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2024 RESULTS OF THE ENVIRONMENTAL MONITORING PROGRAM FOR NUCLEAR SUSTAINABILITY SERVICES – WESTERN WASTE MANAGEMENT FACILITY AND RADIOACTIVE WASTE OPERATIONS SITE 1

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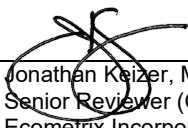
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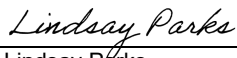
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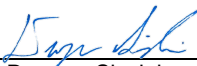
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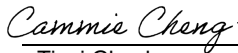
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REPORT PREPARED FOR:

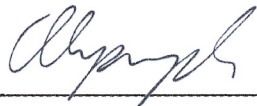
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**2024 RESULTS OF THE ENVIRONMENTAL
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LAND ACKNOWLEDGEMENT

OPG acknowledges that the Nuclear Sustainability Services – Western Waste Management Facility is located on the traditional territory of the Chippewas of Saugeen First Nation and the Chippewas of Nawash Unceded First Nation, collectively known as the Saugeen Ojibway Nation (SON), and are the traditional keepers of the land. The area is also home to many diverse First Nations, Inuit, and Métis peoples and as a company, we remain committed to fostering positive and mutually beneficial relationships with Indigenous people and communities across Ontario.

REPORT REVISIONS

Revision Number	Date	Comments
R000	2025-08-13	Final report issued.

EXECUTIVE SUMMARY

Ontario Power Generation (OPG) maintains an Environmental Monitoring Program (EMP) at the Nuclear Sustainability Services – Western Waste Management Facility (NSS-WWMF). Additionally, OPG maintains the Radioactive Waste Operation Site 1 (RWOS 1), which is a waste storage facility that contains historic low- and intermediate-level waste (LILW). The detailed design of the NSS-WWMF EMP was developed in 2012 in accordance with the Canadian Standards Association (CSA) N288.4-10, *Environmental Monitoring Programs at Class 1 Nuclear Facilities and Uranium Mines and Mills*. The 2024 program was implemented according to the recommended 2012 design with updates made according to recommendations from the 2019 design update review, the 2021 NSS-WWMF Environmental Risk Assessment (ERA) update, and the results of the Conceptual Site Model and Groundwater Protection and Monitoring Programs. The program scope encompasses protection of both the public and the environment from nuclear substances, hazardous substances, and physical stressors resulting from the operation of the NSS-WWMF and RWOS 1.

The EMP is designed to satisfy the following four primary objectives of CSA N288.4-10:

1. Support assessment of the impact on human health and the environment of contaminants and physical stressors of concern resulting from operation of OPG nuclear facilities.
2. Demonstrate compliance with limits on the concentration and/or intensity of contaminants and physical stressors in the environment or their effect on the environment.
3. Demonstrate the effectiveness of containment and effluent control and provide public assurance of the effectiveness of containment and effluent control, independent of effluent monitoring.
4. Verify the predictions made by the ERAs, refine the models used, and reduce the uncertainty in the predictions made by these assessments and models.

The 2024 program results contained in this report include concentrations of radionuclides in air, water, and groundwater as well as ambient dose measurements from the vicinity of the NSS-WWMF and RWOS 1 sites. The relative contribution by NSS-WWMF and RWOS 1 to public dose was assessed through comparison with emissions from the Bruce A and B Generating Stations. For carbon-14 (C-14) emissions, dose to a hypothetical receptor at the NSS-WWMF property boundary was calculated using available data.

Operation of NSS-WWMF resulted in extremely low public dose, well within regulatory limits. The potential exposure of non-Nuclear Energy Workers (non-NEWs) to gamma radiation near NSS-WWMF facilities was shown to be low and well below the derived dose rate target. OPG

continued to meet its commitment to keep its impact on tritium levels at nearby Water Supply Plants (WSPs) below 100 Bq/L on an annual average basis.

Bedrock aquifer groundwater and South Railway Ditch surface water sampling indicate that there are no expected off-site impacts resulting from elevated radionuclide concentrations in groundwater leaving the NSS-WWMF. Previously elevated tritium levels in one area of the Middle Sand Aquifer (MSA) near the Low Level Storage Buildings (LLSB) have steadily decreased since 2017.

Passive air sampling of C-14 was conducted in 2024. The main contributor of C-14 activity in air is by the in-ground containers on the NSS-WWMF site. No adverse effects to workers, the public and the environment are expected due to these emissions.

There is currently no indication of unacceptable levels of radioactivity leaving the site either in air, surface water or groundwater.

Overall, the results of the 2024 NSS-WWMF Environmental Monitoring Program confirm adequate protection of the public, workers, and environment.

TABLE OF CONTENTS

1.0	INTRODUCTION	1.1
1.1	Program Objectives	1.2
1.2	EMP Context and Background Information	1.3
1.3	Overview of the Nuclear Sustainability Services – Western Waste Management Facility	1.4
2.0	ENVIRONMENTAL MONITORING PROGRAM	2.1
2.1	Design of EMP	2.1
2.1.1	Facilities included in EMP.....	2.1
2.1.2	Environmental Risk Assessment.....	2.1
2.1.3	Other Inputs.....	2.3
2.2	EMP Sampling Plan	2.3
2.2.1	Public Radiological Dose Estimation.....	2.3
2.2.2	Tritium Levels at Water Supply Plants	2.3
2.2.3	Direct Gamma and Skyshine Dose.....	2.3
2.2.4	Confirmation of Containment Integrity of In-ground Storage Structures	2.7
2.2.5	Water in South Railway Ditch and East Stormwater Management Pond.....	2.11
2.2.6	Supplementary Sampling of Water and Sediment in South Railway Ditch, West Ditch, Wetland and East Stormwater Management Pond	2.11
2.2.7	Fugitive Emissions of C-14	2.11
2.3	EMP Results	2.15
2.3.1	Reporting Data and Uncertainties.....	2.15
2.3.2	Gamma Radiation Dose Monitoring Results	2.16
2.3.3	Groundwater Monitoring Results	2.22
2.3.4	Water in South Railway Ditch and East Stormwater Management Pond.....	2.29
2.3.5	Supplementary Sampling of Water and Sediment in South Railway Ditch, West Ditch, Wetland and East Stormwater Management Pond	2.31
2.3.6	Passive C-14 Sampling	2.31
3.0	RADIOLOGICAL DOSE TO THE PUBLIC	3.1
3.1	Public Radiological Dose Estimation Results	3.1
3.1.1	Basis for Calculation of Dose to Members of the Public.....	3.1
3.1.2	Public Dose from NSS-WWMF Operations	3.1
3.2	Tritium Levels at Nearby Water Supply Plants	3.1
3.3	Direct Gamma Radiation Exposure	3.2
3.4	Radiation Dose from C-14 in Air	3.2
3.5	Discussion of Results	3.2

4.0	QUALITY ASSURANCE AND PERFORMANCE	4.1
4.1	Laboratory Quality Assurance and Quality Control	4.1
4.2	Program Quality Assurance	4.2
4.2.1	Self-assessments	4.2
4.3	Program Performance	4.3
4.3.1	Sample Unavailability	4.3
5.0	OVERALL SUMMARY OF EMP	5.1
6.0	OUTLOOK FOR EMP.....	6.1
7.0	REFERENCES	7.1
	APPENDIX A RADIOLOGICAL UNITS AND CONVERSIONS	A.1
	APPENDIX B GLOSSARY OF ACRONYMS AND SYMBOLS.....	B.1
	APPENDIX C TRITIUM IN GROUNDWATER 2020-2024	C.1
	APPENDIX D SUMMARY OF SAMPLES COLLECTED	D.1
	APPENDIX E GROUNDWATER AND DITCH SURFACE SAMPLE UNAVAILABILITY	E.1

LIST OF TABLES

Table 1.1: Concordance Table with Reporting Requirements in CSA N288.4-10	1.2
Table 2.1: 2024 TLD Average Air Kerma Rates	2.18
Table 2.2: 2024 Tritium Concentrations (Bq/L) in Groundwater Wells Monitored Semi-Annually	2.24
Table 2.3: 2024 Tritium Concentrations (Bq/L) in Groundwater Wells Monitored Annually	2.25
Table 2.4: 2024 Tritium and Gross β Concentrations (Bq/L) in RWOS 1 Surface Water	2.26
Table 2.5: Mean Annual Tritium Concentration in 2024 at the South Railway Ditch (WOD1 – WOD5) and East Stormwater Management Pond (SMP-1)	2.30
Table 2.6: 2024 C-14 Passive Air Sampling Results	2.33
Table 3.1: 2024 Radiological Emissions from Bruce Nuclear Site Facilities (Bq/year)	3.3
Table D.1: Summary of Samples Collected, Monitoring Period and Deviation from the Plan during the 2024 EMP	D.1
Table E.2: 2024 Planned and Actual Samples and Analyses for Groundwater and Ditch Surface Water at NSS-WWMF	E.1

LIST OF FIGURES

Figure 1-1: Location of Nuclear Sustainability Services – Western Waste Management Facility	1.6
Figure 1-2: Location of Facilities on Bruce Nuclear Site	1.7
Figure 1-3: NSS-WWMF Aerial View	1.8
Figure 2-1: Location of TLDs at NSS-WWMF	2.5
Figure 2-2: Locations of TLDs at RWOS 1	2.6
Figure 2-3: Monitoring Well Network at the NSS-WWMF	2.9
Figure 2-4: Monitoring Well Network at the RWOS 1	2.10
Figure 2-5: C-14 Passive Monitor Locations Across the NSS-WWMF/Bruce Power Site	2.13
Figure 2-6: C-14 Passive Monitor Locations in the Spent Resin Storage Area at the NSS-WWMF	2.14
Figure 2-7: 2024 Annual Average Perimeter Dose Rates – TLD Results	2.20
Figure 2-8: 2020-2024 Perimeter Dose Rates – TLD Results	2.21
Figure 2-9: 2024 Average Annual Tritium Concentrations in Groundwater Monitoring Wells	2.27
Figure 2-10: 2020 to 2024 Annual Average Tritium Concentrations in Groundwater at Well WSH231 and WSH253	2.28
Figure 2-11: 2020-2024 Average Annual Tritium at Surface Water Sampling Locations in South Railway Ditch (WOD1-5) and East Stormwater Management Pond (SMP-1)	2.30
Figure 2-12: 2023 and 2024 C-14 Concentration at the Passive Air Samplers by Quarter	2.34
Figure 2-13: Annual Average C-14 Concentration by Sampling Area (2020-2024)	2.35
Figure 2-14: 2020-2024 C-14 Average Annual Concentration at NSS-WWMF for Samplers B#3 (Near IC-18) and B#13 (Background)	2.36
Figure C-1: Measured Tritium in Groundwater Wells with Statistically Significant Increasing Trends	C.2
Figure C-2: Measured Tritium in Groundwater Wells with Statistically Significant Increasing Trends (Con't)	C.3

1.0 Introduction

Ontario Power Generation (OPG) owns and operates the Nuclear Sustainability Services — Western Waste Management Facility (NSS-WWMF). Additionally, OPG maintains the Radioactive Waste Operation Site 1 (RWOS 1). To ensure activities at OPG facilities are conducted in a manner that minimizes any potential adverse impact on the public and natural environment, OPG has established an Environmental Management System (EMS) that is consistent with the Canadian Nuclear Safety Commission (CNSC) REGDOC-2.9.1: *Environmental Protection: Environmental Principles, Assessments and Protection Measures* (CNSC, 2017). Additionally, the OPG EMS is registered to the International Organization for Standardization (ISO) 14001:2015 *Environmental Management Systems* standard (ISO, 2015).

