent were below the drinking water quality guideline for nitrate of 10 mg/L.
- The target risk for cancer risk was exceeded for the Oshawa/Courtice and Bowmanville Urban Residents and for the Camper due to exposure to maximum and mean concentrations of hydrazine in drinking water,
- The target risk for cancer risk was exceeded for the Industrial/Commercial Worker due to exposure to maximum concentration of hydrazine in drinking water, but not based on the mean hydrazine concentration. Since exposure to the mean concentration is considered more representative of long-term exposures, health risks to the Industrial/Commercial Worker due to hydrazine are not expected.
- The target risk for cancer risk was exceeded for the Sport Fisher due to exposure to maximum and mean concentrations of hydrazine estimated in fish. This receptor was assumed to eat all of the fish portion of their diet from Lake Ontario fish caught at DN, which is very conservative.

Overall, health risks are not expected for human receptors due to nitrate and morpholine in water and in fish. Risks could not be ruled out for the Sport Fisher due to hydrazine in fish, and to the Oshawa/Courtice and Bowmanville Urban Residents as well as Campers due to hydrazine in drinking water.

5.1.2 Radiological HHRA

For exposure of human receptors to radiological COPCs, the relevant exposure pathways and human receptors (critical groups) were those presented in the annual OPG EMP reports. Radiological dose calculations followed the methodology outlined in CSA N288.1-08. The 2011-2015 public dose estimates for the critical groups are at most approximately 0.06% of the regulatory public dose limit of 1 mSv/a, and at most approximately 0.04% of the dose from background radiation in the vicinity of DN. Since these critical groups receive the highest dose from DN, demonstration that they are protected implies that other receptor groups near DN are also protected.

5.2 Conclusions Ecological Risk Assessment (EcoRA)

5.2.1 Non-Radiological EcoRA

The potential for ecological effects was assessed by comparing exposure levels to toxicological benchmarks, and characterized quantitatively in terms HQs. A HQ greater than 1 indicates a need to more closely assess the risk to the concerned VEC.

Lake Ontario

Maximum surface water concentrations for copper (0.004 mg/L) and nitrate (89.7 mg/L) in the nearshore Lake Ontario exceeded the target benchmarks for copper and nitrate for fish and the target benchmarks for nitrate for benthic invertebrates. Based on data collected from the 2016 effluent characterization study, the maximum copper and nitrate concentrations in the CCW were 0.0019 mg/L and 0.44 mg/L, respectively, lower than the maximum measured surface water data from Lake Ontario in 2009. Looking at the data from the 2016 effluent characterization study, the facility contribution for copper and nitrate is low.

Based on mean copper (0.001 mg/L) and nitrate (2.8 mg/L) concentrations no benchmarks were exceeded for copper and nitrate. Because fish are more mobile around a wider area, the HQs for mean water concentrations for copper and nitrate are more representative of fish exposure than maximum concentrations. As such, fish are likely not at toxicological risk from DN operations.

Mean nitrate surface water concentrations are more representative of chronic exposure to benthic invertebrates than maximum nitrate water concentrations because nitrate concentrations are not expected to remain at these high concentrations in the environment. As such, benthic invertebrates may not be at risk to nitrate exposure via water exposure on a long term basis. Additionally, although a few benthic invertebrates may be exposed to these maximum concentrations, the community as a whole is not expected to be affected.

Maximum sediment concentrations for Lake Ontario exceeded the sediment target benchmark for copper for benthic invertebrates. The mean sediment concentrations for Lake Ontario did not exceed the sediment benchmarks. However, there is uncertainty surrounding this risk because sediment in Lake Ontario is transient and the invertebrate community is mainly epifaunal. In other words, this suggests that the sediment exposure pathway is unlikely to be the primary exposure route for benthic invertebrates in Lake

Ontario. Although, a few benthic invertebrates may be exposed to these maximum copper in sediment, the benthic community is not expected to be affected as a whole.

The American Eel is identified as a species at risk; therefore the assessment endpoint is the health of the individual. As discussed above, the fish benchmarks were exceeded for maximum water concentrations of copper and nitrate, but not for mean water concentrations. Since fish are more mobile around a wider area, the HQs for mean water concentrations are more representative than maximum concentrations. As such, the American Eel and other fish VECs are likely not at risk from DN operations.

The HQ target of 1 was exceeded for the Bufflehead when exposed to maximum concentrations of aluminum in water, sediment, but not when exposed to mean concentrations. Exposure to mean concentration is more likely as it is unlikely that the Bufflehead will spend most of its time at the DN diffuser.

There were no data to determine nitrate benchmarks for birds. As such, there is uncertainty around potential health risks to birds due to nitrate Any health risks to birds due to nitrate are, however, expected to be due to sources of nitrate other than DN, since CCW effluent and storm water only contribute small nitrate loadings to Lake Ontario.

Polygon AB

An aquatic and terrestrial assessment of VECs located in Polygon AB (Coots Pond) was performed.

The results of the aquatic assessment in Coots Pond showed exceedances of the HQ target of 1 for:

- aluminum for aquatic plants, benthic invertebrates, bufflehead, mallard, and muskrat based on maximum and mean aluminum concentrations in water and sediment;
- copper, manganese (maximum only), phosphorus, and vanadium for benthic invertebrates based on maximum and mean concentrations in sediment;
- iron for benthic invertebrates based on maximum and mean concentrations in water;
- ammonia for fish and turtle/frog based on maximum and mean concentrations in water.

Although potential risks were identified to aquatic and riparian receptors at Coots Pond from a number of COPCs, the source of these COPCs in Coots Pond is not the result of emissions from the DN site, but likely from construction debris placed in the landfill and subsequent stormwater runoff since the pond is designed to be a settling pond for stormwater runoff. Based on field studies conducted during the Darlington NND EA and subsequent biodiversity studies, Coots Pond has provided and continues to provide valuable habitat and breeding areas for fish (Northern Redbelly Dace), amphibians, birds, and mammals.

The results of the terrestrial assessment in Polygon AB showed exceedances of the HQ target of 1 for boron (hot water soluble, HWS) for terrestrial plants exposed to maximum boron (HWS) soil concentrations, but not for exposure to mean boron (HWS) soil concentrations. This suggests that soils on site that exceed the boron (HWS) maximum are localized on site, rather than deposition from atmospheric sources. Although individual plants may be affected, the plant population should not be affected.

Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium, strontium, and lead. There were no data to determine strontium benchmarks for birds. Strontium competes with calcium but it does not have a toxic effect on bone in chicks. A study (cited in Skoryna, 1981) found that there were no deleterious effects on chicks until very high doses were given. This dose is reported to be much higher than the benchmark value used to assess strontium effects on mammals. If the benchmark value for birds were set to the mammal benchmark, which could be interpreted as a NOAEL, there would be no exceedances.

Polygon C

Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium, strontium, and tin. No risks were identified for terrestrial biota for polygon C.

There were no data to determine strontium benchmarks for birds. As discussed above, when strontium benchmark values for birds are set to strontium benchmarks for mammals, there are no exceedances for polygon C.

There were no data to determine tin benchmarks for soil invertebrates. As such, there are uncertainties associated with the effects assessment for soil invertebrates exposed to tin concentrations in soil. However, it is unlikely that there would be adverse effects to soil invertebrates due to tin, because the maximum tin soil concentration in Polygon C is 15 mg/kg dw, well below the derived sediment effects concentration of 130 mg/kg dw (used as a surrogate for soil).

Polygon D

An aquatic and terrestrial assessment of VECs located in Polygon D (Treefrog Pond) was performed.

The results of the aquatic assessment in Treefrog Pond showed exceedances of the HQ target of 1 for:

- boron for turtle and frog based on the maximum water concentration but not the mean water concentration;

- iron for turtle, frog, and aquatic plants based on the maximum water concentration but not the mean water concentration; and

Overall, turtles and frogs move around; therefore, exposure to mean concentrations is more representative of exposure than the maximum concentrations. Adverse effects to turtles and frogs in Treefrog Pond are not expected.

The results of the terrestrial assessment in Polygon D showed that where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium, strontium, and tin. No risks were identified for terrestrial biota for polygon D.

There were no data to determine strontium benchmarks for birds. As discussed above and based on the study cited in Skoryna (1981) when the benchmark value for birds is set to the mammal benchmark, there are no exceedances for Polygon D.

There were no data to determine tin benchmarks for soil invertebrates. As such, there are uncertainties associated with the effects assessment for soil invertebrates exposed to tin concentrations in soil. However it is unlikely that there would be adverse effects on soil invertebrates due to tin, because the maximum tin soil concentration in Polygon D is 11 mg/kg dw, well below the derived sediment effects concentration of 130 mg/kg dw (used as a surrogate for soil).

Polygon E

Where data were available, the HQ target of 1 was not exceeded for terrestrial biota for barium and strontium. No risks were identified for terrestrial biota for polygon E.

There were no data to determine strontium benchmarks for birds. As discussed above, when the strontium benchmark value for birds is set to the mammal benchmark, there would be no exceedances for Polygon E.

Thermal Effects

An assessment of thermal effects from the warm cooling water discharged by DN was conducted in 2011 and 2012 by Golder (2012b) at 31 locations in and around the discharge, and at reference (ambient) locations. These data indicate that a ΔT of $3^{o}C$ is a rare occurrence within the mixing zone, and never occurs outside this zone.

The Golder (2012b) assessment of thermal effects focused on the round whitefish because its sensitive embryonic life stage is expected to be present in the diffuser area from January through March. Eggs are typically deposited sometime in December, at water depths of 5-10m, and hatch in late March or early April. After hatch, the larvae move inshore to feed over the summer, and then move offshore in the fall. Golder cited an optimal temperature range of $1^{o}C$ to $5^{o}C$ for round whitefish embryos (Wismer and Christie, 1987) and a continuous ΔT of 3.5ºC or a periodic (6h/day) ΔT of 5ºC (Griffiths, 1980) as being consistent with adequate embryonic survival.

Since the studies by Griffiths used an unrealistic temperature regime (base temperature for 16 h/day followed by an abrupt shift to the increased temperature for 8h/day) and had relatively poor survival even at ambient temperature (88%), the CANDU Owners Group (COG) funded new studies of round whitefish embryo survival using a naturally varying base temperature. In these studies (Patrick et al., 2014), survival was 99% under the ambient temperature condition. The COG study found that a reduction to 90% survival required a temperature increase of 3.7ºC above ambient. The ΔT values around the DN diffuser are well below this level.

Round whitefish survival for any sequence of temperatures measured over the embryonic period can be predicted. The predicted survival over the winter of 2011-2012 was greater than 95%.

Impingement/Entrainment

Fish impingement sampling was conducted between May 2010 and April 2011 (SENES, 2011b). Thirteen fish species were taken at DN, with alewife and round goby representing 97% of the counts. The estimated annual total was 274,931 fish impinged. By fish biomass, alewife and round goby represented 97% of the biomass taken. The estimated annual total was 2,362 kg of fish biomass.

Studies of fish egg and larval entrainment at DN were conducted in 2004 (June – August) and 2006 (March – September), and April and July 2010. As a follow-up program to the environmental assessment for DN refurbishment and continued operation, more intensive studies of fish (eggs and larvae) and macro benthic invertebrate entrainment are being completed in 2015/2016 (OPG, 2015d). The lake sampling will indicate whether entrained samples are similar to lake samples, and whether entrainment could be inferred from intake flows and lake sampling data. It will also enable comparison of the intake area with reference areas to determine if there is any measureable effect of DN operations on benthic invertebrate communities.

5.2.2 Radiological EcoRA

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 assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in the CSA N288.6-12 standard (CSA 2012).

Lake Ontario

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota at the SSA in Lake Ontario, including fish and benthic invertebrates. The 2.4 mGy/d radiation benchmark has also not been exceeded for the Bufflehead and Mallard.

Polygon AB

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota in Coots Pond (Polygon AB). Aquatic biota include: Northern Redbelly Dace, turtles, frogs, aquatic plants and benthic invertebrates.

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial and riparian biota for Polygon AB. Terrestrial and riparian biota include: Bufflehead, Mallard and muskrat at Coots Pond, earthworms, terrestrial plants (grass), American Robin, Bank Swallow (a species at risk), Song Sparrow, Yellow Warbler, Eastern cottontail, meadow vole, white-tailed deer, common shrew, raccoon, red fox, and short-tailed weasel.

Although the radiation dose to all receptors located in Coots Pond (Polygon AB) was below the radiation dose benchmarks for aquatic and terrestrial receptors, there is uncertainty regarding the contribution of DN emissions to the tritium concentration measured in Coots Pond. Although Coots Pond receives runoff from the DN landfill it does not receive effluent from the DN site, other than through atmospheric deposition. The maximum tritium concentration measured in Coots Pond to support the 2009 NND EA was 78 Bq/L compared to 7.5 Bq/L in Lake Ontario in the vicinity of DN. Lake Ontario receives tritium emissions from DN, but has a much lower tritium concentration than Coots Pond.

Polygon C

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial biota at Polygon C. Terrestrial biota include earthworms, terrestrial plants (grass), American Robin, Song Sparrow, Yellow Warbler, Eastern cottontail, meadow vole, white-tailed deer, common shrew, raccoon, red fox, and short-tailed weasel.

Polygon D

There are no exceedances of the 9.6 mGy/d radiation benchmark for the aquatic biota present at Treefrog Pond. Aquatic biota at Treefrog Pond include: turtles, frogs, and aquatic plants.

Because Dragonfly and Polliwog Ponds are known to dry up at different times of the year, the surface water and sediment concentrations at Treefrog Pond, along with the aquatic biota present at this pond, have been used to represent surface water and sediment concentrations along with the presence of potential aquatic biota at Dragonfly and Polliwog ponds.

Polygon E

There are no exceedances of the 2.4 mGy/d radiation benchmark for terrestrial biota at Polygon E. Terrestrial biota include: earthworms, terrestrial plants (grass and sugar maple), American robin, song sparrow, yellow warbler, Eastern cottontail, meadow vole, white-tailed deer, common shrew, raccoon, red fox, and short-tailed weasel.

Darlington Waste Management Facility

The maximum dose rate to any ecological VEC residing in close proximity (5 m) to the DWMF could be up to 0.024 mGy/d, lower than the 2.4 mGy/d radiation benchmark for terrestrial biota. The dose also remains below the radiation benchmark if the maximum dose from the DWMF is combined with the dose to ecological VECs from being exposed to radionuclides through other existing DN operations.

5.3 Recommendations for the Monitoring Program

If radiation or chemical doses were predicted to exceed benchmarks, and the exceedances are reasonably expected to be facility related, it is recommended that OPG confirm exposure conditions, and proceed either to monitor for the effects relevant to benchmark exceedance, or to evaluate options for risk management if the need for risk management is clear. The confirmation of exposure may involve refinement of exposure estimates from existing data, or obtaining new monitoring data where exposures were based on predicted concentrations. In general, sufficient monitoring data were available for use in the risk assessment from sampling programs that were initiated to support the 2009 NND EA and 2011 Refurbishment and Continued Operations EA. Monitoring data from the EAs were supplemented with data collected from 2011 to 2015 as part of the annual EMP, ECA, and MISA; and from the 2016 Effluent Characterization Study.

In order to clarify risk in future human and ecological assessments, the following specific recommendations for monitoring are provided:

- Lake water samples should be collected along and at the outlet of the DN diffuser, analyzed using a lower detection limit for hydrazine to help reduce the uncertainty surrounding human exposure to hydrazine through drinking water and fish ingestion.
    - A method detection limit of 0.05 µg/L for hydrazine in water would be appropriate and is achievable, since the human health screening benchmark is 0.01 µg/L at the WSPs (Section 3.1.2.2.2.1). Lake water samples were collected to support the DN NND EA; however, the detection limit was 5 µg/L. This would be considered a supplementary one-time study and would only be part of the monitoring program until the objective is achieved. Hydrazine sampling in Coots Pond is not recommended as there is no direct surface water connection from DN to Coots Pond and hydrazine does not

partition well from air to water, soil, or sediment. Additionally, hydrazine was not identified as a risk to ecological receptors in Lake Ontario or Coots Pond.

- Filtered and unfiltered aluminum effluent samples in the CCW should be collected as part of a supplementary study to clarify risks to ecological receptors in Lake Ontario.
    - Potential risks to some ecological receptors in Lake Ontario were identified resulting from the maximum measured aluminum concentration in water. The maximum measured aluminum concentration was based on aluminum data collected from the 2016 effluent characterization study. Based on mean aluminum concentrations in the effluent, risks to ecological receptors in Lake Ontario were not identified. However, there is uncertainty if elevated concentrations of aluminum are expected to occur occasionally or more frequently. Additionally, the higher levels of aluminum measured in surface water are often associated with suspended sediment and may not be bioavailable. Measurements in both filtered and unfiltered samples would enable interpretation of bioavailability based on the dissolved fraction.

No recommendations are made at this time to reduce uncertainty in future human and ecological assessments.

5.4 Risk Management Recommendations

No risk management recommendations are made at this time.

