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Title:
DARLINGTON ENVIRONMENTAL MONITORING PROGRAM

Darlington Environmental Monitoring Program

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Prepared By: Cammie Cheng
Environmental Advisor
Environment Nuclear

Reviewed By: Carina Cautillo
Senior Environment Specialist
Environment – Corporate Programs

Approved By: Raphael McCalla
Director
Environment Nuclear

Table of Contents

Page

List of Tables and Figures

Page

Revision Summary

Revision Number	Date	Comments
R000	2017-08-25	Initial issue.

1.0 INTRODUCTION

Darlington Nuclear Generating Station (DNGS) and the Darlington Waste Management Facility (DWMF) have operating licence conditions to implement and maintain an Environmental Monitoring Program (EMP) compliant with the requirements of the Canadian Standards Association (CSA) N288.4-10 standard (CSA 2010).

This manual serves as the Darlington EMP program document, as described in CSA N288.4-10. In order to demonstrate that CSA N288.4-10 requirements are satisfied, the structure of this manual aligns with the structure of the CSA N288.4-10 standard (see Appendix A). Where appropriate, reference is made to other relevant EMP documentation.

2.0 SCOPE

The Darlington EMP encompasses all facilities on the Darlington site property, including the DNGS, DWMF, and Tritium Removal Facility. In this manual, the site property as a whole will hereafter be referred to as Darlington Nuclear (DN).

The scope of the EMP includes protection of both the public and environment from nuclear substances, hazardous substances, and physical stressors resulting from normal DN operations.

The EMP does not address monitoring for emergency or accident scenarios.

2.1 Site Description

The DN site contains the DNGS which is a four-unit CANDU (CANada Deuterium Uranium) station with a total output of 3,500 MW. It is located 70 km east of Toronto on the shores of Lake Ontario in the Municipality of Clarington in Durham Region. The DN site also contains the TRF, where tritium is extracted from tritiated heavy water, and the DWMF, where used fuel is stored in a dry state in above ground buildings.

Additional information about the site surroundings and demographics can be obtained from the site specific survey (OPG 2013b). Additional information on terrestrial and aquatic biota living on and around the site can be obtained from the Ecological Risk Assessment technical support documents, which are part of previous environmental assessments (OPG 2009b, OPG 2011b), and the most recent DN Environmental Risk Assessment (OPG 2016a).

DNGS has a once-through condenser cooling water system, taking water from Lake Ontario through a lake-bottom, wide area, low velocity intake structure and returning it through a 1600 m discharge pipe at the lake bottom that has 90 diffuser discharge ports running from 700 m offshore to 1600 m offshore. Releases to the lake of waste heat and low levels of nuclear/hazardous substances are through the discharge diffuser. The intake and discharge structures are tunnels within the bedrock. Airborne nuclear/hazardous substances are released to the atmosphere via ventilation exhaust stacks located on the roof of the powerhouse and the TRF. DWMF does not release

any significant amount of nuclear or hazardous substances. The DWMF is a source of external gamma radiation exposure via direct shine through shielded walls and via skyshine which is diffused, reflected/scattered gamma radiation from the atmosphere above the used fuel storage building.

3.0 RELATIONSHIP TO ENVIRONMENTAL RISK ASSESSMENT

An Environmental Risk Assessment (ERA) considers risks to both humans and non-human biota and its results inform the design of an EMP. An ERA may be its own document, or be a part of an Environmental Assessment (EA) or any other document that contains the required information. The most recent DN ERA was completed at the end of 2016 and is compliant with the CSA N288.6-12 standard (OPG 2016g). However, the results of the 2016 ERA have not yet been incorporated into the DN EMP. Changes to the EMP as a result of the 2016 ERA will be identified and captured in the next EMP design review.

The existing EMP uses results from previous DN Ecological Risk Assessments and Human Health Risk Assessments completed as part of the Darlington New Nuclear Project (DNNP) EA in 2009, as well as the DN Refurbishment and Continued Operations EA in 2011. These assessments addressed the existing conditions and risks and are considered to adequately encompass the required ERA components for the purpose of the design of the DN EMP. Several follow-up monitoring studies are required as a result of the DN Refurbishment and Continued Operations EA (OPG 2013a), most of which are not yet completed at this time. Once completed, any impact these studies may have on the DN EMP will be evaluated and captured in the next EMP design review.