As part of the EMS, each OPG Class 1 Nuclear Generating Station and Facility has an Environmental Monitoring Program (EMP), which identifies the contaminants and physical stressors to be monitored. It also involves monitoring in the environment surrounding the facility.

In 2012, OPG developed a detailed design for an EMP to monitor the NSS-WWMF. It was developed in accordance with the guidance of the Canadian Standards Association (CSA) N288.4-10 standard, *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* (CSA, 2010).

This report provides the results of the NSS-WWMF EMP for 2024. The report has been prepared in compliance with Clause 11.1 of CSA N288.4-10 (CSA, 2010), as shown in Table 1.1.

Table 1.1: Concordance Table with Reporting Requirements in CSA N288.4-10

CSA N288.4-10, Clause 11.1.2	Section in EMP Report
The report shall include: a) the results of the EMP, including <ul style="list-style-type: none"> i) measurements of the monitored hazardous and/or nuclear substances, physical stressors, and physical and biological parameters, including their statistical analyses (i.e., assessments of changes through time and space); ii) radiation doses calculated as doses to receptors where this is required; iii) an assessment of the EMP results compared with the performance indicator targets; and iv) documentation and justification of any deviations from field sampling, and analytical, and data management procedures; 	Section 2.3 Section 3.0 Section 2.3 and Section 3.0 Section 4.3
b) a summary and assessment of the field and laboratory QA/QC results, including any nonconformances;	Section 4.1
c) a summary of the audit and review results and subsequent corrective actions;	Section 4.2
d) a summary of any proposed modifications to the EMP; and	Section 6.0
e) documentation, assessment, and review of any supplementary studies that have been initiated, completed, or both.	Section 2.2.5 and Section 2.3.4

1.1 Program Objectives

The EMP is designed to satisfy the following four primary objectives of CSA N288.4-10:

1. Support assessment of the impact on human health and the environment of contaminants and physical stressors of concern resulting from operation of OPG nuclear facilities.
2. Demonstrate compliance with limits on the concentration and/or intensity of contaminants and physical stressors in the environment or their effect on the environment.

3. Demonstrate the effectiveness of containment and effluent control and provide public assurance of the effectiveness of containment and effluent control, independent of effluent monitoring.
4. Verify the predictions made by the Environmental Risk Assessments (ERAs), refine the models used, and reduce the uncertainty in the predictions made by these assessments and models.

More specifically, the objectives of the NSS-WWMF EMP are to (OPG, 2019):

1. Demonstrate that the radiological risk to the public due to the operation of the NSS-WWMF is low and well within the regulatory public dose limit.
2. Measure external gamma dose at the perimeter of the NSS-WWMF and RWOS 1 to confirm compliance with the operating limit of 0.5 $\mu\text{Sv/h}$.
3. Monitor groundwater to confirm the effectiveness of containment of in-ground storage structures at the NSS-WWMF and the RWOS 1.
4. Monitor the railway ditch water for tritium levels to assess remedial measures taken to reduce tritium in the NSS-WWMF MSA (Middle Sands Aquifer) groundwater.
5. Monitor water and sediment for radionuclides and non-radioactive contaminants in the wetland east of the NSS-WWMF to confirm no ecological impact from the east site drainage discharge.
6. Demonstrate that NSS-WWMF waterborne emissions comply with OPG's commitment to keep tritium concentrations at nearby WSPs below 100 Bq/L on an annual average basis.
7. Update the estimated fugitive tritium and C-14 emissions from the site and determine if additional monitoring and reporting is warranted.

1.2 EMP Context and Background Information

OPG has established the current EMP to monitor and identify potential impacts to the environment associated with operation of the NSS-WWMF. Bruce Power conducts a full EMP for the overall Bruce nuclear site, including radiological monitoring (BP, 2025). Estimation of public radiological dose resulting from NSS-WWMF operations is achieved by estimating the NSS-WWMF contribution to the Bruce Power public radiological dose calculation by comparing the relative levels of monitored radiological emissions. See Section 3.1 for the results of this assessment.

Environmental data obtained through the EMP (and often other supplementary studies) are periodically assessed every five years as part of a detailed environmental risk assessment (ERA), which investigates potential risks posed to humans and the local environment from contaminant releases (radiological and non-radiological) resulting from normal NSS-WWMF operations. The risk calculations and conclusions of the ERA are used to recommend and direct future monitoring

programs, including the current EMP, to verify that risk calculations are accurate and to minimize or eliminate uncertainties in environmental data and other modelling parameters used in the ERA. OPG is currently conducting a series of supplementary studies focused on the sampling of surface water, sediment, soil and benthic invertebrate communities to support the upcoming 2026 update of the NSS-WWMF ERA.

Many of the environmental parameters monitored as part of the EMP and assessed as part of the ERA are of considerable interest to local Indigenous and non-Indigenous communities, with engagement being an important consideration for both programs. Through both the EMP and associated ERAs, OPG demonstrates that operation of the NSS-WWMF poses negligible levels of human health or ecological risks to local and regional waterways, soils, wildlife (including country foods), or regional air quality. Were operational risk levels to change, the EMP and the greater ERA are designed to detect and identify any increases in contaminant releases to the environment, allowing for the immediate investigation and subsequent mitigation of any significant releases.

1.3 Overview of the Nuclear Sustainability Services – Western Waste Management Facility

The NSS-WWMF is located on the Bruce nuclear site along the east shore of Lake Huron, approximately 18 km north of Kincardine and 17 km southwest of Port Elgin (Figure 1-1). Although not located within the NSS-WWMF site boundaries, the former Spent Solvent Treatment Facility (SSTF) and RWOS 1 are also located on the Bruce nuclear site (Figure 1-2) and are owned and operated by OPG. The SSTF has not accepted spent solvent since 2003, was decommissioned in 2019 and the CNSC licence has been removed. RWOS 1 has not received waste since 1976 and the remaining storage structures are in caretaking mode (OPG, 2014).

The Bruce nuclear site also hosts Bruce Nuclear Generating Station A (Bruce NGS-A) and Bruce Nuclear Generating Station B (Bruce NGS-B), the Douglas Point Waste Management Facility, the Central Maintenance Facility (CMF), Central Storage Facility (CSF) and other nuclear facilities and related infrastructures (Figure 1-2). Kinectrics North Facility is located 3 km from the Bruce nuclear site. Its main function is the decontamination and refurbishment of large nuclear reactor tools and equipment. The Bruce nuclear site occupies an area of 932 hectares (2,300 acres) within the Municipality of Kincardine, County of Bruce, in the Province of Ontario. Land use in the immediate vicinity is primarily agricultural, recreational, and rural residential. Surrounding the Bruce nuclear site is a mixture of rural agricultural land, former gravel pits, fragmented woodlands, streams, and wetlands. Recreational land use includes Inverhuron Park and cottages in the hamlet of Inverhuron (south of Bruce nuclear site) and Baie du Doré/Scott Point Area (north of Bruce nuclear site).

The NSS-WWMF is owned and operated by OPG and has been in operation since 1974. It is a Class 1B nuclear facility for the storage of low and intermediate level radioactive waste (LILW) and used fuel. The NSS-WWMF consists of the LILW Management Area and the Used Fuel Management Area. The LILW Management area includes the Low-Level Storage Buildings (LLSBs), a Steam Generator Storage Building (SGSB), a Retube Component Storage Building (RCSB), a Waste Volume Reduction Building (WVRB), and a Transportation Package Maintenance Building (TPMB). In-ground structures include In-

ground Containers (ICs), trenches and tile holes, while above-ground structures in this area include the Quadricells. The Used Fuel Management Area includes a Used Fuel Dry Storage Container Processing Building and six (6) Used Fuel Dry Storage Buildings. The layout of the NSS-WWMF is illustrated in Figure 1-3.

In early 2025, OPG initiated the construction of the Multi-Purpose Storage Building (MPSB) within a parcel of land known as the “North Site” (also “North Yard”) of the NSS-WWMF property. This structure will be used to support Bruce Power’s on-going Major Component Replacement (MCR) activities. The storage structure is planned to accept up to sixty-four (64) steam generators (SGs), twenty-four (24) of which are currently stored in the existing NSS-WWMF SGSB and the remaining forty (40) transferred from Bruce Power’s Unit 3, Unit 4, Unit 5, Unit 7 and Unit 8 reactors. The construction and operation of the MPSB has been assessed in a recent addendum to the 2016 WWMF Expansion Project Predictive Effects Assessment (Ecometrix, 2025a) and its location is also shown in Figure 1-3.