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Appendix A Screening Tables for Chemical COPCs

Table A.1: Screening of Chemicals in Air for Human Health

Chemical	CAS Number	Air Dispersion Model Used [h]	Maximum Emission Rate [h] (g/s)				Maximum Emission Rate 2011-2015 (g/s)	Max. Modeled POI Concentration [h] (μg/m³)				Max POI Concentration 2011-2015 (μg/m³)
			2011	2012	2013	2014		2011	2012	2013	2014	
2-Propenoic Acid	25067-01-0	Reg 346	0.183	0.183	0.183	0.18	0.18	1.54	1.54	1.86	1.9	1.9
Ammonia	7664-41-7	Reg 346	20.35	20.35	20.35	20	20.35	241	171	171	170	241
Aromatic Hydrocarbon Resin	68410-16-2	Reg 346	0.183	0.183	0.183	0.18	0.18	1.54	1.54	1.86	1.9	1.9
Carbon Dioxide	124-38-9	Reg 346	1983	Not Modelled	Not Modelled	Not Modelled	1983	56764	Not Modelled	Not Modelled	Not Modelled	56764
Hydrazine	302-01-2	Reg 346	0.21	0.185	Not Modelled	Not Modelled	0.21	1	0.89	Not Modelled	Not Modelled	1.0
Hydrazine (At West land/Lake Boundary)[d]	302-01-2	Reg 346	0.21	0.185	Not Modelled	Not Modelled	0.21	1.76	1.55	Not Modelled	Not Modelled	1.8
Hydrazine (at residential receptor)	302-01-2	AERMOD	Not Modelled	Not Modelled	0.0038	0.0038[g]	0.0038	Not Modelled	Not Modelled	0.00036	0.00036	0.00036
Hydrazine (at residential receptor)[f]	302-01-2	Reg 346	Not Modelled	Not Modelled	0.185	0.18[g]	0.19	Not Modelled	Not Modelled	0.99	0.99	1
Hydrazine (Along terrestrial property boundary)[f]	302-01-2	AERMOD	Not Modelled	Not Modelled	0.0038	Not Modelled	0.0038	Not Modelled	Not Modelled	0.00085	Not Modelled	0.00085
Hydrazine (at south west land/lake PL boundary)	302-01-2	Reg 346	Not Modelled	Not Modelled	0.185	Not Modelled	0.185	Not Modelled	Not Modelled	1.55	Not Modelled	1.55
Hydrazine (Max POI at western property boundary and Solina Trail)	302-01-2	AERMOD	Not Modelled	Not Modelled	Not Modelled	0.0038[g]	0.0038	Not Modelled	Not Modelled	Not Modelled	0.00089	0.00089
Morpholine	110-91-8	Reg 346	3.1133	3.1133	3.1133	3.1	3.1133	36.9	26.1	26.1	26	36.9
Nitrogen Oxides	10102-44-0	Reg 346	11.33	11.33	11.33	11	11.33	321	321	321	320	321
Phosphoric Acid (asP2O5)	7664-38-2	Reg 346	0.174	0.2	0.174	0.17	0.17	2.06	1.46	1.770	1.8	2.1
Poly (Oxy-1, 2- Ethanediyl), Alph	60864-33-7	Reg 346	0.046	0.046	0.046	0.046	0.046	0.39	0.39	0.46	0.46	0.46
Quaternary Ammonium Compounds (H	68911-87-5	Reg 346	0.046	0.046	0.046	0.046	0.046	0.39	0.39	0.46	0.46	0.46
Suspended Particulate Matter < 44 um aero	N/A	Reg 346	0.689	0.2087	0.2087	0.21	0.69	28.73	28.73	28.73	29	29

Notes:

ND - No Data

N/A - Averaging period was 1/2 hour in 2011 and 2012 and then switched to annual in 2013 and 2014.

(a) OPG has adopted the Jurisdictional Screening Level (Regulation Schedule "JSL") values as Ministry Point of Impingement Limits, in accordance with the "Notification of Amendment to C of A 1607-58ZMQM" (OPG NK38-CORR-00541-12994).

(b) Regulation Schedule items denoted by "MGLC(04)" or "Site Specific" are *Contaminants with No Ministry POI Limits* previously approved by the *Maximum Ground Level Concentration* process during the 2004 C of A application and approval. Items denoted by MGLC(09) are concentration levels requested for approval during the 2009 submission, and corresponding to the most conservative POI modelling locations.

(c) For the purposes of testing emergency power generators, the MOECC accepts a POI concentration of 1880 μg/m3 for nitrogen oxides. The South West property boundary is presented as the NOx receptor location. For non-Emergency Power Generator testing, a Standard of 500 μg/m3 for nitrogen oxides is relevant.

(d) To anticipate potential land development, a second conservative POI location is presented for hydrazine, demonstrating the maximum concentration expected at the nearest terrestrial property boundary location, using the same emission rate. The existing POI is located at the nearest residential receptor, inside a proposed business park zoning

(e) Texas Commission on Environmental Quality Effects Screening Levels Used in the Review of Air Permitting Data September 30, 2015

(f) For hydrazine, a second conservative POI location is presented for a riparian shoreline, demonstrating the maximum concentration expected at the nearest terrestrial property boundary location, using the same emission rate. The existing POI - the most affected human receptor - is located at the nearest residential receptor, inside a proposed business park zoning. Annual emissions include both the nearest human receptor and the highest terrestrial property boundary concentration.

(g) Hydrazine emissions are presented for the maximum probable annual emission scenario, based on the calculation, NK38-CALC-36000-10003 (reference: Appendix C, Supporting Information for Emission Rates). This represents a statistical bias, to ensure the cancer risk threshold is not exceeded, and median emissions are typically 46% less for the six year reference period, considering system chemistry, valve opening position and durations. Annual period emissions presented include both the farmhouse receptor, and the highest terrestrial property boundary concentration at the Solina Trail intersection. The

(h) Source: OPG, 2012a; 2013a; 2014a; 2015a.

Table A.1: Screening of Chemicals in Air for Human Health (continued)

Chemical	Averaging Period (hours)	MOECC Criteria (μg/m^3)[a, b]	Limiting Effect	Regulation Schedule	Equivalent Modeled 1-Hour POI Concentration (μg/m^3)	1-Hour AAQC (MOE, 2012) (μg/m^3)	Equivalent Modeled 24-Hour POI Concentration (μg/m^3)	24-Hour AAQC (MOE, 2012) (μg/m^3)	Equivalent Modeled Annual POI Concentration (μg/m^3)	Annual Criteria (μg/m^3)	Notes	Carried Forward as COPC?
2-Propenoic Acid	0.5	3.32	N/A	MGLC (09)	Not Required	Not Required	Not Required	Not Required	0.12	6	e	no
Ammonia	0.5	300	Health	2	Not Required	Not Required	82	100	Not Required	Not Required		no
Aromatic Hydrocarbon Resin	0.5	2.17	N/A	MGLC (09)	Not Required	Not Required	Not Required	Not Required	0.123	350	e	no
Carbon Dioxide	0.5				Not Required	Not Required	Not Required	Not Required	Not Required	Not Required		no
Hydrazine	0.5	1	Health		Not Required	Not Required	Not Required	Not Required	Not Required	Not Required		no
Hydrazine (At West land/Lake Boundary)[d]	0.5				Not Required	Not Required	Not Required	Not Required	Not Required	Not Required		no
Hydrazine (at residential receptor)	Annual	0.00038	Health	MGLC (14)	Not Required	Not Required	Not Required	Not Required	0.00038	0.013	e	no
Hydrazine (at residential receptor)[f]	0.5	1	Health	Site Specific	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required		no
Hydrazine (Along terrestrial property boundary)[f]	Annual	0.00089	Health	MGLC (14)	Not Required	Not Required	Not Required	Not Required	0.00089	0.013	e	no
Hydrazine (at south west land/lake PL boundary)	0.5	1.8	Health	MGLC (09)	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required		no
Hydrazine (Max POI at western property boundary and Solina Trail)	Annual	0.00089	Health	MGLC (14)	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required		no
Morpholine	0.5	48	Odour	JSL	Not Required	Not Required	Not Required	Not Required	2.392	40	e	no
Nitrogen Oxides	0.5	1880	Health	2 (note c)	264	400	109	200	Not Required	Not Required		no
Phosphoric Acid (asP2O5)	0.5	21	Health	2	Not Required	Not Required	1	7	0.134	1	e	no
Poly (Oxy-1, 2- Ethanediyl), Alph	0.5	0.55	N/A	MGLC (09)	Not Required	Not Required	Not Required	Not Required	0.030	60	e	no
Quaternary Ammonium Compounds (H	0.5	0.55	N/A	MGLC (09)	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required		no
Suspended Particulate Matter < 44 um aero	0.5	100	Visibility	2	Not Required	Not Required	10	25	Not Required	Not Required		no

Table A.2: Screening of Lake Water for Human Health

Analyte	Unit	Canadian Drinking Water Quality Guidelines (HC, 2012)	ODWS/MOE GW1 Component Value (MOE, 2011)	USEPA Human Health for the consumption of Organism Only	CCME	PWQO	Interim PWQO	2015 Mean Background (1)	Selected Surface Water Screening Benchmark	Ref	Pre-2009 Samples			SENES 2009 Max (6)	TRC and Morpholine Max (7)	Overall Max	Carried Forward as COPC?
											2007	May-08	Sep-08				
Alkyl Ethoxylates	mg/L								None	-	N/A	N/A	N/A	N/A	N/A	N/A	no
Alkylphenol Ethoxylates	mg/L								None	-	N/A	N/A	N/A	N/A	N/A	N/A	no
Aluminum	mg/L	0.1			0.1			0.007	0.1	(2)	3.517	0.017	0.021	**3.5**	N/A	**3.5**	no*
Aluminum, filtered	mg/L						0.075	0.009	0.075	(5)	0.013	0.007	0.013	0.01	N/A	0.01	no
Cadmium	mg/L	0.005	0.005		0.00004 - 0.00037	0.0002	0.0005	0.0000095	0.005	(2)	0	0	<0.0001	<0.0001	N/A	<0.0001	no
Chromium	mg/L	0.05	0.05		0.0089	0.0089		<0.0050	0.05	(2)	0.0017	0.0011	0.0012	0.0017	N/A	0.0017	no
Chromium (III)	mg/L	0.05	0.05						0.05	(2)	N/A	N/A	N/A	0.0017	N/A	0.0017	no
Chromium (VI)	mg/L	0.05	0.025						0.025	(3)	N/A	N/A	N/A	<0.005	N/A	<0.005	no
Copper	mg/L	1	1		0.002	0.005	0.005	<0.0010	1	(2)	0.0037	0.0013	0.002	0.004	N/A	0.004	no
Ethylene Glycol	mg/L								None	-	N/A	N/A	N/A	N/A	N/A	N/A	no
Gadolinium	mg/L								None	-	N/A	N/A	N/A	N/A	N/A	N/A	no
Iron	mg/L	0.3			0.3	0.3		<0.1	0.3	(2)	0.129	0.027	0.026	0.13	N/A	0.13	no
Lead	mg/L	0.01	0.01		0.001-0.007	0.025	0.005	<0.0005	0.01	(2)	0.0036	0.0002	0.0002	0.003	N/A	0.003	no
Linear Alkylbenzene Sulphonates	mg/L								None	-	N/A	N/A	N/A	N/A	N/A	N/A	no
Lithium	mg/L								None	-	N/A	N/A	N/A	N/A	N/A	N/A	no
Mercury	mg/L	0.001	0.001		0.000026	0.0002		0.00001	0.001	(2)	0	0	<0.0001	<0.0001	N/A	<0.0001	no
Molybdenum	mg/L		0.07		0.073		0.04	0.0013	0.07	(3)	0.002	0.0018	0.0015	0.002	N/A	0.002	no
Morpholine	mg/L						0.004	<0.004	0.004	(5)	0.0012	<0.0001	0	<0.002	<0.001	<0.001	no
Nickel	mg/L		0.1	4.6	0.025-0.15	0.025		0.001025	0.1	(3)	0.0012	0.0009	0.0009	0.001	N/A	0.001	no
Nitrate	mg/L	10							10	(2)	N/A	N/A	N/A	**89.7**	N/A	**89.7**	yes
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/L		0.82		0.167			<0.025	0.82	(3)	N/A	N/A	N/A	N/A	N/A	N/A	no
Petroleum Hydrocarbons - F1 (C6-C10)	mg/L		0.82		0.167			<0.025	0.82	(3)	<0.1	<0.1	<0.1	<0.1	N/A	<0.1	no
Petroleum Hydrocarbons - F2 (C10-C16)	mg/L		0.3		0.042			<0.1	0.3	(3)	<0.1	<0.1	<0.1	<0.1	N/A	<0.1	no
Petroleum Hydrocarbons - F3 (C16-C34)	mg/L		1					<0.2	1	(3)	<0.1	<0.1	<0.1	<0.1	N/A	<0.1	no
Petroleum Hydrocarbons - F4 (C34-C50)	mg/L		1.1					<0.2	1.1	(3)	<0.1	<0.1	<0.1	<0.1	N/A	<0.1	no
Phosphate	mg/L								None	-	N/A	N/A	N/A	N/A	N/A	N/A	no
Phosphorus	mg/L					0.02			0.02	(4)	N/A	N/A	N/A	**0.05**	N/A	**0.05**	no*
Propylene Glycol	mg/L								None	-	N/A	N/A	N/A	N/A	N/A	N/A	no
Selenium	mg/L	0.01	0.01	4.2	0.001	0.1		0.00013875	0.01	(2)	0.001	0	<0.001	<0.001	N/A	0.001	no
Total Residual Chlorine	mg/L	0.04 - 2.0			0.0005	0.002		<0.0012	0.04	(2)	<0.002		<0.002	<0.002	<0.0012	<0.0012	no
Zinc	mg/L	≤5	5	26	0.03	0.03	0.02	<0.0050	≤5	(2)	0.0032	0.0051	0.0069	0.01	N/A	0.01	no

Notes:
* See Section 3.1.2.2.1 of the report.
1. Mean background concentration from LWC-1.
2. Canadian Drinking Water Quality Guidelines (HC, 2012
3. Ontario Ministry of the Environment (MOE). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario. Standards Development Branch. Ap
4. PWQO Ontario MOE.
5. Interim PWQO
6. Maximum value from NND EA EcoRA baseline study (SENES, 2009a
7. Maximum value from 2014 Supplementary EMP Study (EcoMetrix, 2015
Shaded cells exceed the selected screening benchmark

Table A.3: Screening of CCW Effluent (ECA Data) for Human Health

Parameters	Unit	Selected Benchmark *	Maximum Measured Concentrations from ECAs				Max Conc.	Carried forward as COPC?
			2011	2012	2013	2014		
Unionized Ammonia	mg/L	0.02	0.01	0.01	0.01	0.02	0.02	no
Hydrazine	mg/L	0.00001	**0.005**	**0.006**	**0.007**	**0.008**	**0.008**	yes
Morpholine	mg/L	0.004	0.002	0.003	**0.008**	0.004	**0.008**	yes
pH	pH units	6.5 - 8.5	**7.1-8.6**	**8.0-8.7**	7.8-8.5	**7.9-8.6**	**8.7**	no**
TRC	mg/L	0.002	**0.005**	**<0.004**	**0.008**	**0.008**	**0.008**	no**

Notes:

* See Table A.2 for references for these selected screening benchmarks.

** See Section 3.1.2.2.2.1

Shaded cells exceed the selected screening benchmark.

Table A.4: Screening of MISA Control Point Effluents for Human Health

Parameter	Units	Intake Conc. (Golder, 2011a)	MISA Limit at Station Discharge	Estimated Maximum Concentration in Station Discharge (Section 3.1.2.2.2.2)	Screening Benchmark *	Carried Forward as COPC?
RLWMS						
Phosphorus	mg/L	0.0154	1	0.016	0.02	No
TSS	mg/L	5.175	73	5.2	<1 - <10	No
Zinc	mg/L	0.0019	1	0.0020	5	No
Iron	mg/L	0.0282	9	0.029	0.3	No
Oil and Grease	mg/L	0	36	0.0040	None	No
WTP						
Aluminum	mg/L	0.0377	13	0.042	0.1	No
TSS	mg/L	5.175	70	5.2	<1 - <10	No
Iron	mg/L	0.0282	2.5	0.029	0.3	No

Notes:

* See Table A.2 for references for these selected screening benchmarks.

Shaded cells exceed the selected screening benchmark.

Table A.5a: Screening of 2016 CCW Effluent for Human Health

Parameter	Units	Detection Limit	Surface Water Screening Level *	Measured Stream Concentrations (EcoMetrix, 2016)					Carried Forward as COPC?
				RLW	BB	IAD	WTP	CCW	
				Max_Value	Max_Value	Max_Value	Max_Value	Max_Value	
Morpholine	µg/L	4	4	**6**					no**
Gadolinium (Gd)	µg/L	2	None	46				9.6	no
Mercury (Hg)	µg/L	0.01	1	0.1				0.1	no
Total Aluminum (Al)	µg/L	0.5	100	59.9		19.2	0.012	**150**	no**
Total Cadmium (Cd)	µg/L	0.005	5	0.257	0.013	0.008	4.76	0.015	no
Total Chromium (Cr)	µg/L	0.1	50	6.97	0.44	0.64	9.91	0.79	no
Total Copper (Cu)	µg/L	0.05	1000	15.5	0.914	3.25	13.8	1.92	no
Total Iron (Fe)	µg/L	1	300	32	13.1	37.7		250	no
Total Lead (Pb)	µg/L	0.005	10	**19.8**	0.213	0.086	0.199	0.335	no**
Total Lithium (Li)	µg/L	0.5	None	330				3.82	no
Total Molybdenum (Mo)	µg/L	0.05	70	7.78			65.6	1.59	no
Total Nickel (Ni)	µg/L	0.02	100	50.6	0.087	0.752	1.83	0.932	no
Total Selenium (Se)	µg/L	0.04	10	1	0.04	0.141	2.05	0.199	no
Total Zinc (Zn)	µg/L	0.1	5000	25.5	2.95		21.2	8.79	no
Nitrate (N)	mg/L	0.1	10				4.88	0.44	no
Total Phosphorus	mg/L	0.02	0.02	**0.177**				**0.029**	no**
Ethylene Glycol	mg/L	5	None	<20		<5		<5	no
Propylene Glycol	mg/L	5	None	<20		<5		<5	no
F1 (C6-C10)	µg/L	25	820	<25			<25	<25	no
F1 (C6-C10) - BTEX	µg/L	25	820	<25			<25	<25	no
F2 (C10-C16 Hydrocarbons)	µg/L	100	300	<100			<100	<100	no
F3 (C16-C34 Hydrocarbons)	µg/L	200	1000	<200			<200	<200	no
Total Residual Chlorine (TRC)	µg/L	4	2				**4**		no**

Notes:

* See Table A.2 for references for these selected screening benchmarks.

** See Section 3.1.2.2.2.3

Shaded cells exceed the selected screening benchmark.