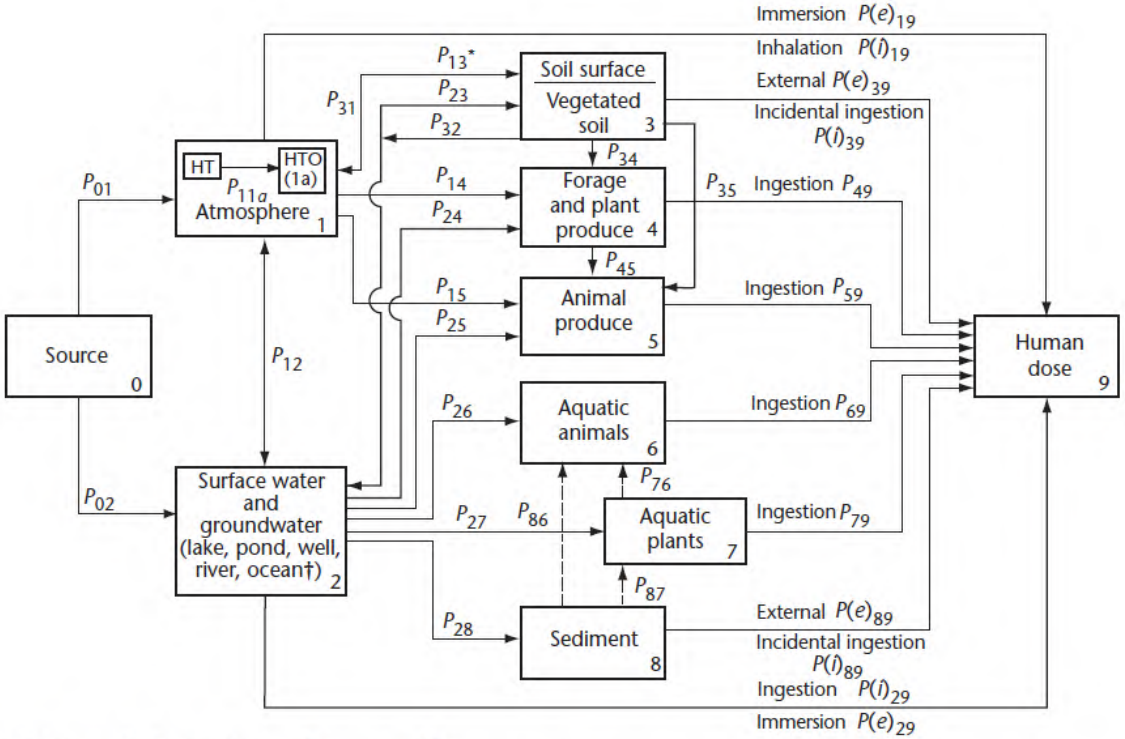
3.1 Results of ERAs

Humans and non-human biota are exposed to radiation via different pathways. To assess the potential effects of radiation and radioactivity on humans and non-human biota, conceptual exposure models have been established.

A generalized model of environmental radioactivity transport and human exposure pathways is illustrated in Figure 1, taken from the CSA N288.1-08 (CSA 2008) standard. This dose calculation model is used for DN's annual public dose calculations, which are done as part of the EMP and reported in the annual Results of Environmental Monitoring Programs report. Results of these calculations are used to assess the risk from radiological emissions from DN. They indicate that the dose to the representative person is around 1 µSv/year, 3 orders of magnitude below the 1,000 µSv/year Canadian Nuclear Safety Commission (CNSC) dose limit for members of the public. It is also well below the CNSC's As Low As Reasonably Achievable (ALARA) criterion of 50 µSv/year for individual dose (CNSC 2004). As the dose estimates are a small fraction of the regulatory public dose limit, no discernible health effects are anticipated due to exposure to radioactive releases from DN.

Human health risk assessments consider human exposures to conventional (non-radiological) factors that have the potential to influence physical health, including air

quality, noise, surface water quality and groundwater quality. These were all predicted to have an acceptably low level of risk to human health. (OPG 2009a, OPG 2011a)



*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.*

Figure 1 – Conceptual Model for Human Exposure to Radioactivity (CSA 2008)

Exposure pathways for non-human biota are illustrated in another conceptual model shown in Figure 2 taken from the Ecological Risk Assessment Technical Support Document (OPG 2009b). The resultant doses calculated in the EAs were well below the toxic reference levels for the different types of biota, and the analysis concluded that there is no risk to non-human biota from radiological exposures.

Ecological risks resulting from exposures of both terrestrial and aquatic biota to non-radiological and physical stressors were also evaluated. The analyses concluded that there were no biota for which adverse effects are expected from exposure to hazardous substances (OPG 2009b, OPG 2011b). Additionally, the number of fish affected by impingement, entrainment, and thermal effects is negligible in terms of population abundance and conservation (OPG 2011c).

Some risks assessed in the EAs were judged to require further clarification or have levels of uncertainty warranting additional monitoring to confirm predictions. These are addressed as supplementary studies and are discussed in Section 4 below.