Figure 1-1: Location of Nuclear Sustainability Services – Western Waste Management Facility

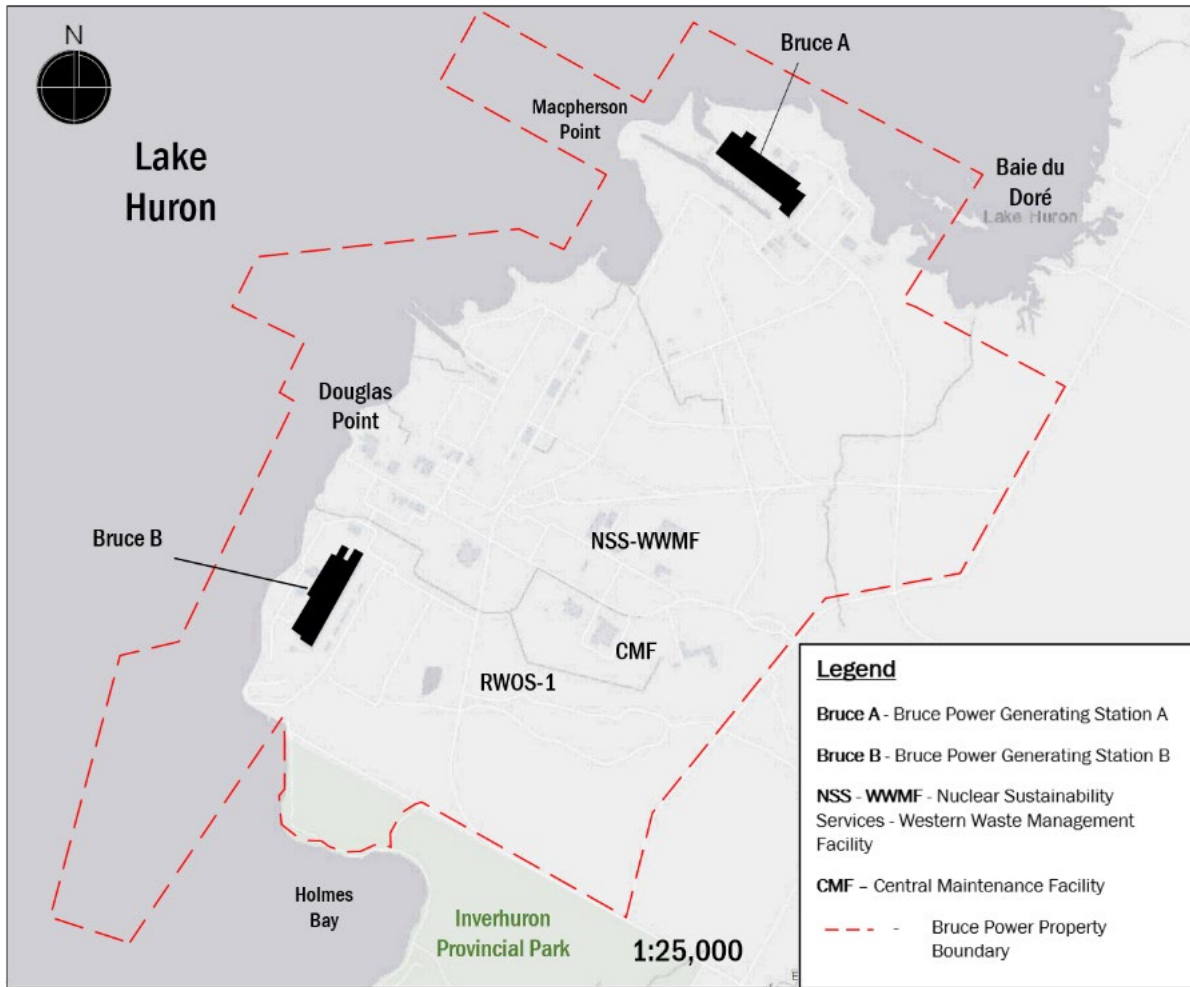


Figure 1-2: Location of Facilities on Bruce Nuclear Site



Figure 1-3: NSS-WWMF Aerial View

Legend:

1. LLSBs
2. In-ground Storage (trenches, tile holes, ICs, In-ground container for heat exchangers (ICHXs))
3. SGSB (3-1) and RCSB (3-2)
4. Used Fuel Processing Building (4-1) and Used Fuel Dry Storage Buildings 1,2,3&4 (4-2)
5. Waste Volume Reduction Building and Amenities Buildings
6. Transportation Package Maintenance Building
7. Quadricells
8. Used Fuel Dry Storage Buildings 5&6
9. Multi-Purpose Storage Building

Source: Modified from Environmental Risk Assessment for the Western Waste Management Facility (AMEC, 2016)

2.0 Environmental Monitoring Program

2.1 Design of EMP

Radiation protection, effluent monitoring, and environmental monitoring have taken place at the NSS-WWMF for many years. Results of the environmental monitoring are reported in the NSS-WWMF Quarterly Operation Reports (QORs) to the CNSC. Current EMP elements that were reported in the QORs include thermoluminescent dosimeter (TLD) measurements of external gamma dose rates, groundwater monitoring results and groundwater trend graphs. In 2012, an EMP for the NSS-WWMF was designed according to the guidance provided in the CSA N288.4-10 standard and monitoring has been ongoing based on this design (AMEC, 2012).

2.1.1 Facilities included in EMP

NSS-WWMF operates under a Class 1B Waste Facility Operating Licence. Although the EMP design report primarily addresses the NSS-WWMF, including all waste storage, waste processing, transportation equipment maintenance, and used fuel dry storage facilities, it also currently includes RWOS 1. Most of the low and intermediate level radiological waste was recovered from RWOS 1 and is stored at the NSS-WWMF. The RWOS 1 is in caretaking mode. Other OPG facilities on the Bruce nuclear site include the conventional landfill, the former SSTF which was decommissioned in 2019, and four (4) construction landfills. These were excluded from the EMP design as they did not meet the criteria for establishing the need for an EMP based on N288.4. These facilities are either regulated by the Ontario Ministry of the Environment, Conservation and Parks (MECP) or were not considered to present any significant risk (AMEC, 2012). The EMP design is also based on the results of NSS-WWMF ERA which did not identify significant risk associated with these other facilities.

2.1.2 Environmental Risk Assessment

The NSS-WWMF ERA assesses potential human health and ecological risks from exposure to radiological contaminants, conventional contaminants, and physical stressors present in the environment as a result of site operations. The ERA helps to identify what monitoring to include in the NSS-WWMF EMP. Subsequently, EMP data are used to update the ERA on a regular time interval, with the data being used to refine models, test predictions of the last ERA and further enhance the understanding of potential risk from the site.

The most recent 2021 NSS-WWMF ERA update (Ecometrix, 2022a) was completed in accordance with the requirements of CSA N288.6-12, *Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills* (CSA, 2012). The ERA provided the following recommendations for monitoring:

- The current quarterly monitoring of tritium within the South Railway Ditch (SRD) as part of the EMP is appropriate and should be continued.

- Hazard quotients above 1 were observed in the surface water at the SRD for several metals, which is consistent with observations from past monitoring and may be attributed to the existence of a former rail line within the ditch for some metals, and to naturally elevated water concentrations for iron and manganese. Additional monitoring is recommended prior to the next ERA to confirm that conditions in the SRD remain unchanged.
- It was previously recommended that the supplementary precipitation study be repeated in 2020-2021 to support the 2021 ERA update. However, based on analysis presented in the 2021 ERA, the precipitation monitoring program is not interpreted to provide additional insight into the NSS-WWMF inputs to precipitation because the results indicated that tritium is most likely attributed to the operation of Bruce A and Bruce B, and the location and elevation of the precipitation samples are not expected to capture the tritium off-gassing processes occurring at the LLSBs. Therefore, monitoring of precipitation was discontinued in Q1 of 2022 and is not included as part of the EMP.
- The source of inputs to the wetland is sufficiently understood; therefore, ongoing monitoring of the wetland is not currently necessary. However, additional wetland monitoring is recommended to support the next ERA update to determine if conditions are stable or have changed.
- The source of C-14 concentrations in vegetation near the IC-18s is understood. Therefore, it is recommended that routine air monitoring using the passive air samplers should continue as part of the EMP design to determine fugitive C-14 emissions, but additional investigations into C-14 in air and vegetation are not required. Future consideration of C-14 in vegetation can be modelled using the specific activity model, as modelled concentrations in vegetation are expected to correlate well with measured air concentrations.
- The 2021 ERA update determined that dioxins and furans are present in the SRD and West Ditch (WD) at concentrations above regulatory screening levels; however, adverse effects to benthic invertebrates at the community level are not expected within the SRD and the WD. Considering that dioxins and furans are not expected to cause adverse effects at the community level at either the SRD or WD, remediation is not warranted. Remediation efforts that involve disturbing the sediment within the SRD and WD are not recommended. Samples of benthic invertebrates can be collected and analyzed for dioxins and furans in a supplementary study to reduce uncertainty in risk characterization for the next ERA update.

As of Fall 2024, OPG has initiated a series of quarterly supplementary field studies to collect site-specific data in support of the next iteration of the NSS-WWMF ERA planned for 2026. The results of these field studies and an interpretation of potential risks associated with chemical and radiological parameters measured in soil, surface water, and sediment will be provided in the upcoming ERA report.

2.1.3 Other Inputs

The EMP design was also informed by other inputs in addition to risk factors identified in the ERA, such as groundwater monitoring results through the groundwater monitoring program, ongoing confirmation of containment of radioactivity in the NSS-WWMF storage structures through the aging management program (OPG, 2022a), and confirmation of predictions in the ERAs.

2.2 EMP Sampling Plan

The EMP sampling plan outlines the parameters monitored, the monitoring locations, the sample types, and the frequency of collection. Samples collected, analyses performed, and interpretation of the data support the EMP objectives outlined in the following sections.

2.2.1 Public Radiological Dose Estimation

A direct determination of public radiological dose from NSS-WWMF operations based on environmental monitoring of nuclear substances is not feasible since environmental media around the Bruce nuclear site (e.g., air, soil, plant and animal food products, water, beach sand) contain radionuclides which are released from all nuclear facilities on the site operated by OPG, Bruce Power and Canadian Nuclear Laboratories (CNL); that is the NSS-WWMF, Bruce NGS-A, Bruce NGS-B, CMF, CSF, and Douglas Point Waste Facility (DPWF). Most of these radionuclides are common to all facilities and for the most part, one cannot determine the level of contributions in environmental media from each specific source by means of environmental measurements and laboratory analyses. Most of the radioactivity monitored in the environment is tritium, C-14, and beta/gamma emitters, all of which are released to some extent in airborne and waterborne effluents by all Bruce nuclear site facilities. Bruce Power conducts a full EMP for the overall Bruce nuclear site, including radiological monitoring (BP, 2025). Estimation of public radiological dose resulting from NSS-WWMF operations is achieved by estimating the NSS-WWMF contribution to the Bruce Power public radiological dose calculation by comparing the relative levels of monitored radiological emissions. See Section 3.1 for the results of this assessment.

2.2.2 Tritium Levels at Water Supply Plants

OPG has a commitment to the government of Ontario to control waterborne emissions of tritium from its facilities to levels that will keep tritium concentrations at nearby WSPs below 100 Bq/L on an annual average basis. Confirmation that OPG is keeping its commitment is achieved by estimating NSS-WWMF's relative contribution to Bruce Power's results of monitoring tritium in the Southampton and Kincardine WSPs, using measured waterborne tritium emissions. See Section 3.2 for the results of this assessment.