RLW - Radioactive Liquid Waste

BB - Boiler Blowdown

IAD - Inactive Drainage

WTP - Water Treatment Plant

CCW - Condenser Cooling Water

Table A.5b: Screening of 2016 CCW Effluent for Human Health

Analyte	Unit	Detection Limit	Derived DW Screening Benchmark	Maximum Measured Concentration in CCW (EcoMetrix, 2016)	Carried forward as COPC?
Alcohol Ethoxylates C8-9	µg/L	0.03	None	ND	no*
Alcohol Ethoxylates C10-11	µg/L	0.03	None	ND	no*
Alcohol Ethoxylates C12 -13	µg/L	0.03	None	108.7	no*
Alcohol Ethoxylates C14-15	µg/L	0.03	None	16	no*
Alcohol Ethoxylates C16-18	µg/L	0.03	None	1	no*
Total Alcohol Ethoxylates	µg/L	0.03	512500 *	121	no
Nonylphenol Ethoxycarboxylate	µg/L	0.01	None	ND	no*
Linear Alkylbenzene Sulphonates C10	µg/L	0.06	None	1.1	no*
Linear Alkylbenzene Sulphonates C12	µg/L	0.06	None	15.3	no*
Total Linear Alkylbenzene Sulphonates	µg/L	0.06	929333 *	15.3	no

Notes:

* See Section 3.1.2.2.2.3 of the report.

ND = non-detect

Table A.6: Screening of Storm Water for Human Health

Parameter	Maximum Storm Water Loading (Section 3.1.2.2.3)	Unit	Modeled Diluted Concentration in Lake Water (Section 3.1.2.2.3)	Unit	Human Health Screening Benchmark *	Carried Forward as COPC?
Bicarb. Alkalinity (calc. as CaCO3)	3.32E+04	mg/s	3.07E+00	mg/L	--	
Carb. Alkalinity (calc. as CaCO3)	<3.92E+02	mg/s	<3.63E-02	mg/L	--	
Hydrox. Alkalinity (calc. as CaCO3)	<1.93E+02	mg/s	<1.79E-02	mg/L	--	
Total Alkalinity (as CaCO3)	3.35E+04	mg/s	3.10E+00	mg/L	--	
Dissolved Chloride (Cl)	3.33E+05	mg/s	3.08E+01	mg/L	--	
Hardness (CaCO3)	4.99E+04	mg/s	4.62E+00	mg/L	--	
Total Dissolved Solids	5.99E+05	mg/s	5.55E+01	mg/L	--	
Total Suspended Solids	<1.75E+04	mg/s	<1.62E+00	mg/L	--	
Total Ammonia-N	<1.94E+02	mg/s	<1.80E-02	mg/L	--	
Unionized ammonia	<7.65E+03	µg/s	<7.08E-01	µg/L	2.00E+01	no
Nitrite (N)	<6.12E+00	mg/s	<5.67E-04	mg/L	1.00E+00	no
Nitrate (N)	<4.44E+02	mg/s	<4.11E-02	mg/L	1.00E+01	no
Nitrite + Nitrate (N)	<4.44E+02	mg/s	<4.11E-02	mg/L	--	
Total Oil & Grease	<9.65E+01	mg/s	<8.94E-03	mg/L	--	
Total Phosphorus	2.14E+01	mg/s	1.98E-03	mg/L	2.00E-02	no
Chromium (VI)	<1.54E+02	µg/s	<1.43E-02	µg/L	2.50E+01	no
Dissolved (0.2u) Aluminum (Al)	<5.67E+03	µg/s	<5.25E-01	µg/L	1.00E+02	no
Total Aluminum (Al)	2.12E+05	µg/s	1.97E+01	µg/L	1.00E+02	no
Total Antimony (Sb)	<1.38E+02	µg/s	<1.27E-02	µg/L	6.00E+00	no
Total Arsenic (As)	<1.93E+02	µg/s	<1.79E-02	µg/L	1.00E+01	no
Total Barium (Ba)	4.95E+04	µg/s	4.59E+00	µg/L	1.00E+03	no
Total Beryllium (Be)	<9.65E+01	µg/s	<8.94E-03	µg/L	4.00E+00	no
Total Bismuth (Bi)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Boron (B)	2.91E+04	µg/s	2.70E+00	µg/L	5.00E+03	no
Total Cadmium (Cd)	<9.18E+01	µg/s	<8.50E-03	µg/L	5.00E+00	no
Total Calcium (Ca)	1.53E+07	µg/s	1.41E+03	µg/L	--	
Total Chromium (Cr)	<9.65E+02	µg/s	<8.94E-02	µg/L	5.00E+01	no
Total Cobalt (Co)	<1.54E+02	µg/s	<1.43E-02	µg/L	3.00E+00	no
Total Copper (Cu)	<1.74E+03	µg/s	<1.61E-01	µg/L	1.00E+03	no
Total Iron (Fe)	<3.09E+05	µg/s	<2.86E+01	µg/L	3.00E+02	no
Total Lead (Pb)	<7.22E+03	µg/s	<6.69E-01	µg/L	1.00E+01	no
Total Lithium (Li)	<1.27E+03	µg/s	<1.18E-01	µg/L	--	
Total Magnesium (Mg)	4.30E+06	µg/s	3.98E+02	µg/L	--	
Total Manganese (Mn)	6.44E+04	µg/s	5.96E+00	µg/L	5.00E+01	no
Total Molybdenum (Mo)	<3.49E+03	µg/s	<3.23E-01	µg/L	7.00E+01	no
Total Nickel (Ni)	<9.18E+02	µg/s	<8.50E-02	µg/L	1.00E+02	no
Total Potassium (K)	<1.03E+06	µg/s	<9.50E+01	µg/L	--	
Total Silicon (Si)	6.18E+05	µg/s	5.72E+01	µg/L	--	
Total Selenium (Se)	<3.86E+02	µg/s	<3.57E-02	µg/L	1.00E+01	no
Total Silver (Ag)	<1.93E+01	µg/s	<1.79E-03	µg/L	1.00E+02	no
Total Sodium (Na)	2.22E+08	µg/s	2.05E+04	µg/L	2.00E+05	no
Total Strontium (Sr)	6.35E+05	µg/s	5.88E+01	µg/L	--	
Total Tellurium (Te)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Thallium (Tl)	<1.40E+01	µg/s	<1.29E-03	µg/L	2.00E+00	no
Total Thorium (Th)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Tin (Sn)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Titanium (Ti)	<1.18E+04	µg/s	<1.09E+00	µg/L	--	
Total Tungsten (W)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Uranium (U)	3.33E+02	µg/s	3.08E-02	µg/L	2.00E+01	no
Total Vanadium (V)	<1.22E+03	µg/s	<1.13E-01	µg/L	6.20E+00	no
Total Zinc (Zn)	4.13E+04	µg/s	3.82E+00	µg/L	5.00E+03	no
Total Zirconium (Zr)	<1.93E+02	µg/s	<1.79E-02	µg/L	4.00E+00	
F1 (C6-C10)	<1.93E+04	µg/s	<1.79E+00	µg/L	8.20E+02	no
F1 (C6-C10) - BTEX	<1.93E+04	µg/s	<1.79E+00	µg/L	8.20E+02	no
Benzene	<1.93E+04	µg/s	<1.79E+00	µg/L	5.00E+00	no
Toluene	<1.93E+04	µg/s	<1.79E+00	µg/L	2.40E+01	no
Ethylbenzene	<1.93E+04	µg/s	<1.79E+00	µg/L	2.40E+00	no
o-Xylene	<1.93E+04	µg/s	<1.79E+00	µg/L	--	
p+m-Xylene	<1.93E+04	µg/s	<1.79E+00	µg/L	--	
Total Xylenes	<1.93E+04	µg/s	<1.79E+00	µg/L	3.00E+02	no
F2 (C10-C16 Hydrocarbons)	<1.93E+04	µg/s	<1.79E+00	µg/L	3.00E+02	no
F3 (C16-C34 Hydrocarbons)	<1.93E+04	µg/s	<1.79E+00	µg/L	1.00E+03	no
F4 (C34-C50 Hydrocarbons)	<1.93E+04	µg/s	<1.79E+00	µg/L	1.10E+03	no
Aroclor 1016	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1221	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1232	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1262	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1268	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1242	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1248	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1254	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1260	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Total PCB	<1.93E+00	µg/s	<1.79E-04	µg/L	3.00E+00	no

Notes:

* See Table A.2 for references for these selected screening benchmarks.

Shaded cells exceed the selected screening benchmark.

Loadings and modeled concentrations are based on data from Golder (2011b; 2011c).

Table A.7: Non-Radiological Screening of Air COPCs for Ecological Health

Contaminant	Max. POI Concentration (µg/m^3)				Max 1/2 hour POI Concentration (µg/m^3)	Concentration in Averaging Period of Screening Level (µg/m3)	Screening Level (µg/m^3)	Averaging Period	Reference	Carried Forward as COPC?
	2011	2012	2013	2014						
2-Propenoic Acid	1.54	1.54	1.86	1.9	1.9	0.123	6	Annual	TCEQ, 2015	no
Ammonia	241	171	171	170	241	81.521	100	24 Hour	MOECC AAQC	no
Aromatic Hydrocarbon Resin	1.54	1.54	1.86	1.9	1.9	0.123	350	Annual	TCEQ, 2015	no
Carbon Dioxide	56764	Not Modelled	Not Modelled	Not Modelled	56764	Not applicable - major component of air				no
Hydrazine	1	0.89	Not Modelled	Not Modelled	1.0	1.0	10600	1/2 hour	EC/HC, 2011	no
Hydrazine (At West land/Lake Boundary)[d]	1.76	1.55	Not Modelled	Not Modelled	1.8	1.8	10600	1/2 hour	EC/HC, 2011	no
Hydrazine (Along terrestrial property boundary[f]	Not Modelled	Not Modelled	0.00085	Not Modelled	0.00085	0.00085	6	Annual	EC/HC, 2011	no
Hydrazine (at south west land/lake PL boundary)	Not Modelled	Not Modelled	1.55	Not Modelled	1.55	1.55	10600	1/2 hour	EC/HC, 2011	no
Hydrazine (Max POI at western property boundary and Solina Trail)	Not Modelled	Not Modelled	Not Modelled	0.00089	0.00089	0.00089	6	Annual	EC/HC, 2011	no
Morpholine	36.9	26.1	26.1	26	36.9	36.9	780000	1/2 hour	WHO, 1996	no
Nitrogen Oxides	321	321	321	320	321	108.6	200	24 hour	MOECC AAQC	no
Phosphoric Acid (asP2O5)	2.06	1.46	1.770	1.8	2.1	0.134	1	Annual	TCEQ, 2015	no
Poly (Oxy-1, 2- Ethanediyl), Alph	0.39	0.39	0.46	0.46	0.46	0.030	60	Annual	TCEQ, 2015	no
Quaternary Ammonium Compounds (H	0.39	0.39	0.46	0.46	0.46	Species of limited concern			TCEQ, 2015	no
Suspended Particulate Matter < 44 um aero	28.73	28.73	28.73	29	29	10	25	24 hour	MOECC AAQC	no

Table A.8: Screening of Lake Water for Ecological Health

Analyte	Unit	CCME CWQG	PWQO	Interim PWQO	Toxicity Benchmark (7)	2015 Mean Background (1)	Selected Surface Water Screening Benchmark	Ref	SENES 2009 Max (5)	TRC and Morpholine 2014 Max (6)	Overall Max	Carried Forward as COPC?
Alkyl Ethoxylates	mg/L						None	-	N/A	N/A	N/A	no
Alkylphenol Ethoxylates	mg/L						None	-	N/A	N/A	N/A	no
Aluminum	mg/L	0.1				0.007	0.1	(2)	**3.5**	N/A	**3.5**	no*
Aluminum, filtered	mg/L			0.075		0.009	0.075	(4)	0.01	N/A	0.01	no
Cadmium	mg/L	0.00019	0.0002	0.0005		0.0000095	0.00019	(2)	<0.0001	N/A	<0.0001	no
Chromium	mg/L	0.0089	0.0089			<0.0050	0.0089	(2)	0.0017	N/A	0.0017	no
Chromium (III)	mg/L	0.0089	0.0089				0.0089	(2)	0.0017	N/A	0.0017	no
Chromium (VI)	mg/L	0.001	0.001				0.001	(2)	**<0.005**	N/A	**<0.005**	no*
Copper	mg/L	0.0029	0.005	0.005		<0.0010	0.0029	(2)	**0.004**	N/A	**0.004**	yes
Ethylene Glycol	mg/L	192	2				2	(3)	N/A	N/A	N/A	no
Gadolinium	mg/L				150		150	(7)	N/A	N/A	N/A	no
Iron	mg/L	0.3	0.3			<0.1	0.3	(2)	0.13	N/A	0.13	no
Lead	mg/L	0.0043	0.025	0.005		<0.0005	0.0043	(2)	0.003	N/A	0.003	no
Linear Alkylbenzene Sulphonates	mg/L						None	-	N/A	N/A	N/A	no
Lithium	mg/L				0.65		0.65	(7)	N/A	N/A	N/A	no
Mercury	mg/L	0.000026	0.0002			0.00001	0.000026	(2)	**<0.0001**	N/A	**<0.0001**	no*
Molybdenum	mg/L	0.073		0.04		0.0013	0.073	(2)	0.002	N/A	0.002	no
Morpholine	mg/L			0.004		<0.004	0.004	(4)	<0.002	<0.001	<0.001	no
Nickel	mg/L	0.11	0.025			0.001025	0.025	(3)	0.001	N/A	0.001	no
Nitrate	mg/L	13					13	(2)	**89.7**	N/A	**89.7**	yes
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/L	0.167				<0.025	0.167	(2)	N/A	N/A	N/A	no
Petroleum Hydrocarbons - F1 (C6-C10)	mg/L	0.167				<0.025	0.167	(2)	<0.1	N/A	N/A	no
Petroleum Hydrocarbons - F2 (C10-C16)	mg/L	0.042				<0.1	0.042	(2)	**<0.1**	N/A	**<0.1**	no*
Petroleum Hydrocarbons - F3 (C16-C34)	mg/L					<0.2	0.2	(1)	<0.1	N/A	<0.1	no
Petroleum Hydrocarbons - F4 (C34-C50)	mg/L					<0.2	0.2	(1)	<0.1	N/A	<0.1	no
Phosphate	mg/L						None	-	N/A	N/A	N/A	no
Phosphorus	mg/L		0.02				0.02	(3)	**0.05**	N/A	**0.05**	no*
Propylene Glycol	mg/L	500	10				500	(2)	N/A	N/A	N/A	no
Selenium	mg/L	0.001	0.1			0.00013875	0.001	(2)	<0.001	N/A	<0.001	no
Total Residual Chlorine	mg/L	0.0005	0.002			<0.0012	0.0005	(2)	<0.002	<0.0012	<0.0012	no
Zinc	mg/L	0.03	0.03	0.02		<0.0050	0.03	(2)	0.01	N/A	0.01	no

Notes:
* See Section 4.1.4.2.1 of the report.
1. Mean background concentration from LWC-1.
2. CCME Canadian Water Quality Guidelines for Protection of Aquatic Life
3. PWQO Ontario MOE.
4. Interim PWQO.
5. Maximum value from NND EA EcoRA baseline study (SENES, 2009a)
6. Maximum value from 2014 Supplementary EMP Study (EcoMetrix, 2015)
7. Based on Borgmann *et al.*, 2005.
Shaded cells exceed the selected screening benchmark.

Table A.9: Screening of CCW Effluent (ECA Data) for Ecological Health

Parameters	Unit	Selected Benchmark *	Measured Maximum Concentrations from ECAs				Max Conc.	Carried forward as COPC?
			2011	2012	2013	2014		
Unionized Ammonia	mg/L	0.02	0.01	0.01	0.01	0.02	0.02	no
Hydrazine	mg/L	0.0026	**0.005**	**0.006**	**0.007**	**0.008**	**0.008**	yes
Morpholine	mg/L	0.004	0.002	0.003	**0.008**	0.004	**0.008**	yes
pH	pH units	6.5 - 8.5	**7.1-8.6**	**8.0-8.7**	7.8-8.5	**7.9-8.6**	**8.7**	no**
TRC	mg/L	0.0005	**0.005**	**<0.004**	**0.008**	**0.008**	**0.008**	yes

Notes:

* See Table A.7 for references for these selected screening benchmarks.

** See Section 4.1.4.2.2.1

Shaded cells exceed the selected screening benchmark.

Table A.10: Screening of MISA Control Point Effluents for Ecological Health

Parameter	Units	Intake Conc. (Golder, 2011a)	MISA Limit at Station Discharge	Estimated Maximum Concentration in Station Discharge (Section 4.1.4.2.2.2)	Screening Benchmark *	Carried Forward as COPC?
RLWMS						
Phosphorus	mg/L	0.0154	1	0.016	0.02	No
TSS	mg/L	5.175	73	5.2	<1 - <10	No
Zinc	mg/L	0.0019	1	0.0020	5	No
Iron	mg/L	0.0282	9	0.029	0.3	No
Oil and Grease	mg/L	0	36	0.0040	None	No
NWTP						
Aluminum	mg/L	0.0377	13	0.042	0.1	No
TSS	mg/L	5.175	70	5.2	<1 - <10	No
Iron	mg/L	0.0282	2.5	0.029	0.3	No

Notes:

* See Table A.7 for references for these selected screening benchmarks.

Shaded cells exceed the selected screening benchmark.