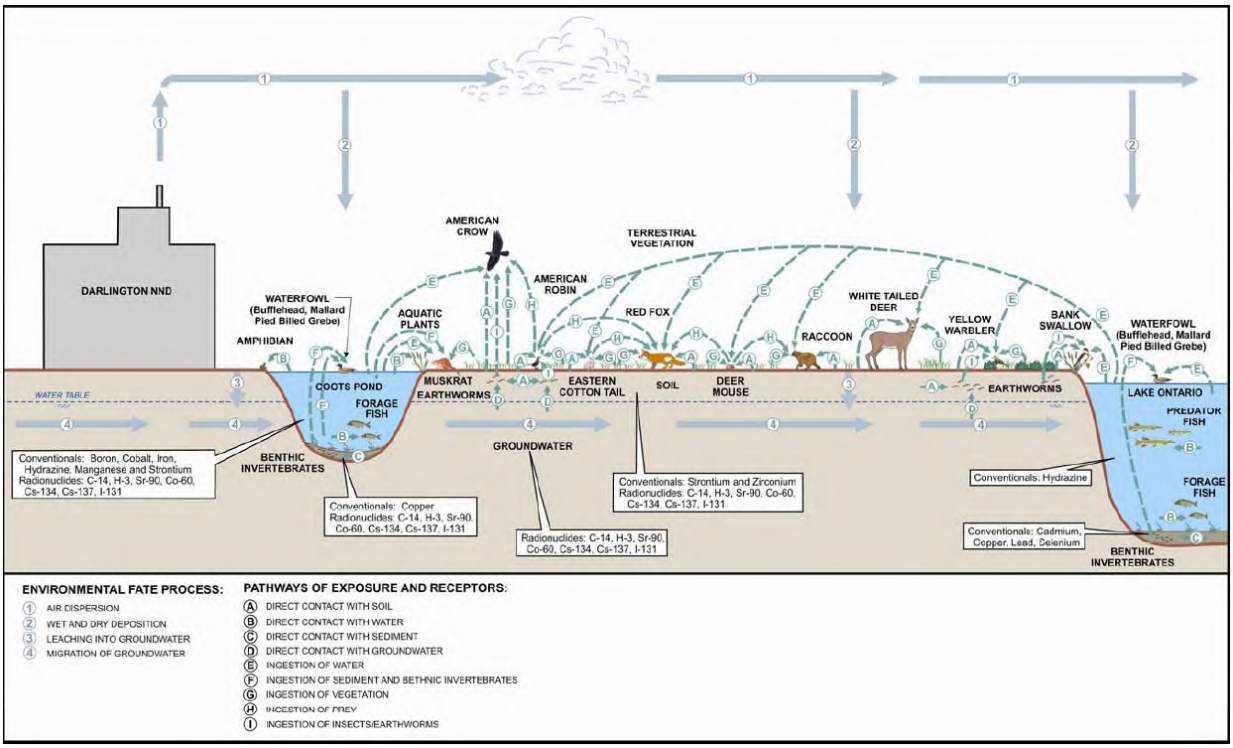


Figure 2 – Pictorial Conceptual Model for Non-Human Biota Exposure to Radiation and Nuclear Substances for DN site (from OPG 2009a)

3.2 Changes Since the Previous EAs

Chlorine was not identified as a contaminant of potential concern (COPC) in the previous EAs. However, since that time, DN has made changes to their chlorination process. Chlorination has increased due to a zebra mussel infestation, but de-chlorination is applied to reduce the total residual chlorine (TRC) discharge to the lake. The concentrations measured at the discharge are mostly below the detection limit, however some detectable values have been observed.

Morpholine was not identified as a COPC in the previous EAs because at the time it was being used only at one DNGS unit on a trial basis. Morpholine is now being used in all units as a boiler feed chemical.

Supplementary studies to clarify the risk from chlorine and morpholine are described in Section 4.0.

4.0 OBJECTIVES OF THE EMP

CSA N288.4-10 clause 4.1 (CSA 2010) contains general objectives that shall be considered in an EMP. CSA N288.4-10 clause 4.2 contains additional objectives that can be included in an EMP. These objectives are discussed in Table 4-1 and shape the DN EMP Specific Monitoring Objectives.

Table 4-1 – DN EMP Objectives

CSA N288.4-10 General Objectives	Discussion / Applicability	DN EMP Specific Monitoring Objectives
4.1a) To assess the level of risk on human health and safety, and the potential biological effects in the environment of the contaminants and physical stressors of concern arising from the facility.	The Technical Support Documents for the previous EAs contained these assessments and did not identify any receptors for which exposure to contaminants or physical stressors was a concern in terms of risk to human health and safety or potential biological effects in the environment. However, human radiation dose resulting from the operation of DN continues to be calculated annually as part of the EMP to demonstrate that the risk to human health and safety is very low. Any DN Refurbishment EA follow-up monitoring studies are being addressed outside of the EMP (OPG 2013a). No significant changes to DN operation have taken place since the EAs, with the exception of these noted in Section 3.2: o DN has made changes to their chlorination process since completion of the previous EAs, therefore confirmation is required that chlorine levels in the lake remain below the detection limit. o DN has made changes to the use of morpholine since completion of the previous EAs, therefore confirmation is required that morpholine levels in the lake remain below the Provincial Water Quality Objective (PWQO).	1) To measure chlorine in the lake water along and downstream of the diffuser to demonstrate that TRC concentrations measured in the DNGS receiving water are below the detection limit of 2 ug/L and toxicity reference values. (supplementary study) 2) To measure morpholine in the lake water along and downstream of the diffuser to demonstrate levels are below the PWQO and toxicity reference values. (supplementary study) The public dose objective is addressed under clause 4.1b).

CSA N288.4-10 General Objectives	Discussion / Applicability	DN EMP Specific Monitoring Objectives
4.1b) To demonstrate compliance with limits on the concentration and/or intensity of contaminants and physical stressors in the environment or their effect on the environment.	Canadian Nuclear Safety Commission (CNSC), Environment Canada (EC), and Fisheries and Oceans Canada (DFO) have concerns about potential effects on aquatic species in the lake as a result of entrainment and impingement losses and thermal emissions. CNSC REGDOC-3.1.1 (CNSC 2014) requires calculations of annual radiation doses to representative persons/critical group(s) in comparison to the regulatory public dose limit.	3*) To conduct entrainment and impingement monitoring and any necessary mitigation/contingency/offsetting measures. 4*) To conduct thermal plume monitoring and assess effects on Round Whitefish embryos. 5) To obtain radionuclide concentrations in environmental media and environmental external radiation exposure rates to calculate the dose to the Representative Person for comparison with public dose limits as required in REGDOC-3.1.1. Further, CSA N288.4-10 requires measurement of significant contaminants/media to support dose estimates. This includes use of the following: - Radionuclide concentrations in environmental media - Gamma dose rates from noble gases - Site specific survey data - Meteorological and lake current data* - Radioactive emissions data*