2.2.3 Direct Gamma and Skyshine Dose

Direct gamma and skyshine doses resulting from radioactivity in the waste storage facilities fall off rather quickly with distance. The NSS-WWMF storage facilities are located reasonably far

from the Bruce nuclear site perimeter, and gamma dose from the NSS-WWMF is not a significant contributor to the radiological dose of the general public. However, external gamma doses near the storage facilities are monitored to ensure that potential non-Nuclear Energy Workers (non-NEWs) working in proximity of the NSS-WWMF are adequately protected. To protect non-NEWs near the NSS-WWMF site, the storage facilities have a gamma dose limit of 0.5 $\mu\text{Sv/h}$ at the fence line. This ensures that a non-NEW at a nearby location over the course of a normal work year would not be exposed to more than the non-NEW regulatory dose limit of 1 mSv/a (or 1,000 $\mu\text{Sv/h}$).

Environmental TLDs are placed at several locations around the perimeters of the NSS-WWMF and RWOS 1 to measure direct gamma doses. There are 63 TLDs at the NSS-WWMF (16 around the Used Fuel Dry Storage Facility (UFDSF) buildings 1-4, 20 around the UFDSF buildings 5-6, and 20 around the rest of the NSS-WWMF). There are seven (7) TLDs around RWOS 1. The specific locations are shown in Figure 2-1 and Figure 2-2. The TLDs are replaced every quarter and shipped to the OPG Whitby Health Physics laboratory (HPL) for analysis. Preparation, shipping, deployment, and analysis of the TLDs are described in the Environmental Gamma Monitors (EGM) System Overview (OPG, 2013). See Section 2.3.2 and Section 3.3 for results of TLD measurements. TLD data for 2024 can also be found in the NSS-WWMF annual compliance report (OPG, 2025a).

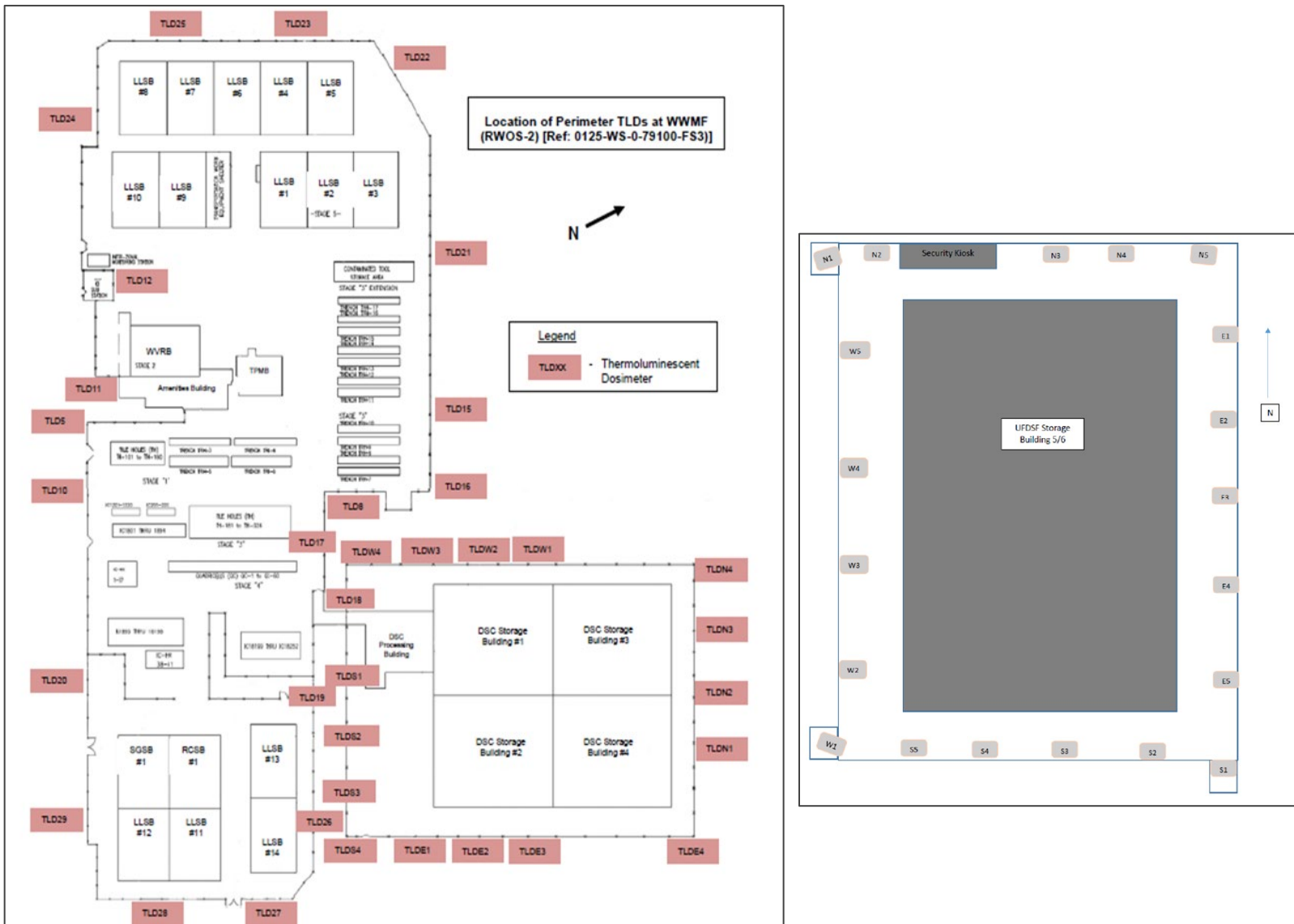


Figure 2-1: Location of TLDs at NSS-WWMF

Source: NSS-WWMF Annual Compliance Report (OPG, 2025a)

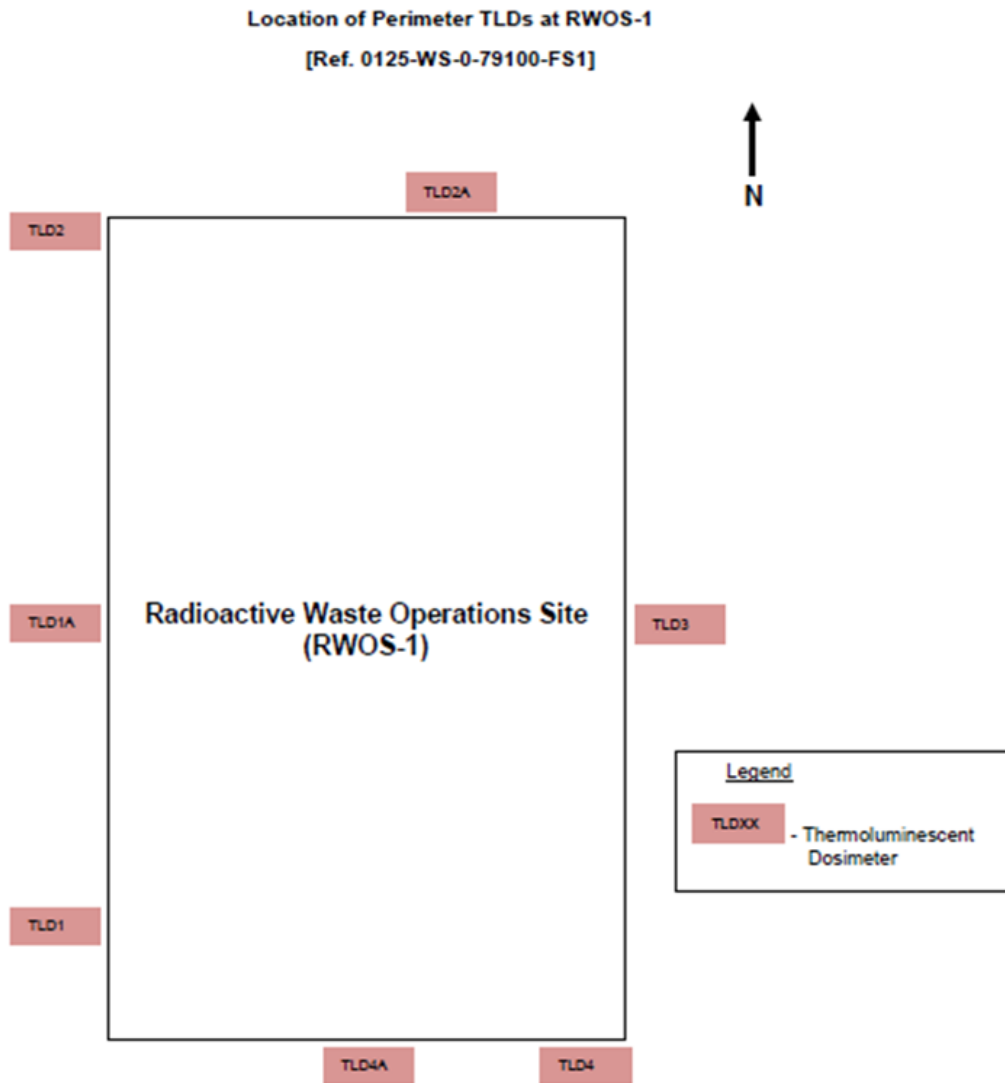


Figure 2-2: Locations of TLDs at RWOS 1

Source: NSS-WWMF Annual Compliance Report (OPG, 2025a)

2.2.4 Confirmation of Containment Integrity of In-ground Storage Structures

In-ground storage structures are monitored in different ways. The trenches and tile holes have an engineered subsurface drainage system, which is routinely monitored for tritium. IC-12s and IC-18s have an accessible space outside the IC walls that is routinely checked for any water accumulation and radioactivity, thus providing a primary check of containment. As an additional barrier to ensure effective storage structure containment, groundwater around the NSS-WWMF and RWOS 1 is routinely sampled. The sampling wells are technically sound, sealed groundwater sampling wells, but are referred to as water sampling holes (WSHs). The WSHs are placed to detect a potential loss of containment in storage structures and any movement of radioactivity in groundwater from the NSS-WWMF. The specific locations of the WSHs at the NSS-WWMF are shown in Figure 2-3, and the locations of those at RWOS 1 are shown in Figure 2-4.

Both the shallower MSA and the deeper bedrock aquifer are monitored. Detailed procedures are followed for technically sound monitoring of the groundwater wells (OPG, 2018).

The MSA is generally localized to the NSS-WWMF but is hydraulically connected to the bedrock aquifer. Groundwater from the MSA generally leaves the NSS-WWMF site via the bedrock aquifer. However, it appears that due to excavations and backfill material associated with the installation of a Stormceptor in the mid-2000s, some groundwater from the MSA discharges to the SRD (near the north-western area of the NSS-WWMF). For a more detailed description of groundwater flow within and outside of the NSS-WWMF, see the EMP design report (AMEC, 2012). A source term assessment and groundwater monitoring network design enhancement were completed in 2016 at the NSS-WWMF.