Table A.11a: Screening of 2016 CCW Effluent for Ecological Health

Parameter	Units	Detection Limit	Selected Surface Water Screening Benchmark *	Measured Stream Concentrations					Carried Forward as a COPC?
				RLW	CCW	IAD	WTP	CCW	
				Max_Value	Max_Value	Max_Value	Max_Value	Max_Value	
Morpholine	µg/L	4	4	**6**					no **
Gadolinium (Gd)	µg/L	2	150	46	9.6			2	no
Mercury (Hg)	µg/L	0.01	0.2	0.1	0.1			0.1	no
Total Aluminum (Al)	µg/L	0.5	100	59.9	**150**	19.2	0.012	**150**	yes
Total Cadmium (Cd)	µg/L	0.005	0.19	**0.257**	0.015	0.008	**4.76**	0.015	no **
Total Chromium (Cr)	µg/L	0.1	8.9	6.97	0.79	0.64	**9.91**	0.79	no **
Total Copper (Cu)	µg/L	0.05	2.9	**15.5**	1.92	**3.25**	**13.8**	1.92	no **
Total Iron (Fe)	µg/L	1	300	32	250	37.7		250	no
Total Lead (Pb)	µg/L	0.005	4.3	**19.8**	0.335	0.086	0.199	0.335	no **
Total Lithium (Li)	µg/L	0.5	650	330	3.82			3.82	no
Total Molybdenum (Mo)	µg/L	0.05	73	7.78	1.59		65.6	1.59	no
Total Nickel (Ni)	µg/L	0.02	25	**50.6**	0.932	0.752	1.83	0.932	no **
Total Selenium (Se)	µg/L	0.04	1	1	0.199	0.141	**2.05**	0.199	no **
Total Zinc (Zn)	µg/L	0.1	30	25.5	8.79		21.2	3.75	no
Nitrate (N)	mg/L	0.1	13		0.44		4.88	0.44	no
Total Phosphorus	mg/L	0.02	0.02	**0.177**	**0.029**			**0.029**	no **
Ethylene Glycol	mg/L	5	192	<20	5	<5		<5	no
Propylene Glycol	mg/L	5	500	<20	5	<5		<5	no
F1 (C6-C10)	µg/L	25	167	<25	25		<25	<25	no
F1 (C6-C10) - BTEX	µg/L	25	167	<25	25		<25	<25	no
F2 (C10-C16 Hydrocarbons)	µg/L	100	42	<100	100		<100	<100	no **
F3 (C16-C34 Hydrocarbons)	µg/L	200	None	<200	200		<200	<200	no
Total Residual Chlorine (TRC)	µg/L	4	0.5		no**		**4**		no **

Notes:

* See Table A.7 for references for these selected screening benchmarks.

** See discussion in Section 4.1.4.2.2.3.

RLW - Radioactive Liquid Waste

BB - Boiler Blowdown

IAD - Inactive Drainage

WTP - Water Treatment Plant

CCW - Condenser Cooling Water

Table A.11b: Screening of 2016 CCW Effluent for Ecological Health

Analyte	Unit	Detection Limit	FEQG (1)	CWQG (2)	HERA (3)	Selected Surface Water Benchmark	Reference	Maximum Concentration in CCW (EcoMetrix, 2016)	Carried forward to detailed screening?
Alcohol Ethoxylates C8-9	µg/L	0.03	179	-	-	179	(1)	ND	no
Alcohol Ethoxylates C10-11	µg/L	0.03	80	-	-	80	(1)	ND	no
Alcohol Ethoxylates C12 -13	µg/L	0.03	32	-	-	32	(1)	108.7	yes
Alcohol Ethoxylates C14-15	µg/L	0.03	11	-	-	11	(1)	16	yes
Alcohol Ethoxylates C16-18	µg/L	0.03	2	-	-	2	(1)	1	no
Total Alcohol Ethoxylates	µg/L	0.03	-	-	-	None	-	121	yes
Nonylphenol Ethoxycarboxylate	µg/L	0.01	-	1	-	1	(2)	ND	no
Linear Alkylbenzene Sulphonates C10	µg/L	0.06	-	-	1700	1700	(3)	1.1	no
Linear Alkylbenzene Sulphonates C12	µg/L	0.06	-	-	320	320	(3)	15.3	no
Total Linear Alkylbenzene Sulphonates	µg/L	0.06	-	-	-	None	-	15.3	no*

Notes:

* See discussion in Section 4.1.4.2.2.3.

1. Federal Environmental Quality Guidelines - Alcohol Ethoxylates, n = 0 (EC, 2013b)
2. Canadian Water Quality Guideline for the Protection of Aquatic Life (CCME, 2002)
3. Revised Human and Environmental Risk Assessment (HERA) Report - Linear Alkylbenzene Sulphonate, Table 10 (HERA, 2013)

ND = non-detect

Table A.11c: Screening of 2016 CCW Effluent for Ecological Health

AEO Fraction	Ethoxylate Number	FWQG (1) (ng/L)	Maximum Concentration in CCW (EcoMetrix, 2016)	Carried forward as COPC?
C12 (ng/L)	E4	128000	80253	no
	E5	158000	5136	no
	E6	193000	5164	no
	E7	233000	4847	no
	E8	279000	5568	no
	E9	332000	4268	no
	E10	392000	3375	no
C13 (ng/L)	E3	62000	1674	no
	E4	78000	1762	no
	E5	96000	224	no
	E6	118000	93	no
	E7	142000	14	no
	E8	170000	32	no
	E9	203000	14	no
	E10	240000	39	no
C14 (ng/L)	E3	37000	11832	no
	E4	46000	2692	no
	E5	57000	2278	no
	E6	70000	2094	no
	E7	84000	1601	no
	E8	102000	1257	no
	E9	121000	1377	no
	E10	144000	829	no
C15 (ng/L)	E3	21000	202	no
	E4	26000	2176	no
	E5	33000	943	no
	E6	40000	830	no
	E7	49000	461	no
	E8	59000	752	no
	E9	71000	625	no
	E10	84000	128	no

Notes:

1. Federal Environmental Quality Guidelines - Alcohol Ethoxylates (EC, 2013b)

Table A.12: Screening of Storm Water for Ecological Health

Parameter	Maximum Storm Water Loading (Section 4.1.4.2.3)	Unit	Modeled Diluted Concentration in Lake Water (Section 4.1.4.2.3)	Unit	Ecological Health Screening Benchmark *	Carried Forward as COPC?
Bicarb. Alkalinity (calc. as CaCO3)	3.32E+04	mg/s	3.07E+00	mg/L	--	
Carb. Alkalinity (calc. as CaCO3)	<3.92E+02	mg/s	<3.63E-02	mg/L	--	
Hydrox. Alkalinity (calc. as CaCO3)	<1.93E+02	mg/s	<1.79E-02	mg/L	--	
Total Alkalinity (as CaCO3)	3.35E+04	mg/s	3.10E+00	mg/L	--	
Dissolved Chloride (Cl)	3.33E+05	mg/s	3.08E+01	mg/L	1.20E+02	no
Hardness (CaCO3)	4.99E+04	mg/s	4.62E+00	mg/L	--	
Total Dissolved Solids	5.99E+05	mg/s	5.55E+01	mg/L	--	
Total Suspended Solids	<1.75E+04	mg/s	<1.62E+00	mg/L	--	
Total Ammonia-N	<1.94E+02	mg/s	<1.80E-02	mg/L	--	
Unionized ammonia	<7.65E+03	µg/s	<7.08E-01	µg/L	2.00E+01	no
Nitrite (N)	<6.12E+00	mg/s	<5.67E-04	mg/L	6.00E+01	no
Nitrate (N)	<4.44E+02	mg/s	<4.11E-02	mg/L	1.30E+01	no
Nitrite + Nitrate (N)	<4.44E+02	mg/s	<4.11E-02	mg/L	--	
Total Oil & Grease	<9.65E+01	mg/s	<8.94E-03	mg/L	--	
Total Phosphorus	2.14E+01	mg/s	1.98E-03	mg/L	2.00E-02	no
Chromium (VI)	<1.54E+02	µg/s	<1.43E-02	µg/L	1.00E+00	no
Dissolved (0.2u) Aluminum (Al)	<5.67E+03	µg/s	<5.25E-01	µg/L	7.50E+01	no
Total Aluminum (Al)	2.12E+05	µg/s	1.97E+01	µg/L	1.00E+02	no
Total Antimony (Sb)	<1.38E+02	µg/s	<1.27E-02	µg/L	2.00E+01	no
Total Arsenic (As)	<1.93E+02	µg/s	<1.79E-02	µg/L	5.00E+00	no
Total Barium (Ba)	4.95E+04	µg/s	4.59E+00	µg/L	--	
Total Beryllium (Be)	<9.65E+01	µg/s	<8.94E-03	µg/L	1.10E+03	no
Total Bismuth (Bi)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Boron (B)	2.91E+04	µg/s	2.70E+00	µg/L	2.00E+02	no
Total Cadmium (Cd)	<9.18E+01	µg/s	<8.50E-03	µg/L	1.90E-01	no
Total Calcium (Ca)	1.53E+07	µg/s	1.41E+03	µg/L	--	
Total Chromium (Cr)	<9.65E+02	µg/s	<8.94E-02	µg/L	8.90E+00	no
Total Cobalt (Co)	<1.54E+02	µg/s	<1.43E-02	µg/L	9.00E-01	no
Total Copper (Cu)	<1.74E+03	µg/s	<1.61E-01	µg/L	2.90E+00	no
Total Iron (Fe)	<3.09E+05	µg/s	<2.86E+01	µg/L	3.00E+02	no
Total Lead (Pb)	<7.22E+03	µg/s	<6.69E-01	µg/L	4.30E+00	no
Total Lithium (Li)	<1.27E+03	µg/s	<1.18E-01	µg/L	6.50E+02	no
Total Magnesium (Mg)	4.30E+06	µg/s	3.98E+02	µg/L	--	
Total Manganese (Mn)	6.44E+04	µg/s	5.96E+00	µg/L	--	
Total Molybdenum (Mo)	<3.49E+03	µg/s	<3.23E-01	µg/L	7.30E+01	no
Total Nickel (Ni)	<9.18E+02	µg/s	<8.50E-02	µg/L	2.50E+01	no
Total Potassium (K)	<1.03E+06	µg/s	<9.50E+01	µg/L	--	
Total Silicon (Si)	6.18E+05	µg/s	5.72E+01	µg/L	--	
Total Selenium (Se)	<3.86E+02	µg/s	<3.57E-02	µg/L	1.00E+00	no
Total Silver (Ag)	<1.93E+01	µg/s	<1.79E-03	µg/L	1.00E-01	no
Total Sodium (Na)	2.22E+08	µg/s	2.05E+04	µg/L	--	
Total Strontium (Sr)	6.35E+05	µg/s	5.88E+01	µg/L	--	
Total Tellurium (Te)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Thallium (Tl)	<1.40E+01	µg/s	<1.29E-03	µg/L	3.00E-01	no
Total Thorium (Th)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Tin (Sn)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Titanium (Ti)	<1.18E+04	µg/s	<1.09E+00	µg/L	--	
Total Tungsten (W)	<1.93E+02	µg/s	<1.79E-02	µg/L	--	
Total Uranium (U)	3.33E+02	µg/s	3.08E-02	µg/L	5.00E+00	no
Total Vanadium (V)	<1.22E+03	µg/s	<1.13E-01	µg/L	6.00E+00	no
Total Zinc (Zn)	4.13E+04	µg/s	3.82E+00	µg/L	3.00E+01	no
Total Zirconium (Zr)	<1.93E+02	µg/s	<1.79E-02	µg/L	4.00E+00	no
F1 (C6-C10)	<1.93E+04	µg/s	<1.79E+00	µg/L	1.67E+02	no
F1 (C6-C10) - BTEX	<1.93E+04	µg/s	<1.79E+00	µg/L	1.67E+02	no
Benzene	<1.93E+04	µg/s	<1.79E+00	µg/L	3.70E+02	no
Toluene	<1.93E+04	µg/s	<1.79E+00	µg/L	2.00E+00	no
Ethylbenzene	<1.93E+04	µg/s	<1.79E+00	µg/L	9.00E+01	no
o-Xylene	<1.93E+04	µg/s	<1.79E+00	µg/L	4.00E+01	no
p+m-Xylene	<1.93E+04	µg/s	<1.79E+00	µg/L	2.00E+00	no
Total Xylenes	<1.93E+04	µg/s	<1.79E+00	µg/L	2.00E+00	no
F2 (C10-C16 Hydrocarbons)	<1.93E+04	µg/s	<1.79E+00	µg/L	4.20E+01	no
F3 (C16-C34 Hydrocarbons)	<1.93E+04	µg/s	<1.79E+00	µg/L	--	
F4 (C34-C50 Hydrocarbons)	<1.93E+04	µg/s	<1.79E+00	µg/L	--	
Aroclor 1016	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1221	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1232	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1262	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1268	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1242	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1248	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1254	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Aroclor 1260	<1.93E+00	µg/s	<1.79E-04	µg/L	--	
Total PCB	<1.93E+00	µg/s	<1.79E-04	µg/L	1.00E-03	no

Notes:

* See Table A.7 for references for these selected screening benchmarks.

Loadings and modeled concentrations are based on data from Golder (2011b; 2011c).

Table A.13: Screening of Ponds for Ecological Health

Analyte	Unit	CCME CWQG (1)	PWQO (2)	Interim PWQO (3)	Toxicity Benchmark (4, 5, 6)	Selected Surface Water Screening Benchmark	Ref	Coot's Pond (7)		Treefrog Pond (7)	
								Maximum	Carried Forward as COPC?	Maximum	Carried Forward as COPC?
field pH	pH unit	6.5-9.0	6.5-8.5			6.5-8.5	(1)	9.3		7.6	
Alkyl Ethoxylates	mg/L	-	-	-		None	-	Not Analyzed	no	Not Analyzed	no
Alkylphenol Ethoxylates	mg/L	-	-	-		None	-	Not Analyzed	no	Not Analyzed	no
Aluminum	mg/L	0.1	-	-		0.1	(2)	**2.94**	**yes**	6.7	no*
Aluminum, filtered	mg/L	-	-	0.075		0.075	(3)	**0.19**	**yes**	0.04	no
Ammonia	mg/L	0.053	0.053			0.053	(1, 2)	**1.2**	**yes**	0.05	no
Ammonia (un-ionized; as NH3)	mg/L	0.019	0.02			0.019	(1)	**0.05**	**yes**	0.0008	no
Antimony	mg/L	-	0.02			0.02	(2)	0.001	no	0.001	no
Arsenic	mg/L	0.005	0.005			0.005	(1, 2)	<0.004	no	<0.001	no
Barium	mg/L	-	-	-	0.004 (SCV; Suter and Tsao, 1996)	0.004	(4)	**0.1**	**yes**	**0.4**	**yes**
Benzene	mg/L	0.37	-	0.1		0.1	(3)	<1.0E-07	no	<1.0E-07	no
Beryllium	mg/L	ins	1.1			1.1	(2)	<0.001	no	<0.001	no
Bismuth	mg/L	-	-		0.2543 (LC50/10 *H. azteca*; Borgmann et al., 2005)	0.2543	(5)	<0.001	no	<0.001	no
Boron	mg/L	1.5	0.2			1.5	(1) **	0.53	no	**2.6**	**yes**
Bromodichloromethane	mg/L	ins	-	0.2	volatile - evaporates to air	0.2	(3)	<0.0001	no	<0.0001	no
Bromoform	mg/L	ins	-	0.06		0.06	(3)	<0.0001	no	<0.0001	no
Cadmium	mg/L	0.00034	0.0002	0.0005		0.00034	(2)	<0.0001	no	<0.0001	no
Calcium	mg/L	-	-		11.6 (LCV/10; Suter and Tsao, 1996)	11.6	(4)	**86**	**yes**	**93**	**yes**
Cesium	mg/L	-	-		0.315 (LC50/10 *H. azteca*; Borgmann et al., 2005)	0.315	(5)	0.00016	no	0.0004	no
Chloroform	mg/L	0.0018	-			0.0018	(1)	0.0001	no	0.0002	no
Chromium	mg/L	0.0089	0.0089			0.0089	(1, 2)	0.004	no	0.006	no
Chromium (III)	mg/L	0.0089	0.0089			0.0089	(1, 2)	0.004	no	0.006	no
Chromium (VI)	mg/L	0.001	0.001			0.001	(1, 2)	**<0.005**	no*	<0.005	no*
Cobalt	mg/L	-	0.0009			0.0009	(2)	**0.004**	**yes**	**0.005**	**yes**
Copper	mg/L	0.0040	0.005	0.005		0.0040	(2, 3)	0.0015	no	0.004	no
Dibromochloromethane	mg/L	ins	-		readily evaporates to a	None	-	<0.0001	no	<0.0001	no
Ethylbenzene	mg/L	0.09	-	0.008		0.0080	(3)	<0.0001	no	<0.0001	no
Ethylene Glycol	mg/L	192	-	2		2	(3)	Not Analyzed	no	Not Analyzed	no
Gadolinium	mg/L	-	-		0.0599 (LC50/10 *H. azteca*; Borgmann et al., 2005)	0.0599	(5)	Not Analyzed	no	Not Analyzed	no
Iron	mg/L	0.3	0.3			0.3	(1, 2)	**1.3**	**yes**	**3.9**	**yes**
Lead	mg/L	0.0070	0.025	0.005		0.007	(1)	0.001	no	0.002	no
Linear Alkylbenzene Sulphonates	mg/L	-	-			None	-	Not Analyzed	no	Not Analyzed	no
Lithium	mg/L	-	-		0.014 (SCV; Suter and Tsao, 1996)	0.014	(4)	0.01	no	0.004	no
Magnesium	mg/L	-	-		8.2 (LCV/10; Suter and Tsao, 1996)	8.2	(4)	**38**	**yes**	**11.2**	**yes**
Manganese	mg/L	-	-		0.12 (SCV; Suter and Tsao, 1996)	0.12	(4)	0.07	no	**0.75**	**yes**
Mercury	mg/L	0.000026	0.0002			0.000026	(1)	**<0.0001**	no*	**<0.0001**	no*
Molybdenum	mg/L	0.073	-	0.04		0.073	(1)	0.0015	no	0.002	no
Morpholine	mg/L	-	-	0.004		0.004	(3)	<0.001	no	<0.001	no
Nickel	mg/L	0.15	0.025			0.025	(2)	0.0019	no	0.003	no
Nitrate	mg/L	13	-			13	(1)	0.2	no	**15**	**yes**
Nitrite	mg/L	0.197	-			0.197	(1)	0.08	no	<0.01	no
PCB (in water)	mg/L	-	0.000001			0.000001	(2)	**<0.00005**	no*	**<0.00005**	no*
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/L	0.167	-			0.167	(1)	Not Analyzed	no	Not Analyzed	no
Petroleum Hydrocarbons - F1 (C6-C10	mg/L	0.167	-			0.167	(1)	<0.1	no	<0.1	no
Petroleum Hydrocarbons - F2 (C10-C16)	mg/L	0.042	-			0.042	(1)	**<0.1**	no*	**<0.1**	no*
Petroleum Hydrocarbons - F3 (C16-C34	mg/L	-	-			None	-	<0.1	no	0.13	no*
Petroleum Hydrocarbons - F4 (C34-C50	mg/L	-	-			None	-	<0.1	no	<0.1	no
Phosphate	mg/L	-	-			None	-	Not Analyzed	no	Not Analyzed	no
Phosphorus	mg/L	0.02-0.03	-	0.02		0.02	(3)	**0.12**	no*	**0.1**	no*
Potassium	mg/L	-	-		5.3 (LCV/10; Suter and Tsao, 1996)	5.3	(4)	**12**	**yes**	**11.8**	**yes**
Propylene Glycol	mg/L	500	10			500	(1)	Not Analyzed	no	Not Analyzed	no
Selenium	mg/L	0.001	0.1			0.001	(1)	<0.001	no	<0.001	no
Silver	mg/L	0.0001	0.0001			0.0001	(1, 2)	<0.0001	no	<0.0001	no
Sodium	mg/L	-	-		68 (LCV/10; Suter and Tsao, 1996)	68	(4)	43.8	no	11.8	no
Strontium	mg/L	-	-		1.5 (LCV/10; Suter and Tsao, 1996)	1.5	(4)	0.73	no	0.3	no
Thallium	mg/L	0.0008	-	0.0003		0.0003	(3)	<0.0001	no	<0.0001	no
Thorium	mg/L	-	-		0.315 (LC50/10 *H. azteca*; Borgmann et al., 2005)	0.315	(5)	0.00037	no	0.0008	no
Tin	mg/L	-	-		0.073 (SCV; Suter and Tsao, 1996)	0.073	(4)	<0.0001	no	<0.0001	no
Titanium	mg/L	-	-		0.315 (LC50/10 *H. azteca*; Borgmann et al., 2005)	0.315	(5)	0.092	no	0.3	no
Toluene	mg/L	0.002	-	0.0008		0.0008	(3)	<0.0001	no	<0.0001	no
Total Dissolved Solids	mg/L	-	-		1000 (ADEC, 2016)	1000	(6)	474	no	407	no
Total Organic Carbon	mg/L	-	-			None	-	10.9	no	14.1	no
Total Residual Chlorine	mg/L	0.0005	0.002			0.0005	(2)	Not Analyzed	no	<0.002	no*
Total Suspended Solids	mg/L	narrative	-			narrative	(1)	62.5	no	80.33	no
Tungsten	mg/L	-	-	0.03		0.03	(3)	0.00013	no	0.0003	no
Uranium	mg/L	0.015	-	0.005		0.005	(3)	0.002	no	0.0025	no
Vanadium	mg/L	-	-	0.006		0.006	(3)	0.0017	no	0.0008	no
m,p xylene	mg/L	-	-	0.002 (m-xylene); 0.03 (p-xylene)		0.002	(3)	<0.0001	no	<0.0001	no
o xylene	mg/L	-	-	0.04		0.04	(3)	<0.0001	no	<0.0001	no
Zinc	mg/L	0.03	0.03	0.02		0.03	(1, 2)	0.014	no	0.01	no
Zirconium	mg/L	-	-	0.004		0.004	(3)	0.002	no	**0.02**	**yes**