CSA N288.4-10 General Objectives	Discussion / Applicability	DN EMP Specific Monitoring Objectives
4.1c) To check, independently of effluent monitoring, on the effectiveness of containment and effluent control, and provide public assurance of the effectiveness of containment and effluent control.	Currently there are excellent monitoring and controls for contaminants in the effluents at DN. An independent ongoing check on their effectiveness via environmental monitoring (e.g. site boundary monitoring, groundwater monitoring, lake water/drinking water monitoring) provides assurance to both the station and the public that there have been no significant errors or omissions. Neither radionuclide emissions nor conventional emissions represent a significant risk to humans or the environment. However, the checking of radiological effluent control and containment is conducted because of public sensitivity to radioactivity in the environment.	6) To obtain environmental measurements of HTO, C-14, and noble gas dose rate in air at the site boundary to confirm that concentrations are as expected from effluent monitoring. 7) To obtain environmental measurements of particulate gross beta gamma activity in air and I-131 activity in air to check the effectiveness of effluent control and monitoring. (supplementary study) 8) To obtain data on HTO concentrations in drinking water from nearby Water Supply Plants (WSPs) to demonstrate effective waterborne effluent control. 9*) To obtain groundwater contamination data (e.g. HTO and PHC) to confirm the effectiveness of containment, confirm levels of nuclear/hazardous substances comply with provincial standards, and demonstrate due diligence.
4.1d) To verify the predictions made by the Environmental Risk Assessment (ERA), refine models used in the ERA, or reduce the uncertainty in the predictions made by the ERA.	Models are used during the ERA process and some degree of uncertainty exists in the predictions that are model-based. Environmental monitoring can contribute to verification and/or reduce the uncertainty of some of these predictions.	10) To monitor radionuclides in soil to determine if evidence of radionuclide accumulation is observed Uncertainty due to changes since the previous EAs are addressed under clause 4.1a).

CSA N288.4-10 General Objectives	Discussion / Applicability	DN EMP Specific Monitoring Objectives
4.2a) Providing data required to support operations or to plan for future stages of the facility lifecycle.	Some of the environmental data collected in the EMP may be used for future EAs, although currently there is no specific monitoring required solely for this purpose. DN Refurbishment EA follow-up monitoring studies are being addressed outside of the EMP (OPG 2013a).	None
4.2b) Providing resources and data that can be of value during the response to an accident or upset, and in the recovery from such an event.	Although some of the EMP data may be useful in the event of an accident, the Emergency Preparedness group of OPG maintains their own monitoring programs for response to accidents. The availability and design of the EMP is not intended for accident response purposes.	None
4.2c) Demonstrating due diligence	Clause 4.1c) discussed above contributes to demonstrating due diligence. The environmental monitoring and dose calculation performed for more potential critical groups than the one with the highest dose is an example of demonstrating due diligence. Taking drinking water samples every shift (analyzed as weekly composites) at WSPs is another example of due diligence. The availability of samples for every shift permits a more detailed subsequent analysis in the event of an upset (such as a large scale tritium spill to the lake) so that initial impacts can be determined until additional lake or WSP monitoring is implemented. This sampling frequency is not required for human dose assessment nor for demonstrating compliance with the voluntary limit on HTO of 100 Bq/L.	None

CSA N288.4-10 General Objectives	Discussion / Applicability	DN EMP Specific Monitoring Objectives
4.2d) Meeting a stakeholder commitment	OPG committed to the Province of Ontario that HTO emissions to water will remain low enough that HTO in WSPs will not be greater than 100 Bq/L on an annual average basis. OPG installed a lake current meter and makes routine measurements of flow/direction at various depths at DN as a result of a commitment to the local municipalities.	11) To obtain data on HTO concentration in drinking water from the nearby WSPs to confirm OPG's commitment to the province that annual average levels of HTO remain below 100 Bq/L. 12) To obtain data on HTO and gross beta activity concentration in drinking water from the nearby WSPs to provide data to Durham Region to confirm that their WSPs meet Canadian drinking water quality guidelines for radiological parameters. Note: Data from Durham Region Annual Water Quality Reports for Ajax, Whitby, Oshawa, Bowmanville, and Newcastle indicated (Durham 2012) that the level of gross alpha in drinking water was consistently less than the Minimum Detectable Concentration of 0.04 Bq/L, far below the drinking water screening level of 0.5 Bq/L (HC 2017). Therefore, the additional routine monitoring of gross alpha in drinking water is not required. 13*) To obtain lake current flow and direction data to meet a stakeholder commitment. Data is also useful for dose modeling.
4.2e) Other business purposes	This objective is not currently applicable for the DN EMP.	None

* The design for these objectives are documented outside of this EMP manual.

Objectives 3 and 4 are addressed in Fisheries Act Authorization (OPG 2015a), and DN Refurbishment and Continued Operation Environmental Assessment Follow-Up Program (OPG 2013a).

Objective 5, with respect to providing radioactive emissions data, is the responsibility of DN Environment.

Objective 9 is managed under Contaminated Lands and Groundwater Management (OPG 2014a).

Objectives 5 and 13, with respect to meteorological and lake current data, are managed by the DN station responsible engineer and system monitoring is done by the Computers and Control Design organization.

5.0 CRITERIA FOR ESTABLISHING AND REVISING THE EMP

5.1 Need for an EMP

The criteria for determining the need to establish an EMP are set out in N-PROC-OP-0025 (OPG 2016b). The DN EMP meets the following criteria:

1) A governing statute, regulation, licence, or permit that governs the operation of the nuclear facility requires it,

2) The potential effective dose to members of an off-site critical group from all radioactive emissions from the site in the event on an accident is estimated to exceed 1mSv per year, which is the public dose limit prescribed by Section 1(3) of the Nuclear Safety and Control Act (NSCA) Radiation Protection Regulations, and

3) There are other business reasons, i.e. stakeholder concerns, due diligence, etc.

As a DNGS licence condition, the CNSC regulatory document REGDOC-3.1.1 (CNSC 2014) requires OPG to calculate the annual dose to the Representative Person. The Representative Person is an individual who is representative of the average characteristics of the Critical Group for the year, i.e. the group of members of the public receiving the highest dose. DNGS and DWMF also have licence conditions to comply with CSA N288.4-10, which requires the measurement of significant contaminants and environmental media to support dose estimates. Therefore, the EMP includes routine environmental monitoring of radionuclides in various environmental media. Additionally, Section 3(h) of the Class I Nuclear Facilities Regulation specifies that an application for a Class I nuclear facility licence shall contain the proposed environmental monitoring program.