Based on the results of previous monitoring programs, the development of the Conceptual Site Model and Groundwater Monitoring Program (Ecometrix, 2022b, 2025b) identified tritium as the only contaminant of potential concern (COPC) at the site and discontinued the sampling of gross β and C-14 in groundwater in 2022. Groundwater sampling for gross β was conducted as a supporting analysis for the purposes of general radiological trending and was removed because it does not include tritium, which is a low-energy β . Groundwater sampling for C-14 was conducted to confirm storage structure containment, but was removed because the majority of samples were non-detect, or well below the Ontario Drinking Water Quality Standard of 200 Bq/L (OPG, 2021a, 2021b, 2021c, 2022b). These efforts also resulted in the re-establishment of seven previously monitored wells, including WSH 252, WSH 256, WSH 267, WSH 275, WSH 276 and WSH 277 and the establishment of six new wells including WSH 301, WSH 302, WSH 307, DGRB12, DGRB12A and DGRB14 for the purposes of monitoring downgradient perimeter groundwater, upgradient groundwater, subsurface drainage, and general background tritium concentrations at the NSS-WWMF. Seven wells monitored in 2021 were also discontinued primarily due to redundancy, including WSH233, WSH 241, WSH246, WSH 248, WSH 271, WSH 127 and WSH 20S. Section 2.3.3 provides the WSHs monitored in 2024 for tritium at both RWOS 1 and the NSS-WWMF. Most wells at RWOS 1 and the NSS-WWMF are now monitored either annually or semi-annually. Results of this program are reported in Section 2.3.3 of this document

and are also documented in the annual groundwater monitoring reports compliant with CSA N288.7:23.

While there are no specific regulatory targets or limits for radioactivity in groundwater at the NSS-WWMF and RWOS1, OPG's groundwater monitoring program has established several evaluation criteria for tritium concentrations in groundwater. The primary groundwater evaluation criterion established for the NSS-WWMF site is if there is a clear departure from background tritium concentration for the hydrostratigraphic unit (HU) in which the well is completed. Furthermore, OPG has developed three site-specific administrative limits for tritium in groundwater, which include:

- 9,800 Bq/L in HU4 (MSA)-HU7 (Bedrock) at the NSS-WWMF and all wells in the RWOS1;
- 98,000 Bq/L in shallow groundwater (HU1-3 (perched/shallow water table), and in select HU4 wells) and the subsurface drainage sampling locations at the NSS-WWMF; and
- a "property boundary check" value of 1,750 Bq/L to be applied to evaluate tritium concentrations at, or in wells closest to, the property boundary of the NSS-WWMF and RWOS 1 with adjacent properties.

Further information regarding the derivation and application of these groundwater criteria, as well as the methodology for determining background concentrations of tritium in groundwater are available in OPG's N288.7-compliant annual groundwater reports.

For the purposes of this report, groundwater tritium concentrations at each well are compared to a value of 500 Bq/L. Historically, most tritium concentrations in wells throughout the NSS-WWMF and RWOS 1 sites are below 500 Bq/L, thus the use of this value for comparative purposes highlights groundwater wells with tritium concentrations that are outside the range of what is typically expected across these sites. This allows for the effective identification of concentration spikes, and any changes in trends over time when compiling and examining the results of the groundwater monitoring portion of this EMP across years. In general, the radioactivity in each WSH is examined to see if there is an increasing trend over time that may indicate a loss of integrity of a storage structure. In the case of WSH 231, where elevated tritium concentrations in the MSA had been identified for some time, remedial measures such as sealing of select building sumps and pumpouts of water from LLSB electrical manhole sumps were initiated in 2010. WSH231 data were examined for a decreasing trend from February 2010 onward to determine how effective the remedial measures have been in reducing tritium concentrations. See Section 2.3.3 and Appendix C for results of groundwater monitoring.



Figure 2-4: Monitoring Well Network at the RWOS 1

2.2.5 Water in South Railway Ditch and East Stormwater Management Pond

The SRD and the East Stormwater Management Pond has been monitored routinely for tritium since 2010 and was also monitored in 2013 as part of the NSS-WWMF EMP supplementary studies (OPG, 2014), in 2020 and 2021 as part of the NSS-WWMF ERA update (Ecometrix, 2022a), and again in 2024 and 2025 in support of the upcoming 2026 NSS-WWMF ERA update. Historical results provided no firm conclusions about changes in tritium in the SRD as compared with tritium concentrations measured in WSH 231 over the same period. Quarterly routine monitoring of the ditch continues at four locations (WOD1, WOD2, WOD4 and WOD5). The continued quarterly monitoring in the SRD and the groundwater wells should provide a better understanding of any trends in tritium concentrations moving forward.

2.2.6 Supplementary Sampling of Water and Sediment in South Railway Ditch, West Ditch, Wetland and East Stormwater Management Pond

In addition to the regular environmental sampling that occurs as part of OPG's annual EMP, sampling of water and sediment may occur, as required, in support of future iterations of the NSS-WWMF ERA. In 2024, additional water and sediment sampling was conducted within the SRD, the WD, the Wetland and the East Stormwater Management Pond. Results of these supplementary field studies will be provided in the next iteration of the NSS-WWMF ERA. More information regarding past sampling programs conducted at these locations in support of the 2021 NSS-WWMF ERA are provided in the 2022 NSS-WWMF EMP report (OPG, 2024).

2.2.7 Fugitive Emissions of C-14

Elevated C-14 in air on the NSS-WWMF site was identified in the 2013 EMP Report (OPG, 2014) and an integration into routine sampling was recommended. Bruce Power nuclear site passive C-14 samplers are shown in Figure 2-5. Passive sampler results from Bruce Power indicated higher levels of C-14 than provincial background locations. The highest concentrations were localized at NSS-WWMF. Measured C-14 levels were near provincial background levels at the site boundary (BP, 2025).

The C-14 passive samplers consist of mixed soda lime pellets to absorb CO₂ from air at a controlled rate. Twenty samplers are positioned around the area of the NSS-WWMF for passive monitoring (Figure 2-6). The samples are collected and analyzed quarterly.

Elevated concentrations of C-14 at the NSS-WWMF are associated with the spent resin storage area, specifically the in-ground containers (IC-12s and IC-18s). The fugitive emissions reassessment was designed to update the estimated fugitive tritium and C-14 emissions from the site and determine if additional monitoring and reporting is warranted. Sampling for this assessment was completed in 2019 at the spent resin storage area. During this assessment air samples were also collected from 67 ICs. Emissions estimates from this sampling campaign confirmed that C-14 emissions from ICs were elevated. Following the fugitive emissions reassessment, gaskets were replaced on IC-12s and IC-18s to provide better sealing, and scrubbers were installed in select IC-18s to sequester C-14.

OPG will continue monitoring and reporting C-14 concentration using the existing C-14 passive samplers. Both environmental and health physics monitoring confirm that there is no significant impact on workers, the public, nor the environment.