Notes:
* See Section 4.1.4.2.4 of the report
** The interim PWQO for boron of 0.2 mg/L is an emergency value that is not based on protection of aquatic life, and is therefore not suitable for this screen
1. CCME Canadian Water Quality Guidelines for Protection of Aquatic Li
2. PWQO Ontario MOE.
3. Interim PWQO.
4. Toxicity benchmark from Suter and Tsao, 199
5. Toxicity benchmark from Borgmann et al., 200
6. Toxicity benchmark from ADEC, 2016
7. Maximum value from NND EA EcoRA baseline study (SENES, 2009a
Bold font indicates that the maximum constituent concentration exceeded the selected screening benchma

Table A.14: Screening for Chemical COPCs in Soil

Constituent	Units	PSO Component Value (1)	BM Component Value (1)	SQG_E (2)	Interim CSQC (3)	Rural Parkland OTR_{98} (4)	Dragun & Chiasson (1991)	Measured 2009 Concentrations (5)				Measured 2011 Concentrations (6)	Carried Forward as COPC for Plants & Soil Organisms?	Carried Forward as COPC for Birds & Mammals
								AB	C	D	E	AB		
								Max	Max	Max	Max	Max		
Aluminum	µg/g					30000		25200	28200	**32200**	13700	23100	No*	No*
Antimony	µg/g	20	25		20			0.296	0.159	0.193	0.180	0.23	No	No
Arsenic	µg/g	20	51	17				12.32	4.14	3.22	3.12	3.78	No	No
Barium	µg/g	750	390		750			**409**	**428**	**525**	**449**	280	No	Yes (AB, C, D, E)
Beryllium	µg/g	4	13		4			1.18	1.35	1.31	1.18	1.26	No	No
Bismuth	µg/g						<10 - 15	0.200	0.132	0.135	0.193	0.13	No	No
Boron	µg/g		120					31.70	45.85	35.93	25.10	18.3	-	No
Boron-hot water	µg/g	1.5			2			0.24	1.13	1.51	0.84	**1.98**	Yes (AB)	-
Cadmium	µg/g	12	1.9	3.8				0.40	0.25	0.24	0.23	0.38	No	No
Calcium	µg/g					54000		40200	36900	**67400**	17100	**99400**	No*	No*
Cesium	µg/g							2.05	1.32	1.55	1.12	1.54	No*	No*
Chromium	µg/g	310	160	64				39.2	53.0	39.3	34.5	53.5	No	No
Cobalt	µg/g	40	180	40				8.05	10.40	8.09	7.75	14.5	No	No
Copper	µg/g	140	770	63				23.70	14.80	13.30	9.23	29.2	No	No
Iron	µg/g					36000		22400	26900	22800	20500	26800	No	No
Lead	µg/g	250	32	70				**54.11**	18.35	22.13	30.90	16.1	No	Yes (AB)
Lithium	µg/g						<5.0 - 140	29.06	24.97	17.12	18.27	25.3	No	No
Magnesium	µg/g					19000		6120	6890	8580	3440	7880	No	No
Manganese	µg/g					1900		659	714	559	521	680	No	No
Mercury	µg/g	10	20	12				<0.0125	<0.0125	<0.0125	<0.0125	Not Analyzed	No	No
Molybdenum	µg/g	40	6.9		5			1.00	1.46	1.10	0.61	1.69	No	No
Nickel	µg/g	100	5000	45				15.9	25.2	18.2	13.9	**58.1**	No*	No*
Phosphorus	µg/g					1100		938	690	921	517	748	No	No
Potassium	µg/g					6500		**15100**	**17000**	**20500**	**14600**	**11500**	No*	No*
Selenium	µg/g	10	2.4	1				0.706	0.385	0.566	0.435	**2.32**	No*	No*
Silver	µg/g	20			20			0.221	0.258	0.271	0.281	0.16	No	No
Sodium	µg/g					690		**9970**	**8200**	**15200**	**11500**	**11700**	No*	No*
Strontium	µg/g					63		**200.0**	**180.0**	**304.0**	**169.0**	**293**	Yes (AB, C, D, E)	Yes (AB, C, D, E)
Thallium	µg/g	1.4	3.9	1				0.41	0.64	0.45	0.61	0.29	No	No
Thorium	µg/g						2.2 - 31	6.49	1.87	4.65	1.32	5.71	No	No
Tin	µg/g				5			4.70	**15.41**	**10.85**	2.58	1.33	Yes (C, D)	Yes (C, D)
Titanium	µg/g					4500		1810	1820	2540	1960	1920	No	No
Tungsten	µg/g						<100 - 1000	0.295	0.236	0.479	2.735	0.38	No	No
Uranium	µg/g	500	33	33				1.67	1.23	1.28	2.62	0.93	No	No
Vanadium	µg/g	200		130		86		60.9	73.7	62.6	57.2	54.5	No	No
Zinc	µg/g	400	340	200				84.3	72.5	75.3	63.7	79.6	No	No
Zirconium	µg/g						<20 - 2000	74.0	74.1	78.7	75.1	59.5	No	No

Note: all units on a dry weight basis.
* See discussion in Section 4.1.4.3.
1. Ontario Ministry of the Environment, 2011
2. CCME Soil Quality Guidelines
3. CCME Interim Canadian Soil Quality Criteria, 1991
4. Ontario Ministry of the Environment, 1993 (cited in MOE, 2011)
5. Maximum value from NND EA EcoRA baseline study (SENES, 2009a)
6. Maximum value from RCO EA EcoRA baseline study (SENES, 2011c)

Table A.15: Screening of Pond Sediment for Ecological Health

Analyte	Unit	PSQO (1)	CSQG (2)	Toxicity / Regulatory Benchmark (3, 4, 5)	Selected Sediment Screening Benchmark	Ref	Coot's Pond (6)		Treefrog Pond (6)	
							Maximum	Carried Forward as COPC?	Maximum	Carried Forward as COPC?
Aluminum	mg/kg	-	-	58030 (3)	58030	(3)	28715	no	14021	no
Antimony	mg/kg	-	-	-	None	-	0.41	no	0.21	no
Arsenic	mg/kg	6	5.9	-	5.9	(2)	3.35	no	3.18	no
Barium	mg/kg	-	-	-	None	-	342	no	494	no
Beryllium	mg/kg	-	-	-	None	-	1.41	no	2.01	no
Bismuth	mg/kg	-	-	-	None	-	0.27	no	0.41	no
Boron	mg/kg	-	-	-	None	-	55.1	no	40.9	no
Boron-hot water	mg/kg	-	-	-	None	-	12.24	no	0.14	no
Cadmium	mg/kg	0.6	0.6	-	0.6	(1), (2)	0.25	no	0.38	no
Calcium	mg/kg	-	-	-	None	-	201620	no	68349	no
Cesium	mg/kg	-	-	-	None	-	2.46	no	1.97	no
Chromium	mg/kg	26	37.3	-	26	(1)	25.3	no	**47.0**	**yes**
Cobalt	mg/kg	-	-	50 (4)	50	(4)	9.9	no	14.5	no
Copper	mg/kg	16	35.7	-	16	(1)	**26.9**	**yes**	**25.2**	**yes**
Iron	mg/kg	21200	-	-	21200	(1)	14387	no	**26228**	**yes**
Lead	mg/kg	31	35.0	-	31	(1)	19.0	no	25.8	no
Lithium	mg/kg	-	-	-	None	-	29.2	no	34.8	no
Magnesium	mg/kg	-	-	-	None	-	10257	no	6836	no
Manganese	mg/kg	460	-	-	460	(1)	**503**	**yes**	**517**	**yes**
Mercury	mg/kg	0.2	0.17	-	0.17	(2)	0.0334	no	0.0637	no
Molybdenum	mg/kg	-	-	13.8 (5)	13.8	(5)	1.41	no	0.73	no
Nickel	mg/kg	16	-	-	16	(1)	12.7	no	**20.1**	**yes**
PCB in solid	mg/kg	-	-	-	None	-	<0.05	no	<0.05	no
Petroleum Hydrocarbons F1	mg/kg	-	-	-	None	-	<10	no	<10	no
Petroleum Hydrocarbons F2	mg/kg	-	-	-	None	-	<10	no	<10	no
Petroleum Hydrocarbons F3	mg/kg	-	-	-	None	-	313.0	no	25.0	no
Petroleum Hydrocarbons F4	mg/kg	-	-	-	None	-	59.0	no	<10	no
Phosphorus	mg/kg	600	-	-	600	(1)	**673**	**yes**	**725**	**yes**
Potassium	mg/kg	-	-	-	None	-	11959	no	14152	no
Selenium	mg/kg	-	-	1.9 (5)	1.9	(5)	1.06	no	0.25	no
Silver	mg/kg	-	-	0.5 (4)	0.5	(4)	<0.05	no	<0.05	no
Sodium	mg/kg	-	-	-	None	-	8949	no	6752	no
Strontium	mg/kg	-	-	-	None	-	701.6	no	202	no
Thallium	mg/kg	-	-	-	None	-	0.40	no	0.61	no
Thorium	mg/kg	-	-	-	None	-	5.99	no	4.72	no
Tin	mg/kg	-	-	-	None	-	2.17	no	2.55	no
Titanium	mg/kg	-	-	-	None	-	1103	no	1920	no
Tungsten	mg/kg	-	-	-	None	-	0.74	no	0.35	no
Uranium	mg/kg	-	-	104.4 (5)	104.4	(5)	2.62	no	1.95	no
Vanadium	mg/kg	-	-	35.2 (5)	35.2	(5)	**40.9**	**yes**	**70.8**	**yes**
Zinc	mg/kg	120	123	-	120	(1)	82.8	no	81.9	no
Zirconium by ICP	mg/kg	-	-	-	None	-	35.9	no	54.0	no

Notes:
1. MOE (1993) Provincial Sediment Quality Objective
2. CCME CSQG
3. Probable Effect Concentration (Jones *et al.* , 1997)
4. Open Water Disposal Guideline (MOEE, 1993)
5. Lowest Effect Level, SLC Approach (weighted method, Thompson et al., 2005)
6. Maximum value from NND EA EcoRA baseline study (SENES, 2009a)

Appendix B Ecological Receptor Profiles

One of the key considerations, which defines the scope of a risk assessment, is the selection of ecological receptors. In selecting ecological receptors it is important to identify plants and animals that are likely to be most exposed to the effects of the project. As it is not possible to evaluate all ecological species at a site, representative VECs are generally selected based on several criteria as discussed in Section 4.1.2 of the main report.

This appendix details the aquatic and terrestrial ecological receptors (groups or species) selected for the assessment.

B.1 Aquatic Biota

B.1.1 Fish

B.1.1.1 Northern Redbelly Dace

The Northern Redbelly Dace (*Chrosomus eos*) is a cool water forage fish that inhibits lakes, bogs, ponds, and creeks across Canada and the northern areas of the St. Lawrence (Ontario Freshwater Fishes Life History Database, n.d; Stasiak, 2006). Spawning events typically take place in the late spring (May) and early summer (July) with five to 30 fertilized eggs being produced per event (Ontario Freshwater Fishes Life History Database, n.d; Stasiak, 2006). Eggs hatch about eight to 10 days later (Stasiak, 2006). The Northern Redbelly Dace is an invertivore and planktivore fish that primarily feeds on plant material (detritus, macrophytes and filamentous algae) (Stasiak, 2006). Predators of the Northern Redbelly Dace include fish such as trout, birds such as the kingfishers and mergansers, and aquatic invertebrates such as beetles and giant water bugs (Scott and Crossman, 1973; Stasiak, 2006).

B.1.1.2 Round Whitefish

The Round Whitefish (*Prosopium cylindraceum*) is a cold water lake fish. Spawning migrations may be undertaken by some round whitefish populations. Adults typically weigh between 454 g and 1360 g. Spawning occurs along lake and stream shorelines in late fall or early winter in southern Canada over gravel shoals or river mouths. Round whitefish are shallow water bottom feeders. Females lay an average of 5,000 to 12,000 eggs. Round whitefish hatch as sac fry in March to May and remain on the bottom, seeking shelter in rubble and boulders. Older juveniles, age 1 and 2, live in the same areas as adults but in shallower water and tend to move into deeper and faster water as they grow. Round whitefish eat a variety of invertebrates including mayfly larvae, chironomid larvae, small mollusks, crustaceans, fish, and fish eggs. Fish in lakes may eat more molluscs and small crustaceans than those in rivers (DFO, 2007; IF&W, 2001).

B.1.1.3 White Sucker

White Sucker (*Catostomus commersonni*) is a freshwater fish found in lakes and streams across North America. It is a bottom feeding fish that resides mainly in shallow, warm waters. The white sucker spawns in spring, April or May, in moderate to swift riffles, in gravelly and stony areas, when the water temperature is above 4°C. Spawning may also take place in the shallow water of lakes. Females randomly scatter 30,000 to 130,000 eggs over the spawning grounds. Fry (1.2 cm in length) feed primarily on plankton and other small free-floating invertebrates. When the white sucker reaches a length of about 1.6 to 1.8 cm, it begins bottom feeding. White suckers are preyed upon by birds, fishes, lamprey and mammals. In this assessment, white suckers are assumed to spend half of their time at the sediment surface and the other half immersed in the water (Ontario Fish Species, n.d.).

B.1.1.4 Alewife

Alewife (*Alosa pseudoharengus*) is a member of the herring family. Alewife are found in Lake Ontario, although there is debate as to whether the alewife population found in Lake Ontario is native or introduced. In its native range, alewives are anadromous, they are quite capable of completing its life cycle in freshwater environments. Adult alewife average about 6 to 7 inches in length in the freshwater variety. Alewives live for about 6 to 7 years and usually begin to reproduce around two years of age. Alewife spawn once a year from late April to early June. Females randomly deposit 10,000 to 12,000 eggs. In less than a week, the young alewives hatch and begin feeding primarily on zooplankton. In the fall, the young alewives make their way back to the sea or into the deep waters of freshwater lakes or rivers. Adult alewives feed on zooplankton, aquatic insects, and small fish (Indiana DNR, n.d.).

B.1.1.5 Lake Trout

Lake Trout (*Salvelinus namaycush*) is a freshwater char. Lake trout mainly reside in deep lakes in northern North America where the water is cold and oxygen-rich. In spring, lake trout are widely dispersed in the shallow waters of their habitat but, as soon as the water warms they migrate to deeper and colder water. Adults are generally 38 to 52 cm in length and have an average weight of 4.5 kg. In general, lake trout spawn on rocky reefs or shoals in the fall. Spawning takes place at night during which the eggs are scattered over the rocky bottom. The eggs remain among the rocks for weeks and hatch the following spring. Within a month or so after hatching, the young lake trout usually seek deeper water and are thought to be reclusive, plankton feeders during their first few years of life. The lake trout's diet varies depending on the season; in the summer months they become more planktivorous and during the cooler months, they become piscivorous (DFO, 2013).