The EA technical support documents did not identify any receptors for which exposure to contaminants or physical stressors was a concern in terms of risk to human health or potential effects in the environment. However, there are areas warranting supplementary studies to provide additional support for EA conclusions.

There may also be voluntary criteria for the need for an EMP that could drive monitoring (e.g. due diligence or commitments to stakeholders).

5.2 Revising the EMP

The criteria for determining the need to review/revise an EMP are set out in N-PROC-OP-0025 (OPG 2016b).

Consideration should be given to the fact that monitoring and locations may change from year to year due to availability of samples, start or conclusion of supplementary studies, or other changes. The Master Schedules contained in the EMP SiteFX Database are the most up-to-date reflection of the current EMP sampling and analysis regime. This manual is not expected to be revised for every minor change. It has a

minimum five year review cycle and should be reviewed following the implementation of changes from the next EMP design review.

6.0 DESIGN OF THE EMP

The principles outlined in N-PROC-OP-0025 (OPG 2016b) guide the design of the EMP. The EMP is designed to address the DN EMP Specific Monitoring Objectives identified in Section 4 using the conceptual models illustrated in Section 3 and the receptors identified in the EMP design review (OPG 2008). An overview of the required monitoring is provided in Table 6-1 (excludes those objectives indicated as being documented outside of this EMP manual). Details on each of the design elements are provided in Section 7.

Table 6-1 – Environmental Media to be Monitored in the DN EMP

Environmental Media	Contaminants and Physical Stressors	
	Radiological Contaminants	Non-Radiological Contaminants
Air	Y	
Terrestrial Plants	Y	
Terrestrial Animals	Y	
Soil	Y	
Drinking Water	Y	
Lake Water	Y	Y
Aquatic Animals	Y	

Note: For radiological contaminants, see the latest DN Pathway Analysis for determination of specific contaminants and media requiring monitoring.

Monitoring locations for the DN EMP are generally within 5 km of DN site, with a handful of locations between 5-10 km. Some dairy farm locations are >10 km from DN site as there are no closer participating dairy farms available. Figure 3 shows the 2016 DN EMP monitoring locations.

Locations considered to be outside the influence of nuclear station operations are also monitored to allow for a baseline comparison with background values. These are identified in the EMP SiteFX database.

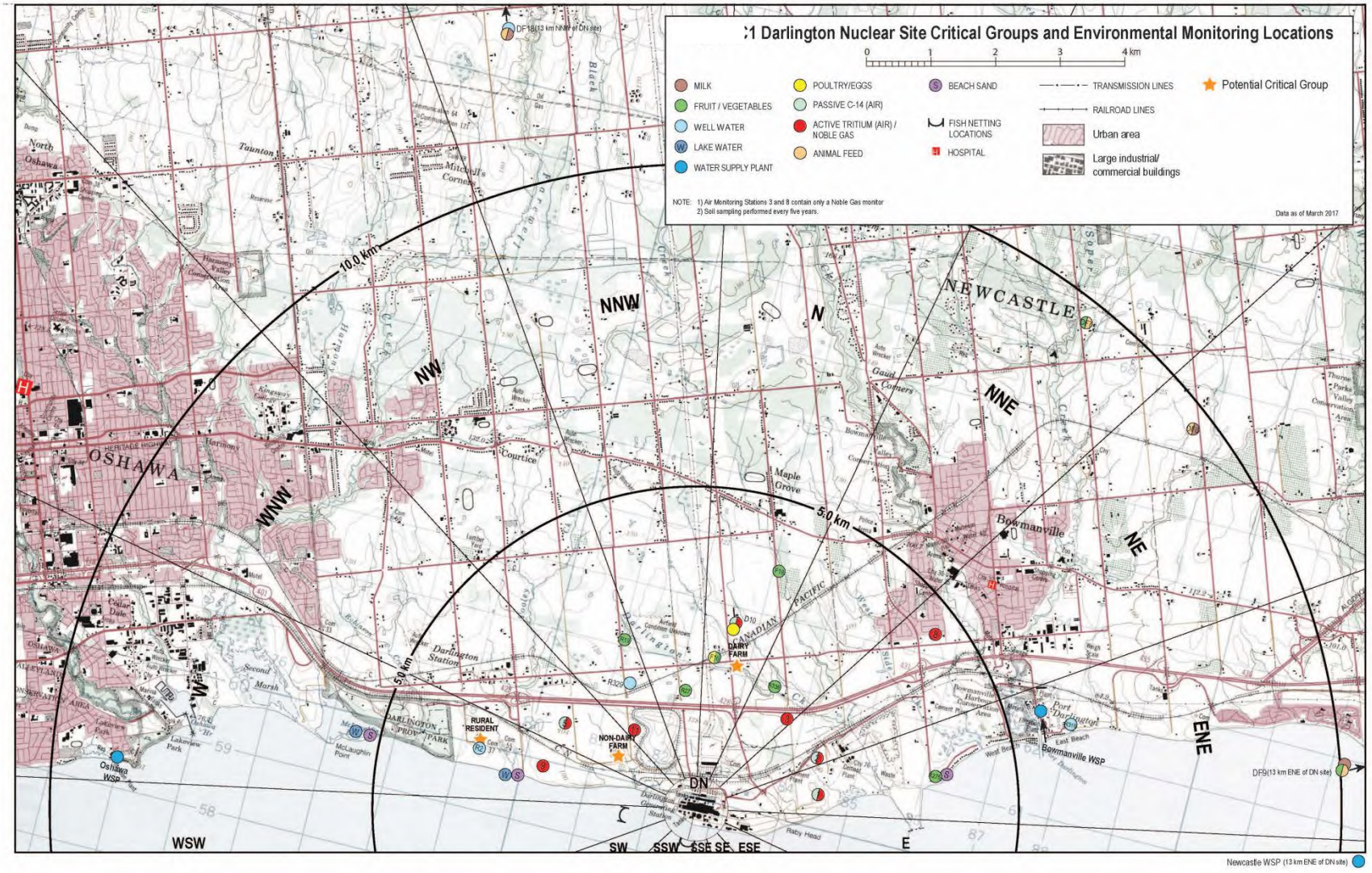


Figure 3 – 2016 DN EMP Monitoring Locations

7.0 DESIGN ELEMENTS OF THE EMP

The EMP is developed using a systematic planning process known as the data quality objectives (DQO) process which is outlined in CSA N288.4-10 (CSA 2010). A detailed design document for the DN EMP was prepared in 2012 by AMEC and accepted by OPG (OPG 2012). Elements of AMEC's detailed design that have been implemented in the DN EMP, as well as any other EMP monitoring, are documented in this manual.