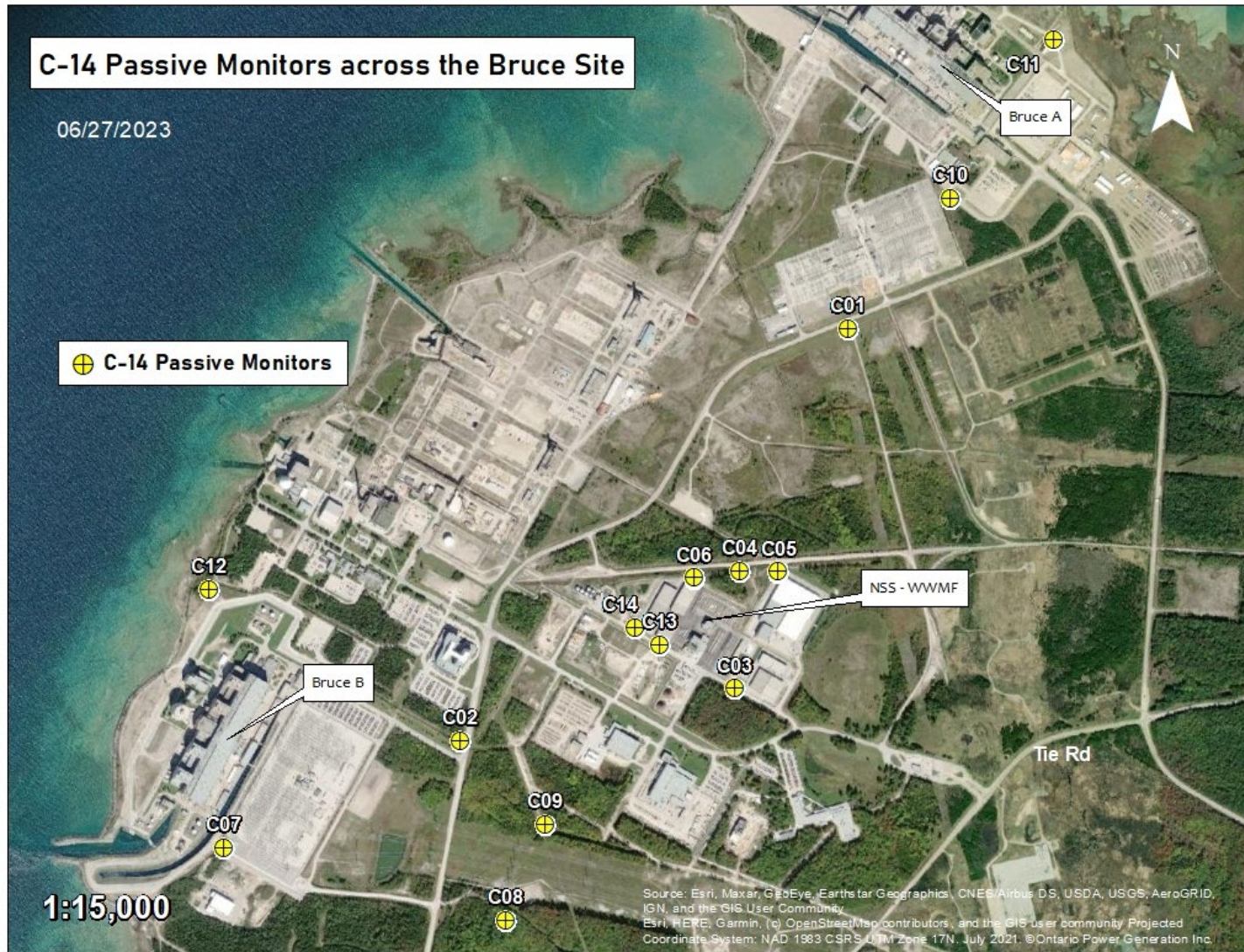


Figure 2-5: C-14 Passive Monitor Locations Across the NSS-WWMF/Bruce Power Site

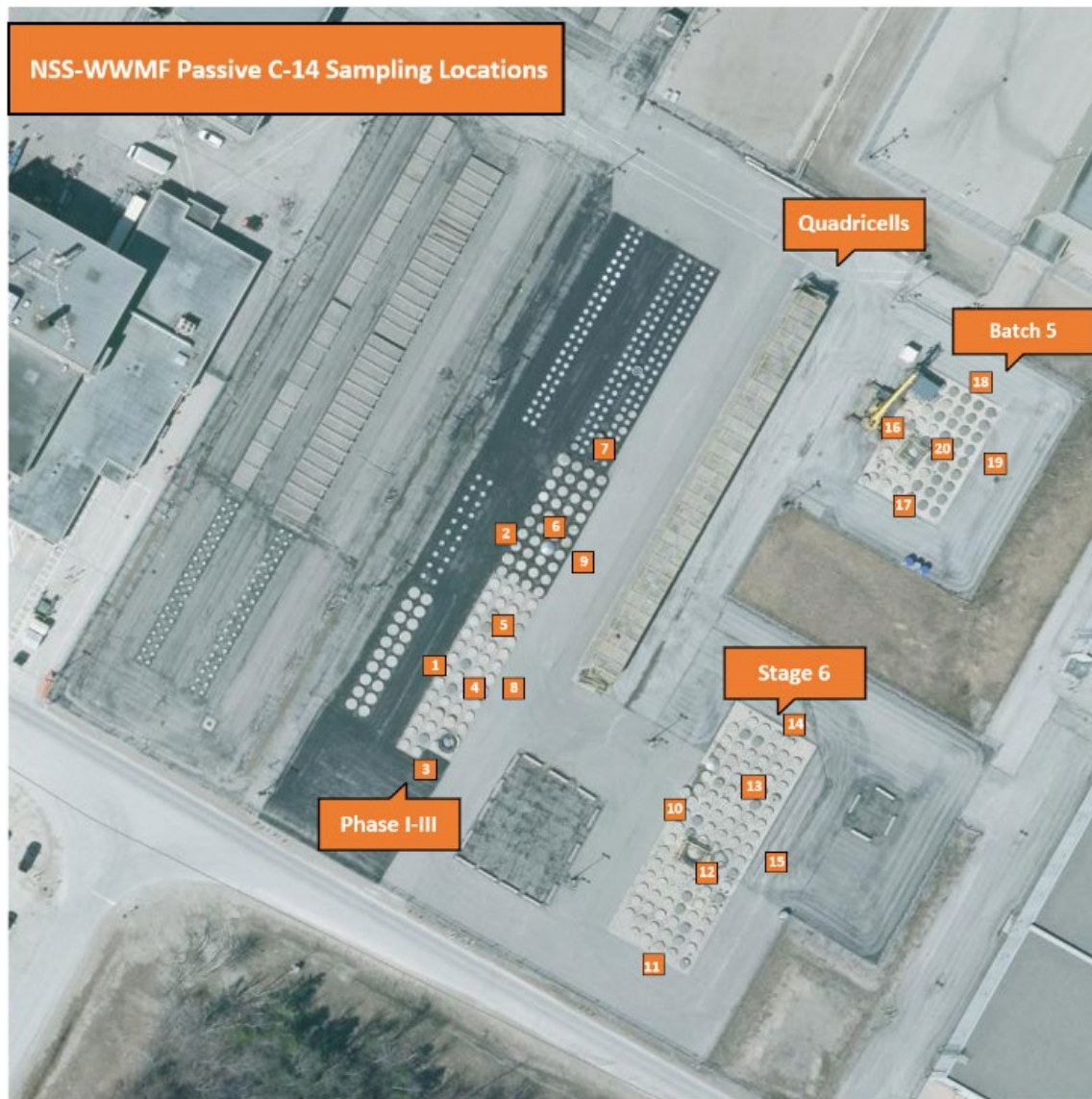


Figure 2-6: C-14 Passive Monitor Locations in the Spent Resin Storage Area at the NSS-WWMF

2.3 EMP Results

This section contains the 2024 results of the EMP for the NSS-WWMF and RWOS 1. Sampling methods, analyses, and quality assurance and quality control (QA/QC) measures are identified.

2.3.1 Reporting Data and Uncertainties

Descriptive statistics such as means, and standard deviations were calculated in Microsoft® Excel® unless the dataset contained non-detects with values specified. Statistical analysis for trends were performed using the Microsoft® Excel® Real Statistics package (Zaiontz, 2025).

Radionuclide concentrations and radiation levels in the environment are low and at times below levels which can be detected by routine analytical techniques. In these situations, the analytical result is reported as being below the detection limit (Ld). Regarding critical levels and detection limits, the following are considered:

- **Lc:** The critical level is the level (relative to background) below which a quantity cannot reliably be measured. More specifically, the critical level is the largest value or the quantity for which the probability of a wrong conclusion that a quantity is present exceeds a specified probability (OPG, 2016). The EMP uses a probability of 5%. For the EMP, Lc is approximately equal to half of the Ld.
- **Ld:** The detection limit is the level (relative to background) above which a quantity can confidently be measured. More specifically, the detection limit is the smallest value of the quantity for which the probability of a wrong conclusion that the quantity is not present does not exceed a specified probability (OPG, 2016). The EMP uses a probability of 5%.

Furthermore, when reporting the analytical data in this report, the following conventions are used:

- Where a measured value is below the analytical Ld but above the Lc, the measured value is reported in bold type.
- Where a measured value is below the Lc, then "< Lc" is reported without an uncertainty measure.
- Where a measured value is censored at the Ld, it is reported as "< Ld". This is the case for gamma spectrometer results, noble gas data, and conventional contaminants.
- For a dataset comprised of a single measured value, the associated uncertainty is the laboratory analytical uncertainty for that specific sample.
- For a dataset without any data censored at the Ld, the arithmetic mean is reported and associated uncertainty is two times the standard deviation of the dataset.
- For a dataset containing some data censored at the Ld, the Kaplan-Meier (KM) estimation method is used. The KM mean is reported and associated uncertainty is two

times the KM standard deviation of the dataset. An asterisk "*" is used to identify these datasets.

- For a dataset that consists entirely of data censored at the Ld, the average is reported as "<Ld" without an uncertainty measure.
- For a dataset that consists entirely of data below the Lc (with no censored data), the average is reported as "<Lc" without an uncertainty measure.

2.3.2 Gamma Radiation Dose Monitoring Results

The Harshaw Environmental TLD System was used to measure the direct gamma and skyshine doses around the perimeters of the NSS-WWMF and RWOS 1.

The dosimeters are changed quarterly and shipped to the OPG HPL for readout. For quality control (QC), transport dosimeters always accompany the field dosimeters on the trip to and from the field locations so that extraneous radiation dose received in transit is monitored and accounted for. Additional information on the TLDs and the readout procedure can be found in the EGM System Overview (OPG, 2013).

The 2024 TLD gamma dose results are shown in Table 2.1. Results are given as air kerma rates ($\mu\text{Gy/h}$). The highest dose rate measured was $0.275 \mu\text{Gy/h}$ in Q2 at TLD location DFSB56-W3; overall, all quarterly results and annual average results at RWOS 1 and the NSS-WWMF, including the UFDSF area, are well below the derived dose rate target of $0.5 \mu\text{Gy/h}$, and no effects are expected at this exposure level. A graphical representation of the 2024 results is shown in Figure 2-7.

All TLD locations were analyzed for any statistically significant trends in the last five years (2020 – 2024) at the 95% significance level using the Mann-Kendall Test (Zaiontz, 2025). A statistically significant trend is represented by a probability (p-value) of less than 5% (i.e., $p < 0.05$), which indicates the probability of the null hypothesis (i.e., no statistically significant trend) being true, and the statistically significant trend result being produced by random chance, is below 5%. Most locations did not show any appreciable changes or trends that would warrant further investigation. Only four TLD locations at the Western Low and Intermediate Level Waste Storage Facility (WLILWSF) showed statistically significant trends spanning between Q1 of 2020 to Q4 of 2024:

- TLD 11 increased from $0.062 \mu\text{Gy/h}$ to $0.073 \mu\text{Gy/h}$ ($p=0.029$).
- TLD 12 increased from $0.070 \mu\text{Gy/h}$ to $0.082 \mu\text{Gy/h}$ ($p=0.008$).
- TLD 24 increased from $0.069 \mu\text{Gy/h}$ to $0.083 \mu\text{Gy/h}$ ($p=0.004$).
- TLD 28 decreased from $0.092 \mu\text{Gy/h}$ to $0.072 \mu\text{Gy/h}$ ($p=0.030$).

One TLD location (DFSN-1) at the Used Fuel Dry Storage Buildings 1-4 showed a statistically significant trend from 2020 to 2024. Specifically, TLD DFSN-1 decreased from 0.091 $\mu\text{Gy/h}$ in Q1 of 2020 to 0.074 $\mu\text{Gy/h}$ in Q4 of 2024 ($p=0.037$).

Five TLD locations at the Used Fuel Dry Storage Buildings 5-6 showed statistically significant trends spanning between Q1 of 2022 to Q4 of 2024:

- TLD DFSB56-E3 increased from 0.067 $\mu\text{Gy/h}$ to 0.117 $\mu\text{Gy/h}$ ($p=0.005$).
- TLD DFSB56-E4 increased from 0.076 $\mu\text{Gy/h}$ to 0.127 $\mu\text{Gy/h}$ ($p=0.002$).
- TLD DFSB56-E5 increased from 0.070 $\mu\text{Gy/h}$ to 0.086 $\mu\text{Gy/h}$ ($p=0.004$).
- TLD DFSB56-W4 increased from 0.085 $\mu\text{Gy/h}$ to 0.183 $\mu\text{Gy/h}$ ($p=0.006$).
- TLD DFSB56-S3 increased from 0.101 $\mu\text{Gy/h}$ to 0.124 $\mu\text{Gy/h}$ ($p=0.012$).

Overall, all quarterly and annual average TLD gamma dose results between 2020 and 2024 are below the dose rate limit of 0.5 $\mu\text{Gy/h}$ (Figure 2-8).