B.1.1.6 American Eel

The American Eel (*Anguilla rostrata*) is a freshwater species found on the eastern coast of North America, and enter Ontario through the St. Lawrence River and Lake Ontario. The eel has a snake-like body and a dorsal fin that extends from half-way down the length of its back to the underside of its body. At maturity, eel range from 75 to 100 centimetres (cm) in length and weigh one to three kilograms. American eels have a complex life cycle, which begins with breeding in the Sargasso Sea in the Atlantic Ocean (OMNR, 2007). Young eels migrate to inland streams where they proceed to feed and mature in freshwater bodies for 10 to 25 years, before returning to the Sargasso Sea to spawn (OMNR, 2007). The majority of American eels found in Ontario are large, highly fecund (egg-laden) females. The eel is an important indicator of ecosystem health, and is a top predator. The American Eel is designated an endangered species and is protected under the Provincial *Endangered Species Act,* 2007. The American Eel is designated as “threatened” under COSEWIC.

B.1.2 Reptiles and amphibians

Reptiles (class: Reptilia) are cold blooded animals with scales or scutes rather than fur and feathers like mammals and birds. Common animals within the class include turtles, snakes and lizards. Most reptiles are oviparous (egg-laying) but do not require water bodies in which to breed.

Amphibians (class: Amphibia) typically inhabit a wide variety of habitats with most species bridging terrestrial and aquatic ecosystems during their life cycle. Common animals within the class include frogs and salamanders. Amphibians rely on surface water for reproduction as larvae are typically born in water. The young generally undergo metamorphosis from larva with gills to an adult air-breathing form with lungs. With their complex reproductive needs and permeable skins, amphibians are often used as ecological indicators.

Reptiles represented by turtles and amphibians represented by frogs are being model for Treefrog Pond, Polliwog Pond and Dragonfly Pond because these ponds provide a habitat for reptiles and amphibians.

B.1.3 Aquatic Plants

B.1.3.1 Macrophytes

Macrophytes are aquatic plants growing in or near water and can be either emergent, submergent or floating. Macrophytes are primary producers that provide food, cover and shelter for wildlife, such as spawning and nursey habitats for fish and nesting habitats for waterfowl, improve water quality and clarity, and help to stabilize shorelines and bottom sediments. Emergent aquatic plants such as cattails and bur-reed are found along the edges of on-site ponds at DN (Golder and SENES, 2009). Macrophytes such as cattails provide food for muskrats.

Because of the waves and/or unsuitable substrates along the nearshores of Lake Ontario, rooted aquatic plants are not found along the shores of Lake Ontario near the DN. Photosynthetic organisms are limited to attach algae.

Macrophytes are aquatic plants in the ecological model for Coots Pond and Treefrog Pond, which includes Dragonfly and Polliwog ponds.

B.1.4 Benthic Invertebrates

Benthic invertebrates or “benthos” live and feed within sediments. Benthic invertebrates include, among others, amphipods, bivalves, shrimps, crabs, snails, worms, and aquatic insects. They play an integral role in the integrity of the freshwater ecosystem through their role in nutrient cycling and function as an important food source for wildlife such as the diving (e.g. Bufflehead) and dabbling (e.g. Mallard) ducks and fish (e.g. White Sucker) . Benthic invertebrates provide a sediment to fish pathway link and a link between aquatic and terrestrial ecosystems. Many species feed on decaying organic matter and thereby form an important link between the decomposer and primary consumer levels.

The Lake Ontario nearshore benthic community is limited to species such as the zebra mussels and quagga mussels, which can withstand the abrasive wave actions and coarse substrates of the nearshore environment, whereas the habitat of Coots Pond is favourable to support a diverse benthic community (Golder and SENES, 2009).

Benthic invertebrates are being model for Lake Ontario and Coots Pond.

B.1.5 Riparian Birds

Birds are mobile receptors that will forage from a large home range. During breeding and rearing of young, the home range is often reduced.

B.1.5.1 Bufflehead

The Bufflehead (*Bucephala albeola*) is Canada’s smallest diving duck. Males average 450 g in weight and females about 340 g. During migration they may carry up to an additional 115 g of fat. Their breeding habitat is small ponds, usually in wooded areas. They are not gregarious and typically occur in groups of 10 birds or fewer. Their summer breeding range is north and west of the Great Lakes. Their Canadian overwinter range includes the west coast and favoured spots around Lake Ontario and the southern coasts of New Brunswick and Nova Scotia. Buffleheads nest in tree cavities. The female lays a clutch of 7 to 11 eggs. Hatching occurs about 30 days later and ducklings remain in the nest only 24 to 36 hours before being lead to the nearest waterbody. The young may be eaten by pike or other predators. The Buffleheads’ main foods are arthropods, mostly insect larvae in freshwater and small crustaceans, such as shrimps, crabs, amphipods, in salt water. In fall they eat many seeds of aquatic plants, and in winter they take small marine snails or freshwater clams in their respective habitats (EC & CWF, 2013).

The average territory size of the Bufflehead in ponds in British Columbia was measured to be 0.56 hectares (Gauthier, 1993).

For the ecological model it is assumed that the Bufflehead diet consists of benthic invertebrates (90%) and aquatic plants (10%). It is also assumed that the Bufflehead spends 50% of its time at DN.

B.1.5.2 Mallard

The Mallard (*Anas platyrhynchos*) is an omnivorous migratory duck that may breed over winter in Canada (U.S. EPA, 1993; FCSAP, 2012). Males average 1.1 kg in weight and females about 1.2 kg in weight (FCSAP, 2012). The general habitat of the Mallard is wetlands. Mallard typically nest on the ground in thick vegetation away from a waterbody. The female lays a clutch of 1 to 13 eggs with hatching occurring about 23 to 30 days later (Drilling, et al., 2002). Ducklings remain in the nest only 13 to 16 hours before leaving the nest (Drilling, et al., 2002).

The bulk of the Mallard`s diet is plant material (mostly aquatic plants and seeds) with the remaining portions of the diet consisting of aquatic invertebrates, especially in the breeding season (FCSAP, 2012). The Mallard forages by dabbling and filtering though sediment (U.S. EPA, 1993).

The mean home range of a Mallard is between 111 and 620 hectares in spring (U.S. EPA, 1993).

For the ecological model it is assumed that the Mallard diet, based on breeding, consists of benthic invertebrates (75%) and aquatic plants (25%). It is also assumed that the Mallard spends 50% of its time at DN.

B.1.6 Riparian Mammals

B.1.6.1 Muskrat

The muskrat (*Ondatra zibethicus*) is a large rodent, measuring approximately 50 cm from tip of the nose to tail, and weighing on average 1 kg. Muskrats exist all over North America, from the Arctic Ocean in the north to the Gulf of Mexico in the south, from the Pacific Ocean in the west to the Atlantic Ocean in the east. Muskrats prefer freshwater marshes, marshy areas of lakes, and slow-moving streams. The preferred water depth in these areas is 1 to 2 m, deep enough not to freeze fully during the winter but shallow enough to allow aquatic vegetation to grow. Muskrats nest in compact mounds of partially dried and decayed plant material such as cattails and bulrushes. In winter, muskrats generally occupy lodges that they build through burrowing underneath their mounds (EC & CWF, 2013).

Muskrats mainly feed on aquatic plants such as cattails, bulrushes, horsetails, or pondweeds; however, they prefer cattails. When aquatic plants are unavailable, muskrats are also known to feed on fish, frogs, and clams. Breeding generally occurs in March, April, or May. Birth of the litter usually occurs within 1 month of mating and usually contains 5 to 10 young. Breeding can occur multiple times throughout the season (EC & CWF, 2013).

The mean home range size of a muskrat in the summer ranges between 0.048 to 0.17 hectares (U.S. EPA, 1993).

For the ecological model it is assumed that the muskrat's diet consists of aquatic plants (100%) and that it spends 100% of its time at DN.

B.2 Terrestrial Biota

B.2.1 Earthworms

Earthworms live in soil, and depending on the species they either move vertically or horizontally in different soil layers. Earthworms acquire their nutrition through the organic matter in soil as well as the decomposing remains of other animals. They can devour one third of their own body weight per day.

B.2.2 Terrestrial Birds

B.2.2.1 American Robin

The American Robin (*Turdus migratorius*) is a migratory thrush that may breed and over winter in Canada (FCSAP, 2012). During the breeding season, the American Robin is found across the continental United States and Canada (U.S., 1993). The average breeding male weight is 77.4 g and the average breeding female weight is 80.6 g (Wheelright, 1986 as cited in U.S. EPA, 1993). American Robins make use of a wide variety of habitats with open areas. American Robins typically nest in trees, but may also nest in gutters, eaves, external light fixtures and structures (Sallabanks and James, 1999). Females lay a clutch of 3 to 5 eggs. Eggs hatch within 12 to 14 days and the nestling period lasts approximately 13 days (Sallabanks and James, 1999). The American Robin forages on the ground for invertebrates and in shrubs and low tree branches for fruit and foliage-dwelling insects (U.S. EPA, 1993). Earthworms and insects account for most (71%) of the nestlings and fledglings diet with the reminder of the diet consisting of vegetation, seeds and fruit (29%). Before and during the breeding season, robins predominately feed on invertebrates (between 80 to 90% volume), with fruits making up the bulk of the robin's diet for the reminder of the year (between 60 to 90% volume) (Wheelright, 1986 as cited in U.S. EPA, 1993).

The mean territory size of the American Robin ranges between 0.11 and 0.42 hectares in the spring with a mean foraging home range between 0.15 and 0.81 in the summer (U.S. EPA, 1993).

For the ecological model it is assumed that the American Robin's diet consists of 60% fruits represented by berries and 40% invertebrates, represented as earthworms (FCSAP, 2012). It is also assumed that the American Robin spends 50% of its time at DN.

B.2.2.2 Bank Swallow

The Bank Swallow (*Riparia riparia*) nest in colonies along cliffs and the banks of streams and rivers, but can also be found in anthropogenic habitats such as gravel pits and roadcuts across much of North America (COSEWIC, 2013). The Bank Swallow weighs between10 and 19 g. In Ontario, the breeding season spans between early May to mid- August (MNRF, 2016). Females lay a clutch of 3 to 6 eggs. Eggs hatch within 13 to 16 days and the nestling period lasts between 18 to 24 days (Garrison, 1999). Young are tended by both parents. Bank Swallows are aerial insectivores, feeding primarily while flying above clearings or open water (COSEWIC, 2013). Predators of the Bank Swallow include raptors, snakes, rats, chipmunks, raccoons, badgers, skunks, weasels, foxes, and coyotes, among others (COSEWIC, 2013). The Bank Swallow is designated threatened and is protected under the Provincial *Endangered Species Act,* 2007. The Bank Swallow is designated as "threatened" under COSEWIC.

In the United Kingdom, mean foraging ranges from Bank Swallow colonies have been reported to be within 0.26 km when adults were providing for nestlings and within 0.69 km when building nests (MNRF, 2016).

For the ecological model it is assumed that the Bank Swallow's diet consists of 100% insects represented by the caterpillar. It is also assumed that the Bank Swallow spends 50% of its time at DN.

B.2.2.3 Song Sparrow

The Song Sparrow (*Melospiza melodia*) is the most widespread sparrow found throughout most of North America with most of the populations of the song sparrow being migratory. The Song Sparrow weighs between 12 and 53 g. They breed in brushy areas along streamside thickets or the edges of marshes. Nests sites may include the ground under grass or shurbs or in shurbs and low lying trees. Song Sparrows typically lay two or more clutches of eggs per breeding season with clutch size ranging between 1 and 6 eggs. Eggs hatch within 12 to 15 days and the nestling period lasts between 9 to 12 days. The song sparrow forages on the ground feeding primarily on fruits and seeds, with insects being eaten mostly in the summer (Arcese et al., 2002).

The breeding territory of the Song Sparrow is typically less than 0.4 hectares (NatureServe 2015).

For the ecological model it is assumed that the Song Sparrow's diet consists of 90% grains and seeds represented by berries and 10% insects represented by the caterpillar. It is also assumed that the Song Sparrow spends 80% of its time at DN.

B.2.2.4 Yellow Warbler

The migratory Yellow Warbler (*Dendroica petechia*) is widespread throughout North America. They weigh between 9 and 11 g. They breed in streamside thickets and early successional areas typically dominated by willows. Nests are usually placed in the vertical fork of a bush or small tree. Females lay a clutch of 1 to 7 eggs. Incubation by the female lasts within 10 to 13 days and the nestling period lasts between 9 to 12 days. Young are tended by both parents. Yellow Warbler forages along the branches of shrubs, small trees and foliage gleaning off insects (Lowther et al., 1999). The Yellow Warbler may eat fruit and probe in flowers (NatureServe, 2015).

The breeding territory of the Yellow Warbler can be as small as 0.16 hectares (NatureServe, 2015).

For the ecological model it is assumed that the Yellow Warbler's diet consists of 90% insects represented by caterpillar and 10% fruits represented by berries. It is also assumed that the Yellow Warbler spends 50% of its time at DN.

B.2.3 Terrestrial Plants

B.2.3.1 Grass

Cultural meadow and thicket ecosystems make up a large portion of the terrestrial environment at DN. For the ecological model, grasses were used as a food source for the American Robin, Song Sparrow, Yellow Warbler, Eastern cottontail, meadow vole, white-tailed deer, raccoon, and red fox.

B.2.3.2 Sugar Maple

Four primary ecosystems have been identified for the DN: cultural meadow and thickets, shrub bluff, wetland and woodlands (Beacon, 2009). The sugar maple, which is found at the DN, has been identified as an indicator species for the woodland ecosystems because it is used by wildlife. For the ecological model, the sugar maple is used as a food source for the white-tailed deer and raccoon.

B.2.4 Terrestrial Mammals

B.2.4.1 Eastern Cottontail

The Eastern cottontail (*Sylvilagus floridanus*) is a medium sized rabbit, measuring 35 to 43 cm in length, and weighing between 0.7 to 1.8 kg (U.S. EPA, 1993). Females are typically 1 to 2% larger than males (Naughton, 2012). The Eastern cottontail is found in southern Canada and the eastern and western United States (U.S. EPA, 1993). Although the Eastern cottontail may be found in swamps, woodlands and grasslands, they prefer mixed farmland and hedgerow habitats (Naughton, 2012). The mean home range of the Eastern cottontail is between 0.8 and 7.8 hectares (U.S. EPA, 1993).

The Eastern cottontail breeds throughout the year, with peak mating between January and April. Gestation lasts approximately 28 days, with females producing five to seven litters per year and 25 to 35 young per year. Although not fully weaned, young leave the litter after 14 to 16 days (U.S. EPA, 1993; Naughton, 2012).

The Eastern cottontail forages throughout the night and feeds on herbaceous vegetation such as grasses and forbs in the summer and woody vegetation such as twigs and bark in the winter (U.S. EPA, 1993). Predators of the Eastern cottontail include raptors, owls, red foxes and coyotes (U.S. EPA, 1993; Naughton, 2012).

For the ecological model it is assumed that the Eastern cottontail's diet consists of 100% grass and that the Eastern cottontail spends 100% of its time at DN.

B.2.4.2 Meadow Vole

The meadow vole (*Microtus pennsylvanicus*) is a small herbivorous rodent, measuring 8.9 to 13 cm from head to tail, and weighing between 0.02 to 0.04 kg. The meadow vole is found across Canada, Alaska and the northern United States. They can be found mainly in meadows, lowland fields, grassy marshes, and along rivers and lakes. They are also occasionally found in flooded marshes, high grasslands near water, and orchards or open woodland if grassy (US EPA, 1993). The meadow vole has a small home range size with a mean home range between 0.0069 and 0.083 hectares in the summer (U.S. EPA, 1993).

The meadow vole breeds throughout the year, but breeding peaks from April to October. Gestation lasts approximately 21 days, with litter sizes ranging from 1 to 9 (NatureServe, 2012). Meadow voles mainly feed on shoots, grass, and bark. Voles are prey for hawks and owls as well as several mammalian predators such as short-tailed shrews, badgers, and foxes (US EPA, 1993).

For the ecological model it is assumed that the meadow vole's diet consists of 100% grass and spends 100% of its time at DN.

B.2.4.3 White-tailed Deer

The white-tailed deer (*Odocoileus virginianus*) is the smallest of the native Canadian deer, measuring 151 to 240 cm in total length, and weighing between 50 to 135 kg (adult). Males are typically 20 to 55% larger than females (Naughton, 2012).

The white-tailed deer is widespread throughout North America. They prefer open forests intermixed with "*meadows, clearings, grasslands, and riparian flatlands*". The white-tailed deer home range size ranges between 60 to 500 hectares (Naughton, 2012).

The white-tailed deer diet consists mainly of terrestrial vegetation such as fresh grasses, forbs, fruits, nuts, browse, as well as mushrooms. In areas near the Great Lakes, white-tailed deer are known to consume alewives that have washed ashore after spawning. Predators of the white-tail deer include wolves, coyotes, cougars, and black bears (Naughton, 2012).

If a female white-tailed deer is well nourished, it breeds yearly. Mating season for Canadian deer typically take place between late October and mid-December, with a breeding peak in mid-November. Gestation lasts approximately 200 days with first time mothers typically producing one off-spring and repeat, larger, well-nourished mothers producing two or three off-springs. Fawns are fully weaned by four months (Naughton, 2012).

For the ecological model it is assumed that the white-tailed deer's diet consists of 100% terrestrial vegetation (e.g. grass and/or sugar maple) and that the white-tailed deer spends 100% of its time at DN.

B.2.4.4 Common (Masked) Shrew

The common (masked) shrew (*Sorex cinereus*) is the most widespread and adaptable of the North American shrews with reproductive age Canadian shrews measuring 7.5 to 12.5 cm in total length, and weighing on average between 0.0036 and 0.0046 kg. Although the common shrew may occupy a wide variety of habitats they are most abundant in damp and mossy woodlands. Shrews build hollow nests of grass and leaves in stumps, logs, debris or burrows, and forage under leaf litter in tunnels or runways created by other animals (Naughton, 2012).

The common shrew is an insectivore that eats a variety of invertebrates. During the winter, the diet of the shrew consists mostly of dormant insects and pupae with truffles and seeds being consumed when food is limited. Shrews may also eat carrion, salamanders and bird eggs. Shrews are prey for hawks and owls, herons, shrikes, snakes as well as several carnivorous mammals such as weasels, foxes, and larger shrews (Naughton, 2012). The average foraging range size of the shrew is 0.6 hectares (Nagorsen, 1996 as cited in FSCAP, 2012).