Using the DQO process, the following information is provided for each DN EMP specific monitoring objective:

1) Define the objective and/or question to be resolved.

2) Identify what information is required to meet the objective.

3) Define the monitoring/study boundaries (spatial and temporal).

4) Determine how data collected will be used to achieve the objectives, including statistical analyses, metrics, and decision levels, as appropriate.

5) Specify the performance and/or acceptance criteria, including detection limits.

6) Summarize the detailed design (contaminants/physical stressors to be monitored, sample media/locations/frequency/duration).

7.1 DN EMP Specific Monitoring Objectives – Routine Monitoring

DN EMP Specific Monitoring Objective 5	To obtain radionuclide concentrations in environmental media and environmental external radiation exposure rates to calculate the dose to the Representative Person.
Question(s)	What is the estimated dose received by the Representative Person using environmental measurements in accordance with CSA N288.4-10?
Information Required	1) Radionuclide measurements in environmental media (atmospheric, terrestrial, aquatic) 2) Pathway analysis from the most recent DN EMP design review that identifies what media/contaminants require monitoring 3) Meteorological and lake current data (provided by groups outside of EMP) 4) Radioactive emissions data (monitored/reported outside of EMP) 5) IMPACT dose modeling software (aligned with CSA N288.1)
Boundaries	Spatial: The potential critical groups that require monitoring, and the required analyses, are identified in the DN EMP design review. Sample locations are selected based on judgemental design using information from the site specific survey and are documented in the Master Schedule in the EMP SiteFX database.

	Temporal: This is part of the routine EMP. Sample types and frequency are listed in Table 7-1 and are documented in the EMP SiteFX database.
Data Analysis	Annual mean and standard deviations for each data set are used for the dose calculation. Trend analysis is performed for most EMP data and is documented in the annual EMP report. See the EMP report for the rules/conventions for reporting EMP data.
Performance / Acceptance Criteria	Detection limits as per N-GUID-03443-10001 (OPG 2016c). Sample unavailability limits as per N-PROC-OP-0025 (OPG 2016b). Accuracy/Precision: 2 standard deviations
Detailed Design	See the Master Schedule in the EMP SiteFX database for complete sample media, locations, frequency, and contaminants measured.

Table 7-1 – Routine EMP Sample Type and Frequency (for 2016)

Environmental Medium of Interest	Monitored For	Sampling Frequency	Analyses Frequency
SAMPLES USED FOR PUBLIC DOSE CALCULATIONS			
Atmospheric Sampling			
Air	HTO (active monitor)	Continuous	Monthly
Air	C-14 (passive monitor)	Continuous	Quarterly
Air	Noble gases (Ar-41, Xe-133, Xe-135), Ir-192[(a)]	Continuous	Reported monthly
Terrestrial Sampling			
Fruits and Vegetables[(c)]	HTO and C-14	3 grab samples/year	3 times/year
Animal Feed	HTO and C-14	Bi-annual grab samples	Bi-annual
Eggs	HTO and C-14	Quarterly grab samples	Quarterly
Poultry	HTO and C-14	Annual grab samples	Annual
Milk[(b)]	HTO and C-14	Monthly grab samples	Monthly
Aquatic Sampling			
Municipal Drinking Water	HTO	2-3 grab samples/day	Weekly composite
Well Water	HTO	Monthly grab samples	Monthly
Lake Water	HTO	Monthly grab samples	Monthly
Fish	HTO, C-14, Cs-137, Cs-134, Co-60	Annual grab samples	Annual
Beach Sand	Cs-137, Cs-134, Co-60	Annual grab samples	Annual
SAMPLES FOR OTHER EMP OBJECTIVES			
Soil	Cs-137, Cs-134, Co-60	Grab samples every five years	Every five years
Municipal Drinking Water	Gross beta	2-3 grab samples/day	Monthly composite
Fish	OBT	Annual grab samples (composite)	Annual
Lake water	Potassium	Grab samples every three years (composite)	Every three years

(a) Air kerma is measured and converted to external air immersion dose.

(b) Sampling frequency is quarterly for provincial-background locations.

(c) Sampling frequency is annual for provincial-background locations.