Table 2.1: 2024 TLD Average Air Kerma Rates

TLD – Average Air Kerma Rates (µGy/h)						
TLD Location	Q1	Q2	Q3	Q4	Annual Average	Uncertainty ⁽³⁾
RWOS 1						
1	0.048	0.054	0.049	0.046	0.049	0.007
1A	0.052	0.055	0.054	0.051	0.053	0.004
2	0.052	0.058	0.052	0.052	0.054	0.006
2A	0.053	0.056	0.055	0.051	0.054	0.004
3	0.048	0.051	0.052	0.044	0.049	0.007
4	0.045	0.053	0.049	0.045	0.048	0.008
4A	0.049	0.052	0.049	0.046	0.049	0.005
WLILWSF ⁽¹⁾						
5	0.056	0.059	0.054	0.054	0.056	0.005
8	0.061	0.063	0.063	0.061	0.062	0.002
10	0.053	0.055	0.052	0.057	0.054	0.004
11	0.067	0.135	0.079	0.073	0.089	0.063
12	0.076	0.083	0.105	0.082	0.087	0.025
15	0.059	0.064	0.058	0.06	0.06	0.005
16	0.063	0.067	0.06	0.062	0.06	0.006
17	0.061	0.064	0.058	0.062	0.061	0.005
18	0.058	0.063	0.062	0.06	0.06	0.004
19	0.06	0.063	0.059	0.058	0.06	0.004
20	0.054	0.058	0.065	0.066	0.061	0.011
21	0.057	0.063	0.054	0.055	0.057	0.008
22	0.058	0.059	0.058	0.057	0.058	0.002
23	0.065	0.068	0.068	0.065	0.067	0.003
24	0.074	0.078	0.082	0.083	0.079	0.008
25	0.08	0.082	0.08	0.079	0.08	0.003
26	0.076	0.078	0.074	0.074	0.076	0.004
27	0.061	0.07	0.063	0.064	0.06	0.008
28	N/A ⁽⁴⁾	0.078	0.08	0.072	0.08	0.008
29	0.059	0.071	0.072	0.068	0.068	0.012
UFDSF Buildings 1 – 4 ⁽²⁾						
DFSN-1	0.064	0.077	0.075	0.074	0.073	0.012
DFSN-2	0.089	0.089	0.085	0.08	0.09	0.009
DFSN-3	0.078	0.08	0.075	0.08	0.08	0.005
DFSN-4	0.06	0.062	0.059	0.057	0.06	0.004
DFSS-1	0.068	0.069	0.068	0.067	0.068	0.002
DFSS-2	0.067	0.068	0.065	0.068	0.067	0.003
DFSS-3	0.07	0.072	0.068	0.068	0.07	0.004

TLD – Average Air Kerma Rates (μGy/h)						
TLD Location	Q1	Q2	Q3	Q4	Annual Average	Uncertainty ⁽³⁾
DFSS-4	0.061	0.066	0.066	0.061	0.064	0.006
DFSE-1	0.072	0.073	0.073	0.069	0.072	0.004
DFSE-2	0.083	0.085	0.092	0.092	0.088	0.009
DFSE-3	0.082	0.079	0.078	0.076	0.079	0.005
DFSE-4	0.06	0.061	0.06	0.057	0.06	0.003
DFSW-1	0.081	0.08	0.081	0.076	0.08	0.005
DFSW-2	0.08	0.084	0.079	0.075	0.08	0.007
DFSW-3	0.071	0.074	0.071	0.071	0.072	0.003
DFSW-4	0.057	0.059	0.058	0.057	0.058	0.002
UFDSF Buildings 5 – 6 ⁽²⁾						
DFSB56-N1	0.062	0.063	0.067	0.059	0.063	0.007
DFSB56-N2	0.06	0.069	0.068	0.062	0.06	0.009
DFSB56-N3	0.07	0.076	0.073	0.069	0.07	0.006
DFSB56-N4	0.061	0.07	0.072	0.066	0.07	0.010
DFSB56-N5	0.058	0.06	0.067	0.061	0.06	0.008
DFSB56-E1	0.056	0.062	0.06	0.053	0.06	0.008
DFSB56-E2	0.064	0.069	0.068	0.067	0.067	0.004
DFSB56-E3	0.088	0.108	0.123	0.117	0.109	0.031
DFSB56-E4	0.112	0.128	0.126	0.127	0.123	0.015
DFSB56-E5	0.084	0.086	0.089	0.086	0.086	0.004
DFSB56-W1	0.072	0.074	0.073	0.069	0.072	0.004
DFSB56-W2	0.159	0.163	0.157	0.151	0.158	0.010
DFSB56-W3	0.274	0.275	0.268	0.269	0.272	0.007
DFSB56-W4	0.185	0.19	0.192	0.183	0.19	0.008
DFSB56-W5	0.082	0.085	0.086	0.078	0.083	0.007
DFSB56-S1	0.063	0.067	0.066	0.064	0.065	0.004
DFSB56-S2	0.076	0.075	0.078	0.073	0.076	0.004
DFSB56-S3	0.124	0.129	0.127	0.124	0.126	0.005
DFSB56-S4	0.134	0.129	0.132	0.125	0.130	0.008
DFSB56-S5	0.13	0.135	0.131	0.129	0.13	0.005

- 1) WLILWSF: Western Low and Intermediate Level Waste Storage Facility
- 2) UFDSF: Used Fuel Dry Storage Facility
- 3) Uncertainty in annual average is given as ± 2 standard deviations.
- 4) No reading – TLD damaged