Shrews typically breed between May and September, with most females producing one to three litters annually and an average litter size of five to seven. The gestation period of the common shrew is not known. Young shrews leave the nest after approximately 27 days (Naughton, 2012).

For the ecological model it is assumed that the common shrew's diet consists of 100% insects (e.g., caterpillars or earthworms) and that they spend 100% of its time at DN.

B.2.4.5 Raccoon

The raccoon (*Procyon lotor*) is a medium sized generalist nocturnal omnivore. An adult raccoon measures 74 to 105 cm in total length and weighs between 3.9 and 13.5 kg. Adult male raccoons are on average 10 to 15% heavier than female raccoons (Naughton, 2012).

The raccoon is very adaptable and widespread throughout southern Canada. They are abundant in urban, riparian, and wetland areas (Naughton, 2012). Tree cavities, spaces in rocks, caves, brush, uninhibited fox dens, muskrat houses, squirrel and bird nests, buildings such as attics, basements and barns are used as raccoon dens. The raccoon has a mean home range between 39 and 2560 hectares, with male raccoons occupying larger home ranges than female raccoons (U.S. EPA, 1993; Naughton, 2012).

The raccoon eats masts, grains, insects, aquatic invertebrates, fish, reptiles and amphibians, reptile eggs, small mammals, small birds and eggs, carrion, and human garbage. Animal matter makes up a good portion of the raccoon's diet in the spring and early summer, while fruits make up the bulk of the raccoon's diet in the late summer and fall. In the winter, acorns are typically consumed, however if available, grains and masts may also be consumed. Predators of the raccoon include owls, coyotes, wolves, cougars, fishers, and foxes (U.S. EPA, 1993; Naughton, 2012).

Breeding season for the raccoon typically begins in early February and ends in June, with peak breeding taking place in March. Gestation lasts approximately 63 days, with a mean litter size between 2 and 4 cubs. A female typically produces one litter per year. Cubs begin to forage on their own at approximately 18 months of age (U.S. EPA, 1993; Naughton, 2012).

For the ecological model it is assumed that the raccoon's diet consists of 10% benthic invertebrates (for polygon AB); 15% fruits; 25% terrestrial vegetation (represented by grass for polygon AB and C, and grass and sugar maple in equal portion for polygons D and E); 10% small mammals (represented by the meadow vole), and 40 or 50% invertebrates (represented by caterpillars for polygons AB, C and D, and represented by earthworms for polygon E). The raccoon is assumed to spend 100% of its time at DN.

B.2.4.6 Red Fox

The red fox (*Vulpes vulpes)* is a small mammal that ranges in length between 90 and 112 cm, and weighs approximately 4.54 kg (US EPA, 1993). Red foxes are found throughout Canada in all provinces and territories. They generally occupy a home range between 4 to 8 km^2 and reside in a main underground den and one or more other burrows within their home range. The tunnels are up to 10 m long and lead to a chamber 1 to 3 m below surface. Foxes breed between late December and mid-March, and pups are born from March through May, with litter sizes ranging from 1 to 10. Pup-rearing is the primary focus of the red fox during spring and early summer. Their diet is predominantly small mammals such as mice and voles, but they also eat insects, fruits, berries, seeds and nuts.

Their diet varies with the seasons, eating mainly small mammals in fall and winter, nesting waterfowl in the spring, and insects and berries in the summer (EC & CWF, 2013).

For the ecological model it is assumed that the red fox's diet consists of 70% small mammals (48% Eastern cottontails and 32% meadow voles) and 30% terrestrial plants represented by grass for polygons C, D and E, and 50% small mammals (30% Eastern cottontails and 20% meadow voles), 30% aquatic birds (15% Bufflehead and 15% Mallard), and 20% terrestrial plants represented by grass for polygon AB. The red fox is assumed to spend 100% of its time at DN.

B.2.4.7 Short-tailed Weasel

The short-tailed weasel (*Mustela erminea*) or the ermine is a small mammal. A Canadian adult weasel ranges in total length between 22 and 36 cm, and weighs between 0.05 and 0.24 kg, with males being up to 80% heavier than female weasels (Naughton, 2012).

The short-tailed weasel is found throughout Canada in all provinces and territories. They inhabit successional forests, woodlands, parklands, edges of forests, wetlands such as marshes, riverbanks, and farmlands. The weasel uses trees cavities, rock openings, prey burrows, and subnivean runways or areas as their dens, while the fur and feathers of their prey are used to line their nests. The home range of a Canadian male weasel ranges between 1 and 205 hectares, whereas the home range of a Canadian female weasel ranges between 4 and 95 hectares. Weasels found in western Canada occupying larger home ranges than weasels found in eastern Canada (Naughton, 2012).

The diet of the short-tailed weasel is predominantly small mammals such as mice and voles, but they also eat lemmings, rabbits and hares, squirrels, shrews, chipmunks, birds, bird eggs, reptiles, amphibians, fish, and invertebrates. Short-tailed weasels are prey for raptors and owls, foxes, coyotes, snakes and larger weasels. Because of their high metabolism, starvation is the primarily cause of death for the short-tailed weasel. Missing two or three consecutive meals is enough to cause death (Naughton, 2012).

Breeding season for the short-tailed weasel takes place between April and June. Gestation lasts approximately 11 to 12 months, with females producing a mean litter size of 4 and 8 kits. Young are weaned after approximately 12 weeks of age (Naughton, 2012).

For the ecological model it is assumed that the short-tailed weasel's diet consists of 100% meadow voles. It is also assumed that the short-tailed weasel spends 100% of its time at DN.

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Appendix C Modelled Concentrations for Ecological Receptors

Table C.1: Modelled Radiation Concentration for Aquatic Biota for Polygon Lake Ontario

Receptor	Unit	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131	
		Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Lake Trout	Bq/kg (fw)	1.25E+01	7.15E-01	5.40E+01	5.40E+01	3.50E+03	3.50E+03	1.99E+01	4.70E+00	2.15E+01	4.60E+00	2.40E+01	1.24E+01
American Eel	Bq/kg (fw)	1.25E+01	7.15E-01	5.40E+01	5.40E+01	3.50E+03	3.50E+03	1.99E+01	4.70E+00	2.15E+01	4.60E+00	2.40E+01	1.24E+01
Bufflehead	Bq/kg (fw)	3.86E+01	3.86E+01	2.57E-01	2.57E-01	7.16E-01	7.14E-01	5.90E-01	5.82E-01	1.14E+01	4.18E+00	2.00E-01	1.64E-01
Mallard	Bq/kg (fw)	3.86E+01	3.86E+01	2.39E-01	2.39E-01	6.64E-01	6.64E-01	5.41E-01	5.39E-01	1.14E+01	4.18E+00	1.88E-01	1.54E-01

Table C.2: Modelled Radiation Concentration for Media and VECs for Polygon AB

Receptor	Unit	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131	
		Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Loam Pore Water	Bq/L	7.22E-01	5.45E-01	1.73E-03	1.73E-03	3.00E-03	3.00E-03	2.28E-02	8.89E-03	2.61E+03	1.21E+02	4.92E-01	1.05E-01
Turtles	Bq/kg (fw)	2.85E+03	2.85E+03	5.40E+01	5.40E+01	3.50E+03	3.50E+03	3.50E+03	3.50E+03	5.85E+01	3.83E+01	2.40E+01	1.27E+01
Frogs	Bq/kg (fw)	2.85E+03	2.85E+03	5.40E+01	5.40E+01	3.50E+03	3.50E+03	3.50E+03	3.50E+03	5.85E+01	3.83E+01	2.40E+01	1.27E+01
Aquatic Plants	Bq/kg (fw)	3.89E+01	3.46E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	4.30E+01	3.76E+01	2.00E+00	2.00E+00
Benthic Invertebrates	Bq/kg (fw)	2.60E+03	2.60E+03	1.10E+02	1.10E+02	9.90E+01	9.90E+01	9.90E+01	9.90E+01	5.85E+01	3.83E+01	3.84E+01	2.03E+01
Bufflehead	Bq/kg (fw)	2.58E+03	2.58E+03	2.03E+01	2.03E+01	5.09E+01	5.09E+01	5.09E+01	5.09E+01	9.14E+00	5.20E+00	6.57E-02	3.50E-02
Mallard	Bq/kg (fw)	2.17E+03	2.16E+03	1.60E+01	1.60E+01	4.00E+01	4.00E+01	4.00E+01	4.00E+01	9.14E+00	5.20E+00	5.22E-02	2.80E-02
Muskrat	Bq/kg (fw)	1.56E+02	1.39E+02	2.16E-02	2.16E-02	1.11E+00	1.11E+00	1.11E+00	1.11E+00	2.74E+01	1.67E+01	8.38E-01	6.84E-01
American Robin	Bq/kg (fw)	3.07E+01	3.02E+01	5.82E-01	5.82E-01	1.62E+00	1.62E+00	1.75E+00	1.66E+00	2.21E+01	1.82E+01	2.63E-02	2.30E-02
Bank Swallow	Bq/kg (fw)	3.39E+01	2.95E+01	4.99E-01	4.99E-01	1.39E+00	1.39E+00	1.46E+00	1.41E+00	9.14E+00	5.20E+00	2.55E-02	2.03E-02
Song Sparrow	Bq/kg (fw)	4.69E+01	4.62E+01	1.21E+00	1.21E+00	3.37E+00	3.37E+00	3.49E+00	3.41E+00	4.57E+01	3.94E+01	2.63E-02	2.33E-02
Yellow Warbler	Bq/kg (fw)	3.34E+01	2.94E+01	5.46E-01	5.46E-01	1.52E+00	1.52E+00	1.60E+00	1.54E+00	1.13E+01	7.36E+00	2.63E-02	2.10E-02
Eastern Cottontail	Bq/kg (fw)	9.45E+01	5.77E+01	9.52E-02	9.52E-02	5.82E+01	5.82E+01	6.23E+01	5.94E+01	2.39E+02	6.94E+01	3.14E+00	1.40E+00
Meadow Vole	Bq/kg (fw)	9.45E+01	5.77E+01	1.06E-02	1.06E-02	5.40E-01	5.40E-01	5.53E-01	5.44E-01	2.39E+02	6.94E+01	1.97E+00	8.90E-01
White-tailed Deer	Bq/kg (fw)	9.45E+01	5.77E+01	2.79E-01	2.79E-01	3.48E+00	3.48E+00	3.56E+00	3.50E+00	2.65E+02	7.39E+01	9.05E+00	4.08E+00
Common Shrew	Bq/kg (fw)	5.59E+01	4.85E+01	2.81E-02	2.81E-02	1.44E+00	1.44E+00	1.47E+00	1.45E+00	2.74E+01	1.67E+01	2.56E+00	2.08E+00
Raccoon	Bq/kg (fw)	5.33E+02	5.18E+02	1.69E-01	1.69E-01	7.95E+00	7.95E+00	8.09E+00	7.99E+00	6.27E+01	2.00E+01	3.22E+00	1.84E+00
Red Fox	Bq/kg (fw)	6.53E+02	6.27E+02	3.63E-02	3.63E-02	8.76E+00	8.76E+00	9.11E+00	8.87E+00	6.97E+01	2.73E+01	7.74E-01	3.77E-01
Short-tailed Weasel	Bq/kg (fw)	9.45E+01	5.77E+01	4.06E-03	4.06E-03	4.94E-01	4.94E-01	5.60E-01	5.14E-01	2.74E+01	1.67E+01	5.81E-01	2.75E-01

Table C.3: Modelled Radiation Concentration for Media and VECs for Polygon C

Receptor	Unit	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131	
		Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Loam Pore Water	Bq/L	5.68E-01	4.71E-01	1.73E-03	1.73E-03	3.00E-03	3.00E-03	2.49E-02	1.32E-02	2.27E+02	9.22E+01	4.92E-01	2.92E-01
American Robin	Bq/kg (fw)	3.39E+01	3.39E+01	5.26E-01	5.26E-01	1.46E+00	1.46E+00	1.62E+00	1.54E+00	4.26E+01	3.08E+01	2.27E-02	2.23E-02
Song Sparrow	Bq/kg (fw)	5.29E+01	5.29E+01	1.12E+00	1.12E+00	3.11E+00	3.11E+00	3.24E+00	3.17E+00	8.64E+01	6.75E+01	2.53E-02	2.50E-02
Yellow Warbler	Bq/kg (fw)	5.09E+01	5.09E+01	4.69E-01	4.69E-01	1.30E+00	1.30E+00	1.39E+00	1.35E+00	2.37E+01	1.19E+01	3.14E-02	3.11E-02
Eastern Cottontail	Bq/kg (fw)	1.16E+02	9.96E+01	7.37E-02	7.37E-02	4.50E+01	4.50E+01	4.99E+01	4.73E+01	1.83E+02	1.23E+02	2.43E+00	1.77E+00
Meadow Vole	Bq/kg (fw)	2.32E+02	1.99E+02	7.28E-03	7.28E-03	3.73E-01	3.73E-01	3.90E-01	3.81E-01	1.83E+02	1.23E+02	1.48E+00	1.08E+00
White-tailed Deer	Bq/kg (fw)	1.16E+02	9.96E+01	1.97E-01	1.97E-01	2.46E+00	2.46E+00	2.57E+00	2.51E+00	1.86E+02	1.31E+02	6.84E+00	4.99E+00
Common Shrew	Bq/kg (fw)	8.74E+01	8.74E+01	2.58E-02	2.58E-02	1.32E+00	1.32E+00	1.36E+00	1.34E+00	6.94E+01	2.82E+01	3.24E+00	3.23E+00
Raccoon	Bq/kg (fw)	1.04E+02	9.61E+01	2.61E-02	2.61E-02	1.38E+00	1.38E+00	1.55E+00	1.46E+00	1.06E+02	6.05E+01	3.12E+00	2.73E+00
Red Fox	Bq/kg (fw)	1.53E+02	1.31E+02	1.30E-03	1.30E-03	5.89E+00	5.89E+00	6.54E+00	6.19E+00	9.21E+01	4.71E+01	3.99E-01	2.84E-01
Short-tailed Weasel	Bq/kg (fw)	2.32E+02	1.99E+02	2.59E-04	2.59E-04	2.11E-01	2.11E-01	2.90E-01	2.48E-01	6.94E+01	2.82E+01	2.94E-01	2.08E-01

Table C.4: Modelled Radiation Concentration for Media and VECs for Polygon D

Receptor		Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131	
	Unit	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Loam Pore Water	Bq/L	4.16E-01	3.67E-01	1.73E-03	1.73E-03	3.00E-03	3.00E-03	1.38E-02	9.54E-03	5.40E+02	2.19E+02	3.08E-01	2.46E-01
Turtles	Bq/kg (fw)	2.85E+03	2.85E+03	5.40E+01	5.40E+01	3.50E+03	3.50E+03	3.50E+03	3.50E+03	1.19E+02	6.22E+01	3.00E+01	1.28E+01
Aquatic Plants	Bq/kg (fw)	5.75E+01	5.50E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	5.80E+01	5.26E+01	3.00E+00	2.20E+00
American Robin	Bq/kg (fw)	3.69E+01	3.64E+01	5.82E-01	5.82E-01	1.62E+00	1.62E+00	1.69E+00	1.66E+00	3.18E+01	2.19E+01	3.03E-02	1.95E-02
Song Sparrow	Bq/kg (fw)	5.69E+01	5.56E+01	1.21E+00	1.21E+00	3.37E+00	3.37E+00	3.44E+00	3.41E+00	6.22E+01	4.57E+01	2.50E-02	2.25E-02
Yellow Warbler	Bq/kg (fw)	3.58E+01	3.57E+01	5.46E-01	5.46E-01	1.52E+00	1.52E+00	1.56E+00	1.54E+00	2.02E+01	1.09E+01	1.94E-02	1.74E-02
Eastern Cottontail	Bq/kg (fw)	1.14E+02	9.79E+01	9.52E-02	9.52E-02	5.82E+01	5.82E+01	6.04E+01	5.96E+01	7.80E+01	4.59E+01	4.20E+00	3.36E+00
Meadow Vole	Bq/kg (fw)	1.14E+02	9.79E+01	1.06E-02	1.06E-02	5.40E-01	5.40E-01	5.48E-01	5.45E-01	7.80E+01	4.59E+01	2.64E+00	2.08E+00
White-tailed Deer	Bq/kg (fw)	1.14E+02	9.79E+01	2.79E-01	2.79E-01	3.48E+00	3.48E+00	3.52E+00	3.51E+00	7.22E+01	4.37E+01	1.21E+01	9.59E+00
Common Shrew	Bq/kg (fw)	5.91E+01	5.91E+01	2.81E-02	2.81E-02	1.44E+00	1.44E+00	1.46E+00	1.45E+00	5.45E+01	2.75E+01	1.79E+00	1.69E+00
Raccoon	Bq/kg (fw)	7.83E+01	7.24E+01	3.28E-02	3.28E-02	1.74E+00	1.74E+00	1.82E+00	1.79E+00	6.57E+01	3.72E+01	3.63E+00	2.96E+00
Red Fox	Bq/kg (fw)	1.14E+02	9.79E+01	7.82E-03	7.82E-03	7.93E+00	7.93E+00	8.23E+00	8.11E+00	5.92E+01	3.12E+01	1.09E+00	6.90E-01
Short-tailed Weasel	Bq/kg (fw)	1.14E+02	9.79E+01	4.06E-03	4.06E-03	4.94E-01	4.94E-01	5.30E-01	5.16E-01	5.45E+01	2.75E+01	7.42E-01	4.79E-01