DN EMP Specific Monitoring Objective 6	To obtain environmental measurements of HTO, C-14, and noble gas dose rate in air at the site boundary to confirm that concentrations are as expected from effluent monitoring.
Question(s)	Do measurements of HTO, C-14, and noble gas in air at the site boundary roughly reflect what would be expected based on effluent monitoring results?
Information Required	1) Airborne HTO, C-14, and noble gas measurements at the site boundary. 2) Airborne HTO, C-14, and noble gas emissions from DN site (monitored/reported outside of EMP)
Boundaries	Spatial: Sample locations are at EMP stations D1, D2, D5, D10 based on judgemental design. Temporal: This is part of the routine EMP. Samples are continuous with results analysed monthly for HTO and quarterly for C-14. Noble gas measurements are recorded essentially in live time, however data is analysed and results reported on a monthly basis. Additional Information: Monitoring locations are selected to be close to the station to maximize the chance of getting measurements above the detection limit, but far enough away to minimize the effects of on-site buildings and structures that disturb air flow and increase the uncertainty in the atmospheric dispersion factors. For practicality and cost savings, locations are chosen where an existing monitor is being used for another purpose (e.g. dose assessment). The measurements of a single monitor together with the use of meteorological data can be used to confirm effluent control. However, a monitor in one wind sector would see the plume from the station less than 10% of the time, i.e. the confirmation would be based on less than 10% of emissions data. The use of more monitors would make the check on effluent control more reliable. A monitoring coverage of approximately 50% of the total landward wind frequency was set arbitrarily as a design target, so that confirmation is based on half of the total useable data. The cumulative wind frequency captured by the selected locations, which varies from year to year, was 16% out of a total landward frequency of 36%, providing about 44% coverage in 2015 (OPG 2016f). The existing EMP indicates that these radionuclides are normally detectable at site boundary. However, if the results are less than MDL, monitoring is not required.
Data Analysis	This is meant to be a qualitative comparison confirming that similar annual trends exist between environmental measurements and effluent monitoring results and checking for any evidence of substantial disagreement. Rigorous statistical testing is not required as environmental measurements are not expected to very closely reflect effluent monitoring results due to the influence of meteorological and seasonal conditions, locations of sample stations, etc.
Performance / Acceptance Criteria	HTO in air active sampler and C-14 in air passive sampler detection limits as per N-GUID-03443-10001 (OPG 2016c).

	Noble gas detector detection limits are 6, 3, and 3 nGy/month for Ar-41, Xe-133, and Xe-135 respectively based on Health Canada's data analysis methodology. Sample unavailability limits as per N-PROC-OP-0025 (OPG 2016b). Accuracy/Precision: 2 standard deviations
Detailed Design	See Master Schedule in EMP SiteFX database for up-to-date sample media, locations, frequency, and contaminants measured.

DN EMP Specific Monitoring Objective 8	To obtain data on HTO concentrations in drinking water from nearby Water Supply Plants (WSPs) to demonstrate effective waterborne effluent control. The information and monitoring required for this objective is covered by Objective 12 below.
Question(s)	Do HTO concentrations in drinking water reflect adequate control of waterborne effluent?
Information Required	1) HTO concentrations in WSP water 2) Waterborne HTO emissions from DN site (monitored/reported outside of EMP)
Boundaries	See Objective 12 below.
Data Analysis	Due to little difference between HTO concentrations in WSP samples and in lake background, this is meant to be a coarse qualitative comparison looking only for evidence of substantial disagreement as well as confirmation that WSP concentrations remain low and adequately controlled. Rigorous statistical hypothesis testing is not required. Net HTO concentrations from the WSPs are determined by subtracting total lake background HTO (not just natural and weapons fallout contributions as is done for dose assessment) and compared with emissions levels from DN over a fixed period, e.g. one year. The comparisons are not expected to result in close agreement because of limitations imposed by high levels of uncertainty in both the net tritium concentrations at the WSPs and in the expected tritium concentrations at WSPs calculated from effluent data using modeled dilution factors.
Performance / Acceptance Criteria	See Objective 12 below.
Detailed Design	See Objective 12 below.

DN EMP Specific Monitoring Objective 11	To obtain data on HTO concentration in drinking water from the nearby WSPs to confirm OPG's commitment to the province that annual average levels of HTO remain below 100 Bq/L. The information and monitoring required for this objective is covered by Objective 12 below.
Question(s)	Is the annual average HTO concentration in drinking water below 100 Bq/L?

Information Required	1) HTO concentrations in WSP water
Boundaries	See Objective 12 below.
Data Analysis	Single sample hypothesis tests may be performed to demonstrate that the annual average at each WSP is below 100 Bq/L. However, if all data points are below 100 Bq/L, hypothesis testing is not necessary.
Performance / Acceptance Criteria	See Objective 12 below.
Detailed Design	See Objective 12 below.

DN EMP Specific Monitoring Objective 12	To obtain data on HTO and gross beta activity concentration in drinking water from the nearby WSPs to provide data to Durham Region to confirm that their WSPs meet Canadian drinking water quality guidelines for radiological parameters (HC 2017). This meets OPG's commitment to Durham Region to provide data that Durham Region can use to demonstrate compliance at their WSPs.
Question(s)	Do HTO and gross beta concentrations in drinking water meet Canadian drinking water quality guidelines for radiological parameters?
Information Required	1) Drinking water samples analysed for HTO and gross beta activity
Boundaries	Spatial: Sample locations are at Oshawa, Bowmanville, and Newcastle WSPs based on judgemental design. Temporal: This is part of the routine EMP. Grab samples are to be taken every shift (2 or 3 shifts/day). The shiftly samples are composited into weekly samples (4 samples per month for each WSP) for HTO analysis and into monthly samples for gross beta activity analysis.
Data Analysis	Measure tritium and gross beta activity for comparison with the 7,000 Bq/L standard for tritium and the 1.0 Bq/L screening criterion for gross beta activity as specified in the Canadian drinking water quality guidelines. Hypothesis testing is not necessary if all data points are below their respective threshold. Additional Information: Data from Durham Region Annual Water Quality Reports indicated that the level of gross alpha in drinking water is consistently less than the minimum detectable concentration of 0.04 Bq/L, far below the drinking water screening level of 0.5 Bq/L (HC 2017). Therefore, routine monitoring of gross alpha in drinking water is not required.
Performance / Acceptance Criteria	HTO and gross beta in water detection limits as per N-GUID-03443-10001 (OPG 2016c). Sample unavailability limits as per N-PROC-OP-0025 (OPG 2016b). Accuracy/Precision: 2 standard deviations
Detailed Design	See Master Schedule in EMP SiteFX database for up-to-date sample media, locations, frequency, and contaminants measured.