Table C.5: Modelled Radiation Concentration for Media and VECs for Polygon E

Receptor	Unit	Carbon-14		Cobalt-60		Cesium-134		Cesium-137		Tritium		Iodine-131	
		Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Outdoor Air	Bq/m^3	1.41E-01	7.19E-02	4.39E-06	2.13E-06	NA	NA	NA	NA	3.18E+01	1.29E+01	1.41E-05	9.24E-06
Loam Pore Water	Bq/L	7.50E-01	6.48E-01	1.73E-03	1.73E-03	3.00E-03	3.00E-03	2.49E-02	1.95E-02	1.45E+03	5.88E+02	4.30E-01	3.08E-01
Earthworm	Bq/kg (fw)	7.45E+01	3.80E+01	6.75E-03	6.75E-03	9.92E-02	9.92E-02	8.22E-01	6.44E-01	1.63E+03	6.63E+02	1.21E+00	8.67E-01
American Robin	Bq/kg (fw)	5.45E+01	3.85E+01	3.76E-01	3.76E-01	1.10E+00	1.10E+00	1.51E+00	1.37E+00	4.54E+01	3.47E+01	9.84E-03	8.10E-03
Bank Swallow	Bq/kg (fw)	8.18E+01	4.18E+01	8.29E-02	8.29E-02	3.39E-01	3.39E-01	1.05E+00	8.22E-01	1.74E+01	6.64E+00	7.54E-03	4.85E-03
Song Sparrow	Bq/kg (fw)	6.53E+01	5.89E+01	1.10E+00	1.10E+00	3.09E+00	3.09E+00	3.18E+00	3.10E+00	9.51E+01	7.79E+01	2.15E-02	1.94E-02
Yellow Warbler	Bq/kg (fw)	7.73E+01	4.12E+01	1.31E-01	1.31E-01	4.71E-01	4.71E-01	1.18E+00	9.53E-01	2.21E+01	1.13E+01	8.35E-03	5.64E-03
Terrestrial Plants (Grass)	Bq/kg (fw)	6.71E+01	3.43E+01	1.38E-02	1.21E-02	1.18E-02	1.18E-02	9.75E-02	7.63E-02	1.68E+03	6.45E+02	2.47E-01	1.67E-01
Terrestrial Plants (Sugar maple)	Bq/kg (fw)	6.71E+01	3.43E+01	1.38E-02	1.21E-02	1.18E-02	1.18E-02	9.75E-02	7.63E-02	1.68E+03	6.45E+02	2.47E-01	1.67E-01
Eastern Cottontail	Bq/kg (fw)	1.35E+02	6.89E+01	2.36E-02	2.35E-02	1.43E+01	1.43E+01	9.54E+00	7.43E+00	7.49E+02	2.87E+02	2.81E-01	1.56E-01
Meadow Vole	Bq/kg (fw)	1.35E+02	6.89E+01	3.43E-03	3.42E-03	1.75E-01	1.75E-01	5.26E-02	4.07E-02	7.49E+02	2.87E+02	2.35E-01	1.26E-01
White-tailed Deer	Bq/kg (fw)	1.35E+02	6.89E+01	8.52E-02	8.48E-02	1.06E+00	1.06E+00	3.35E-01	2.59E-01	8.51E+02	3.26E+02	1.01E+00	5.42E-01
Common Shrew	Bq/kg (fw)	1.35E+02	6.89E+01	2.52E-03	2.52E-03	2.51E-01	2.51E-01	1.13E+00	8.80E-01	3.19E+01	1.14E+01	6.38E-01	4.28E-01
Raccoon	Bq/kg (fw)	1.24E+02	6.75E+01	1.46E-02	1.46E-02	8.24E-01	8.24E-01	1.11E+00	9.48E-01	2.22E+02	9.09E+01	9.32E-01	6.42E-01
Red Fox	Bq/kg (fw)	1.35E+02	6.89E+01	6.60E-03	6.59E-03	2.20E+00	2.20E+00	1.26E+00	9.80E-01	1.75E+02	6.65E+01	4.29E-01	2.24E-01
Short-tailed Weasel	Bq/kg (fw)	1.35E+02	6.89E+01	3.98E-03	3.98E-03	2.96E-01	2.96E-01	1.04E-01	8.05E-02	3.19E+01	1.14E+01	2.93E-01	1.56E-01

Notes:

For C-14 and HTO, earthworm concentrations were estimated using the specific activity model

NA- Not applicable because air emissons data was not inputted for these parameters.

Table C.6: Modelled Non-Radiation Concentration for Mode VECs that are prey for other VECs for Polygon AB

Receptor		Aluminum		Barium		Cobalt		Copper		Lead		Manganese		Strontium		Vanadium	
	Unit	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Aquatic Plants	mg/kg (ww)	2.45E+03	5.83E+02	6.30E+00	3.15E+00	3.16E+00	7.90E-01	4.50E+00	3.00E+00	1.90E+00	5.70E-01	3.08E+02	1.76E+02	2.70E+02	1.89E+02	2.72E-01	1.12E-01
Benthic Invertebrates	mg/kg (ww)	1.00E+04	2.38E+03	1.80E+01	9.00E+00	4.40E-01	1.10E-01	6.30E-02	4.20E-02	2.20E-02	6.60E-03	4.83E+01	2.76E+01	1.97E+02	1.38E+02	6.63E-01	2.73E-01
Bufflehead	mg/kg (ww)	3.40E+04	9.87E+03	1.04E-01	7.01E-02	2.00E-01	8.77E-02	7.27E-02	5.82E-02	5.94E-02	4.22E-02	3.52E-02	2.20E-02	9.42E-01	6.71E-01	1.02E-02	7.58E-03
Mallard	mg/kg (ww)	2.66E+04	6.85E+03	6.75E-02	3.89E-02	2.31E-01	6.86E-02	7.74E-02	5.44E-02	5.01E-02	2.20E-02	4.42E-02	2.58E-02	8.77E-01	6.17E-01	5.01E-03	3.04E-03
Eastern Cottontail	mg/kg (ww)	3.66E+03	1.60E+03	2.16E-01	5.94E-02	6.62E-03	2.12E-03	1.24E+00	5.05E-01	2.00E-02	6.94E-03	5.58E-01	3.24E-01	1.91E+00	8.60E-01	8.32E-02	3.83E-02
Meadow Vole	mg/kg (ww)	8.79E+02	2.78E+02	7.48E-02	1.81E-02	1.73E-03	4.59E-04	4.42E-01	1.80E-01	4.68E-03	1.37E-03	1.61E-01	8.71E-02	6.78E-01	3.02E-01	2.09E-02	7.08E-03

Notes

Estimates for ammonia (un-ionized; as NH_3), calcium, iron, magnesium, and phosphorus, potassium were not provided because these COPCs were assessed qualitatively for mammals and birds

Estimates for boron (HWS) were not provided because boron (HWS) is not assessed for mammals and birds

Table C.7: Modelled Non-Radiation Concentration for VECs that are prey for other VECs for Polygon C

Receptor	Unit	Barium		Strontium		Tin	
		Maximum	Mean	Maximum	Mean	Maximum	Mean
Eastern Cottontail	mg/kg (ww)	5.48E-02	4.53E-02	6.97E-01	6.25E-01	9.83E-02	5.99E-02
Meadow Vole	mg/kg (ww)	1.33E-02	1.01E-02	2.35E-01	2.10E-01	1.61E-02	1.01E-02

Table C.8: Modelled Non-Radiation Concentration for VECs that are prey for other VECs for Polygon D

Receptor		Barium		Boron		Cobalt		Manganese		Strontium		Tin		Zirconium	
	Unit	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
Eastern Cottontail	mg/kg (ww)	8.93E-02	6.32E-02	3.18E-01	3.02E-01	2.36E-03	2.16E-03	3.79E-01	3.11E-01	1.12E+00	7.60E-01	7.11E-01	3.79E-01	5.33E-05	4.04E-05
Meadow Vole	mg/kg (ww)	2.47E-02	1.71E-02	1.17E-01	1.12E-01	4.60E-04	4.11E-04	1.02E-01	7.93E-02	3.76E-01	2.52E-01	2.55E-01	1.33E-01	8.39E-06	6.37E-06

Notes

Estimates for calcium, iron, magnesium, and potassium were not provided because these COPCs were assessed qualitatively for mammals and birds

Estimates for nitrate were not provided because there was no BAF data for nitrate and nitrate is not suspected to biomagnify through the food chain

Table C.9: Modelled Non-Radiation Concentration for VECs that are prey for other VECs for Polygon E

Receptor	Unit	Barium		Strontium	
		Maximum	Mean	Maximum	Mean
Terrestrial Plants	mg/kg (ww)	2.51E+00	2.36E+00	2.94E+01	2.78E+01
Fruit	mg/kg (ww)	1.26E+00	1.18E+00	1.47E+01	1.39E+01
Earthworm	mg/kg (ww)	1.22E+01	1.15E+01	7.99E+00	7.54E+00
Eastern Cottontail	mg/kg (ww)	4.83E-02	4.53E-02	1.73E+00	1.64E+00
Meadow Vole	mg/kg (ww)	1.05E-02	9.82E-03	6.29E-01	5.94E-01

Appendix D Sample Calculations

Table D.1: Sample Calculation for Urban Resident (Toddler) Exposure and Risk to Morpholine

		Morpholine		
Environmental Media Concentration		**Value**	**Unit**	**Source**
Water Concentration	A	2.25E-04	mg/L	Table 3.15
Human Exposure Factors (Toddler)				
Drinking Water Intake	B	0.6	L/d	Table 3.10
Days per Week/7 (D2)	C	1	d/d	Table 3.10
Weeks per Year/52 (D3)	D	1	wk/wk	Table 3.10
Fraction of Water Obtained from WSP	E	0.835	unitless	Table 3.11
Body Weight	F	16.5	kg	Table 3.10
RAF_{GITi}	G	1	unitless	Table 3.10
TRV (Acceptable Daily Intake)	H	0.48	mg/kg d	Table 3.26
Human Dose and HQ				
Ingestion Dose	I = (A*B*C*D*E*G)/F	6.82E-06	mg/kg d	Calculation
HQ	J = I/H	1.42E-05	unitless	Calculation

Table D.2: Sample Calculation for Sport Fisher Exposure and Risk to Hydrazine

		Hydrazine		
Environmental Media Concentration		**Value**	**Unit**	**Source**
Water Concentration	A	1.14E-03	mg/L	Table 3.15
Fish Concentration				
Bioaccumulation Factor (BAF)	B	3.16	L/kg fw	Section 3.2.6.1.2
Tissue Concentration	C=A*B	0.0036	mg/kg fw	Calculation
Human Exposure Factors (Adult)				
Fish Ingestion	D	0.111	kg/d	Table 3.10
Years Exposed (D4)	E	30	a	Table 3.10
D_{fish} (days in which consumption occurs)	F	365	d/a	Table 3.10
Fraction of Fish in Diet Obtained from Outfall	G	1	unitless	Table 3.11
Body Weight	H	70.7	kg	Table 3.10
Life Expectancy	I	70	years	Table 3.10
RAF_{GITi}	J	1	unitless	Table 3.10
TRV (Oral Slope Factor)	K	3	$(mg/kg\ d)^{-1}$	Table 3.26
Human Dose and ILCR				
Ingestion Dose	L = (C*D*F*G*J*E)/H*365*I	2.43E-06	mg/kg d	Calculation
ILCR	M = K*L	7.29E-06	unitless	Calculation

Table D.3: Sample Calculation for Coots Pond Benthic Invertebrate Dose Calculations for Cobalt-60

		Cobalt-60 (Radiological Dose)		
		Value	Unit	Source
Environmental Media Concentrations				
Coots Pond Water Concentration	A	<1	Bq/L	Table 4.19
Coots Pond Sediment Concentration (dry weight)	B	<1	Bq/kg	Table 4.19
Dry Weight Fraction of Sediment	C	0.2	kg dw/ kg fw	Assumption
Coots Pond Sediment Concentration fresh weight)	D = B * C	0.2	Bq/kg fw	Calculated
Benthic Invertebrate Internal Dose (radiological)				
Bioaccumulation Factor - Benthic Invertebrate	E	110	L/kg fw	Table 4.10
Modeled Benthic Invertebrate Tissue Concentration	F = A * E	110	Bq/kg fw	Calculated
Dose Conversion Factor (Internal)	G	0.000052	(µGy/hr)/(Bq/kg fw)	Table 4.14
Internal Dose	H = F * G	0.00572	µGy/hr	Calculated
Internal Dose (converted units)	H' = H * 24 h/d / 1000 µGy/mGy	0.00013728	mGy/d	Calculated
Benthic Invertebrate External Dose (radiological)				
Occupancy Factor, Water	I	0	unitless	Table 4.9
Occupancy Factor, Water Surface	J	0	unitless	Table 4.9
Occupancy Factor, Sediment	K	1	unitless	Table 4.9
Occupancy Factor, Sediment Surface	L	0	unitless	Table 4.9
Dose Conversion Factor (External)	M	1.40E-03	(µGy/hr)/(Bq/kg)	Table 4.14
Contribution of Water to External Dose	N = M * (I + 0.5*J + 0.5*L) * A	0	µGy/hr	Calculated
Contribution of Sediment to External Dose	O = M * (K + 0.5*L) * D	0.00028	µGy/hr	Calculated
External Dose	P = N + O	0.00028	µGy/hr	Calculated
External Dose (converted units)	P' = P * 24 h/d / 1000 µGy/mGy	6.72E-06	mGy/d	Calculated
Benthic Invertebrate Total Dose (radiological)				
Total Dose	Q = H + P	0.006	µGy/hr	Calculated
Total Dose (converted units)	Q' = H' + P'	1.44E-04	mGy/d	Calculated

Table D.4: Sample Calculation for Polygon AB Mallard Dose and Risk Calculations for Cobalt

		Cobalt (Toxic Dose)		
		Value	**Unit**	**Source**
Environmental Media Concentrations				
Coot's Pond Water Concentration	A	4.00E-03	mg/L	Table 4.19
Coot's Pond Sediment Concentration (dry weight)	B	9.9	mg/kg dw	Table 4.19
Aquatic Plant Concentration				
Bioaccumulation Factor - Aquatic Plant	C	790	L/kg fw	Table 4.10
Aquatic Plant Tissue Concentration	D = A * C	3.16	mg/kg fw	Calculated
Benthic Invertebrate Concentration				
Bioaccumulation Factor - Benthic Invertebrate	E	110	L/kg fw	Table 4.10
Benthic Invertebrate Tissue Concentration	F = A * E	0.44	mg/kg fw	Calculated
Mallard Exposure Factors				
Intake Rate, Water	G	0.06	L/d	Table 4.8
Intake Rate, Sediment	H	0.00206	kg dw/d	Table 4.8
Intake Rate, Aquatic Plant	I	0.0625	kg/d fw	Table 4.8
Intake Rate, Benthic Invertebrate	J	0.1875	kg/d fw	Table 4.8
Fraction of Time Spent on Site	K	0.5	unitless	Section 4.2.4.1.2
Body Weight	L	1.082	kg	Table 4.8
Mallard Exposure Dose (toxic)				
Exposure Dose, Water	M = A * G * K / L	0.00011	mg/kg d	Calculated
Exposure Dose, Sediment	N = B * H * K / L	0.0094	mg/kg d	Calculated
Exposure Dose, Aquatic Plant	O = D * I * K / L	0.091	mg/kg d	Calculated
Exposure Dose, Aquatic Invertebrate	P = F * J * K / L	0.038	mg/kg d	Calculated
Total Exposure Dose	Q = M + N + O + P	0.139	mg/kg d	Calculated
Mallard HQ (toxic)				
Toxicity Reference Value - Birds	R	7.8	mg/kg d	Table 4.39
Hazard Quotient	S = Q / R	0.018	unitless	Calculation

Table D.5: Sample Calculation for Polygon AB Mallard Dose Calculations for Cobalt-60

		Cobalt-60 (Radiological Dose)		
		Value	**Unit**	**Source**
Environmental Media Concentrations				
Coots Pond Water Concentration	A	<1	Bq/L	Table 4.19
Coots Pond Sediment Concentration (dry weight)	B	<1	Bq/kg dw	Table 4.19
Sediment Dry Bulk Density	C	0.4	kg dw/ L	CSA N288.1-14
Mixing Depth	D	0.05	m	Assumption
Coots Pond Sediment Surface Concentration (dry weight)	E = B * C * D * 1000 L/m^3	20	kg dw/ m^2	Calculated
Coots Pond Aquatic Plant Concentration (fresh weight)	F	<1	Bq/kg fw	Table 4.19
Benthic Invertebrate Concentration				
Bioaccumulation Factor - Benthic Invertebrates	G	110	L/kg fw	Table 4.10
Benthic Invertebrate Tissue Concentration	H = A * G	110	Bq/kg fw	Calculated
Mallard Exposure Factors				
Intake Rate, Water	I	0.06	L/d	Table 4.8
Intake Rate, Sediment	J	0.00206	kg dw/d	Table 4.8
Intake Rate, Aquatic Plant	K	0.0625	kg/d fw	Table 4.8
Intake Rate, Aquatic Invertebrate	L	0.1875	kg/d fw	Table 4.8
Fraction of Time Spent on Site	M	0.5	unitless	Section 4.2.4.1.2
Mallard Internal Dose (radiological)				
Biotransfer Factor - Mallard	N	1.54	d/kg fw	Table 4.12
Mallard Tissue Concentration	O = M*N*(A*I+B*J+F*K+H*L)	16	Bq/kg fw	Calculated
Dose Conversion Factor (Internal)	P	2.38E-04	(µGy/hr)/(Bq/kg fw)	Table 4.14
Internal Dose	Q = O * P	3.79E-03	µGy/hr	Calculated
Internal Dose (converted units)	Q' = Q * 24 h/d / 1000 µGy/mGy	9.11E-05	mGy/d	Calculated
Mallard External Dose (radiological)				
Occupancy Factor, Sediment - Mallard	R	0	unitless	Table 4.9
Occupancy Factor, Sediment Surface - Mallard	S	0.5	unitless	Table 4.9
Dose Conversion Factor (External, in soil)	T	0.00E+00	(µGy/hr)/(Bq/kg)	-
Dose Conversion Factor (External, on soil)	U	7.50E-06	(µGy/hr)/(Bq/m^2)	Table 4.14
External Dose	V = M * (T * R * E + U * S * E)	3.75E-05	µGy/hr	Calculated
External Dose (converted units)	V' = V * 24 h/d / 1000 µGy/mGy	9.00E-07	mGy/d	Calculated
Mallard Total Dose (radiological)				
Total Dose	X = V + Q	3.83E-03	µGy/hr	Calculated
Total Dose (converted units)	X' = V' + Q'	9.20E-05	mGy/d	Calculated