7.2 DN EMP Specific Monitoring Objectives – Supplementary Studies

DN EMP Specific Monitoring Objective 1	To measure chlorine in the lake water along and downstream of the diffuser to demonstrate that TRC concentrations measured in the DNGS receiving water are below the detection limit of 2 ug/L and toxicity reference values. This one year supplementary study has been completed (OPG 2015b).

DN EMP Specific Monitoring Objective 2	To measure morpholine in the lake water along and downstream of the diffuser to demonstrate levels are below the PWQO and toxicity reference values. This one year supplementary study has been completed (OPG 2015b).

DN EMP Specific Monitoring Objective 7	To obtain environmental measurements of particulate gross beta gamma activity in air and I-131 activity in air to check the effectiveness of effluent control and monitoring. This one year supplementary study has been completed (OPG 2016d).

7.3 DN EMP Monitoring for Other Purposes

DN EMP Specific Monitoring Objective 10	To monitor radionuclides in soil to determine if evidence of radionuclide accumulation is observed.
Question(s)	Is there any evidence of radionuclide accumulation in offsite soil?
Information Required	1) Undisturbed soil samples analysed by gamma spectrometry for airborne beta-gamma emitters such as Co-60, Cs-134, Cs-137, Zr-95, Nb-95
Boundaries	Spatial: Sample location is at F16 based on judgemental design. Eight replicate samples should be taken to a depth of approximately 5cm each and composited for analysis. Temporal: This is part of the routine EMP, to be repeated every 5 years.
Data Analysis	The trends of gamma emitters in soil over time should be investigated for evidence of accumulation. Since many years of data are already available, discontinuation of this monitoring may be considered if analysis of the data does not indicate accumulation. Consideration should also be given as to whether data is needed for ERA purposes. Additional Information: The effect of background Cs-137 from weapon test fallout should be removed.
Performance / Acceptance Criteria	Detection limits as per N-GUID-03443-10001 (OPG 2016c). Accuracy/Precision: 2 standard deviations

Detailed Design	See Master Schedule in EMP SiteFX database for up-to-date sample media, locations, frequency, and contaminants measured.

Additional Notes/Rationale:

The monitoring described in CSA N288.4-10 clause 7.8.3 Wildlife Interactions with Traffic and Structures (also 7.3.8 and 7.7.12) is not required based on EA conclusions that DN site road mortality and bird/bat strikes are unlikely to cause effects (OPG 2011d, OPG 2009c).

The monitoring described in CSA N288.4-10 clause 7.6.9 is not required as there are no lake sediment depositional areas near DN (COG 2013).

8.0 SAMPLING AND ANALYTICAL PROCEDURES

N-PROC-OP-0025 (OPG 2016b) contains general information and references for sample collection, scheduling, analysis, and equipment maintenance. See N-HPP-03443.4-10145 (OPG 2014b) for laboratory and field collection procedures. Data management and verification is discussed in N-MAN-03443-10005 (OPG 2016e). Applicable documentation for external contracts are saved electronically in the EMP Data Centre shared drive.

9.0 INTERPRETATION OF DATA

See N-PROC-OP-0025 (OPG 2016b) and N-MAN-03443-10005 (OPG 2016e) for information and references on data interpretation, treatment of non-detects, performance indicator targets, statistical analysis, uncertainty, and significant figures.

10.0 QUALITY ASSURANCE AND QUALITY CONTROL

See N-PROC-OP-0025 (OPG 2016b) and N-MAN-03443-10005 (OPG 2016e) for information and references for program and laboratory quality assurance (QA) and quality control (QC) including equipment maintenance, identification of non-conformances, task verification, field verification, and records.

11.0 REPORTING, REVIEW, AND AUDIT

See N-PROC-OP-0025 (OPG 2016b) and N-MAN-03443-10005 (OPG 2016e) for information and references for annual reporting, annual self-assessments, program design reviews, and audits.

12.0 STAFF QUALIFICATIONS AND TRAINING

See N-PROC-OP-0025 (OPG 2016b) and N-MAN-03443-10005 (OPG 2016e) for information and references for personnel qualifications and training.

13.0 DOCUMENTATION

This manual serves as the program document for the DN EMP.

14.0 REFERENCES

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Appendix A: Compliance with CSA N288.4-10

This manual was structured to comply with CSA N288.4-10 *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills*. OPG is required to comply with CSA N288.4-10 per the station operating licence. Corresponding sections are summarized in the table below.

Table A-1: OPG EMP Compliance with CSA N288.4-10

Sections in DN EMP Program Manual	Coverage of N288.4-10 Sections
2. Scope	Sections 0, 1, 2, and 3 do not contain explicit requirements for an EMP. Clauses with indirect recommendations include the following: 0.3 is addressed in DN EMP Manual Section 3.1. 0.7.1 and 1.4.2 are addressed in DN EMP Manual Section 3.0.
3. Relationship to ERA	
4. Objectives of the EMP	Section 4
5. Criteria for Establishing and Revising the EMP	Section 5
6. Design of the EMP	Section 6
7. Design Elements of the EMP	Section 7
8. Sampling and Analytical Procedures	Section 8 8.2.6 and 8.3.2 are addressed in DN EMP Manual Section 10. 8.3.4 is addressed in DN EMP Manual Section 9.
9. Interpretation of Data	Section 9
10. Quality Assurance and Quality Control	Section 10
11. Reporting, Review and Audit	Section 11
12. Staff Qualifications and Training	Section 12
13. Documentation	Section 13 13.5 is addressed in DN EMP Manual Section 6