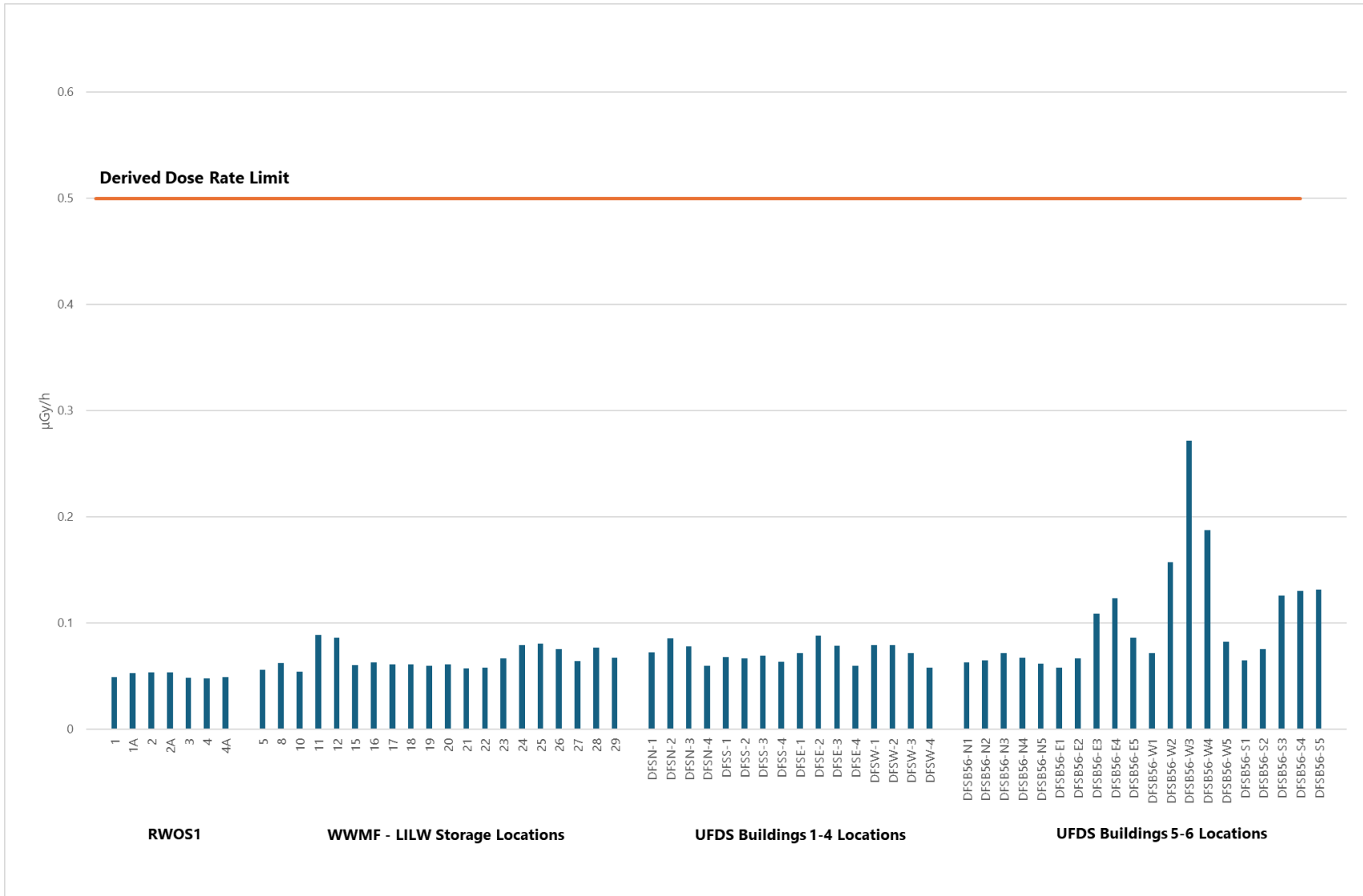


Figure 2-7: 2024 Annual Average Perimeter Dose Rates – TLD Results

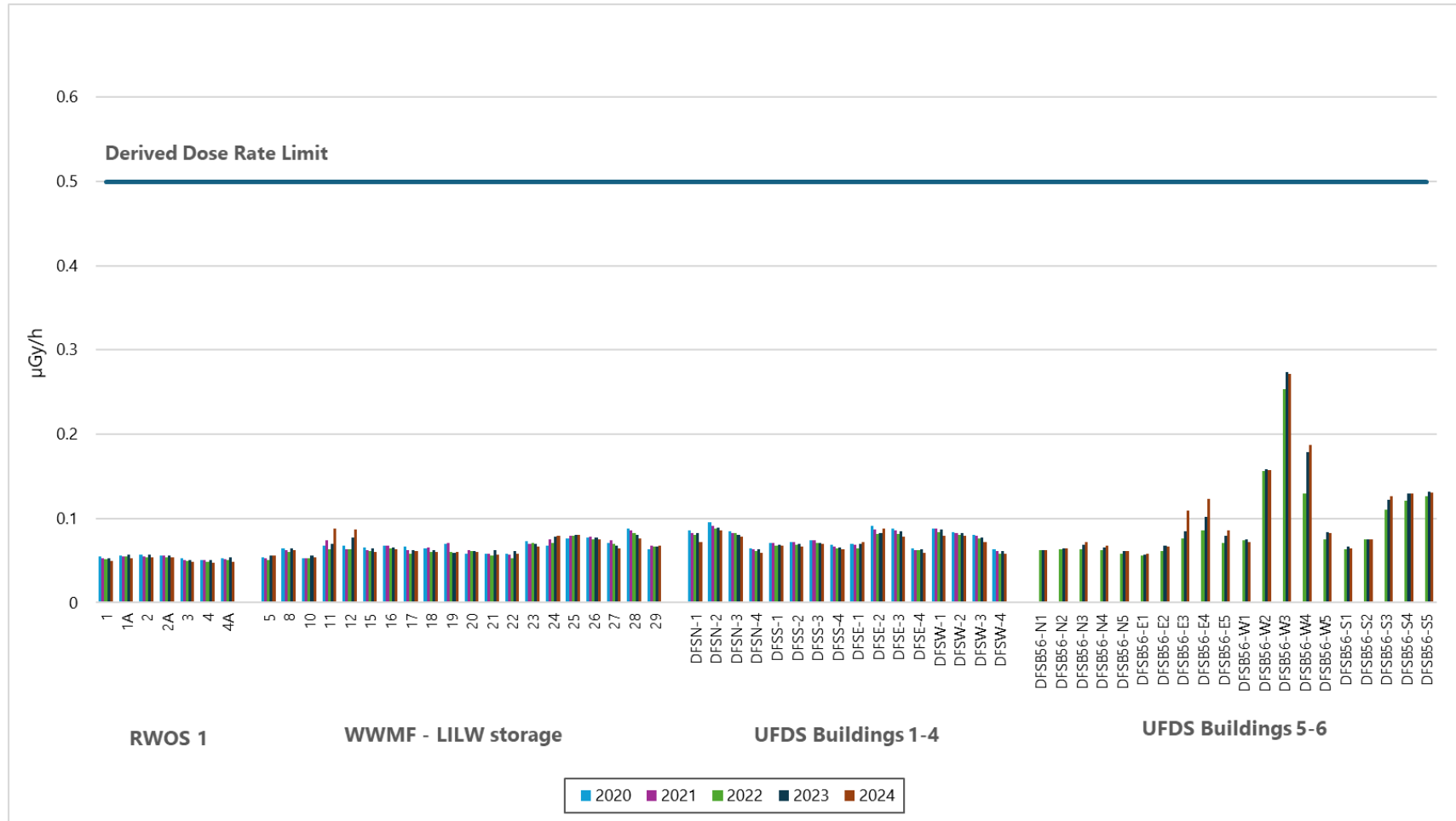


Figure 2-8: 2020-2024 Perimeter Dose Rates – TLD Results

2.3.3 Groundwater Monitoring Results

Groundwater monitoring for tritium concentrations was conducted at 49 wells at the NSS-WWMF and five wells at RWOS1 in 2024. At NSS-WWMF, the wells were sampled twice in 2024 (see Table 2.2) while others were only sampled once (see Table 2.3), and the associated tritium concentrations are presented in these tables. At RWOS1, groundwater sampling for tritium concentrations was conducted quarterly in 2024 (see Table 2.2), and surface water was sampled monthly for tritium and gross β concentrations at Ditch N and Ditch S (see Table 2.4).

In 2024, the five RWOS1 wells and 29 of the NSS-WWMF wells sampled had annual average tritium concentrations in groundwater below 500 Bq/L. Wells with average tritium concentrations higher than 500 Bq/L are listed in Table 2.2 and Table 2.3. Tritium concentrations in WSH231, which characterizes the MSA, averaged 8,530 Bq/L in Q2 and 11,500 Bq/L in Q4. A decreasing trend was identified using a Mann-Kendall Test for tritium concentrations at WSH231 between 2020 and 2024 ($p=0.003$), indicating that tritium is steadily decreasing at this station over time. The highest tritium concentrations were measured at WSH253, located close to WSH231 with tritium concentration of 22,300 Bq/L in Q2, and 21,600 Bq/L in Q4. The 2023 NSS-WWMF EMP report noted, for the first time, a statistically significant decreasing trend for tritium concentrations at WSH253 between 2019 and 2023; however, this trend is not statistically significant ($p=0.142$) when tritium results collected in 2024 are included and the 5-year trend is assessed between 2020 and 2024. While a statistically significant decreasing trend at station WSH253 is not reported in this EMP report, results indicate that gradual improvements have occurred since monitoring for this well began in 2017. The average annual tritium concentration at WSH253 has increased slightly from 20,300 Bq/L in 2023 to 21,950 Bq/L in 2024. The 2024 average tritium concentrations in groundwater for all WSHs are shown in Figure 2-9.

Historical data for tritium activity in the WSHs of both sites from 2020 to 2024 was analyzed for the presence of statistically significant trends over this 5-year period. The Mann-Kendall Test was used for trend analysis and tested for evidence of a statistically significant increasing or decreasing trend at the 95% confidence level. The results of the trend analyses for tritium in the NSS-WWMF wells indicated that WSH230, WSH264, WSH272, WSH282, WSH283, WSH285, WSH286, and WSH287 showed an increasing trend, though these increases are noted to be minor.

The increasing trend observed at WSH230 is discussed in the 2023 NSS-WWMF Groundwater Program Results – Supplementary Addendum report (Ecometrix, 2024a) and is not from any new sources to groundwater, and the same trend was observed in 2024. The expected source of this increase could be attributed to downward migration of tritium in groundwater originating from beneath the LLSBs #1 to #5 through the MSA and deeper till into the bedrock aquifer (WSH230).

For WSH282, WSH283, WSH285, WSH286, and WSH287, concentrations of tritium observed in 2024 remain relatively low and are generally in a similar range to what has been observed historically (i.e., within approximately the last 8 years of available data from 2016 to 2024). Whereas the tritium concentrations measured in 2024 at wells WSH264 and WSH272 represent

the highest concentrations measured at each well since records began in 2016, the measured concentrations at both wells remain below 500 Bq/L. The gradual migration of groundwater across the site is the expected source of the slow increase in concentrations in the noted wells, and not the result of any inadvertent releases. These wells continue to be monitored and analyzed for future trends, consistent with the objectives of the Groundwater Protection and Monitoring Program (Ecometrix, 2025b).

Of the remaining NSS-WWMF wells, two had a decreasing tritium concentration trend (WSH226 and WSH231), and the remainder of wells showed no statistically significant trends for tritium.

From 2020 to 2024, in RWOS1 surface water samples, statistically significant increasing trends were detected in tritium concentrations measured in both Ditch N ($p=0.006$) and Ditch S ($p<0.001$). Tritium concentrations demonstrate regular seasonality, with peak concentrations occurring between May and June each year. Between 2020 and 2024, no statistically significant trends were observed for gross β concentrations measured in Ditch N and Ditch S.

The 2024 results indicate that no off-site impacts are observed from elevated radionuclide concentrations in groundwater leaving the NSS-WWMF in the bedrock aquifer. However, the localized elevated tritium in WSH231 and WSH253 indicate that there is a path from a source of elevated tritium concentration to groundwater in the MSA. There have been investigations to determine the source, which point to tritiated water vapour from waste stored in the LLSBs (Ecometrix, 2024b). Remedial actions have been taken since 2007, which include resealing of select LLSB sumps and regular pump-outs of Electrical Manholes to prevent downgradient migration of tritiated groundwater. Water removed from the NSS-WWMF storage structures and building sumps is noted to be transferred to Bruce Power's Active Liquid Waste (ALW) system. Additionally, the tritium inventory in this area continues to decrease due to decay and off-gassing. As stated above, tritium levels in WSH231 showed a statistically significant decreasing trend over the 2020 to 2024 period ($p=0.003$). While tritium concentrations in WSH253 also demonstrated a decreasing trend over the same period, this did not reach statistical significance ($p=0.142$). WSH231 and the neighbouring WSH253 annual averages over this period are plotted in Figure 2-10.

Table 2.2: 2024 Tritium Concentrations (Bq/L) in Groundwater Wells Monitored Semi-Annually

WSH	Q1	Q2	Q3	Q4	Annual Statistic	
					Average	Uncertainty ^a
RWOS 1						
122	1.93E+02	1.76E+02	1.11E+02	1.22E+02	1.51E+02	8.02E+01
123	4.18E+02	2.89E+02	3.15E+02	2.15E+02	3.09E+02	1.68E+02
124	1.59E+02	1.88E+02	2.05E+02	1.79E+02	1.83E+02	3.83E+01
125	1.86E+02	1.79E+02	1.83E+02	1.46E+02	1.74E+02	3.71E+01
126	1.73E+02	1.64E+02	1.82E+02	1.63E+02	1.71E+02	1.78E+01
NSS-WWMF						
226	-	8.34E+00	-	8.57E+00	8.46E+00	3.25E-01
228	-	1.48E+02	-	1.75E+02	1.62E+02	3.82E+01
229	-	6.62E+02	-	5.19E+02	5.90E+02	2.02E+02
230	-	7.78E+02	-	8.59E+02	8.19E+02	1.15E+02
231	-	8.53E+03	-	1.15E+04	1.00E+04	4.20E+03
240	-	7.03E+00	-	8.88E+00	7.96E+00	2.62E+00
242	-	4.84E+01	-	4.57E+01	4.71E+01	3.82E+00
243	-	3.11E+02	-	3.28E+02	3.20E+02	2.40E+01
253	-	2.23E+04	-	2.16E+04	2.20E+04	9.90E+02
255	-	3.45E+03	-	2.49E+03	2.97E+03	1.36E+03
265	-	5.54E+02	-	3.72E+02	4.63E+02	2.57E+02
269	-	3.87E+02	-	3.80E+02	3.83E+02	9.19E+00
276	-	1.55E+01	-	9.51E+00	1.25E+01	8.47E+00
282	-	6.73E+02	-	5.91E+02	6.32E+02	1.16E+02
283	-	2.28E+02	-	2.19E+02	2.24E+02	1.27E+01
284	-	4.23E+02	-	3.96E+02	4.09E+02	3.75E+01
285	-	3.57E+02	-	3.40E+02	3.49E+02	2.40E+01
286	-	3.61E+02	-	2.75E+02	3.18E+02	1.22E+02
287	-	3.58E+02	-	3.29E+02	3.44E+02	4.10E+01

Note:

Bolded values indicate measurements under the detection limit.

Values in grey are an average of two samples taken within a quarter.

^a Uncertainty is given as ± 2 standard deviations.

Table 2.3: 2024 Tritium Concentrations (Bq/L) in Groundwater Wells Monitored Annually

WSH	Q2
NSS-WWMF	
224	4.15E+01
232	1.65E+01
237	8.81E+00
238	7.17E+00
239	7.01E+00
244	1.13E+02
245	1.69E+01
249	7.86E+00
251	1.99E+03
252	2.81E+03
256	3.08E+03
257	2.47E+03
259	9.10E+02
260	8.98E+01
263	5.83E+01
264	7.11E+01
267	7.84E+00
268	8.48E+00
270	8.06E+00
272	4.22E+02
275	8.00E+00
277	2.35E+02
278	4.02E+01
279	2.51E+02
301	8.48E+00
302	8.61E+00
307	8.57E+00
DGRB12	1.06E+02
DGRB12A	8.70E+00
DGRB14	5.60E+01

Note:
Bolded values indicate measurements under the detection limit.
 Values in grey are an average of two samples taken within a quarter.

Table 2.4: 2024 Tritium and Gross β Concentrations (Bq/L) in RWOS 1 Surface Water

Date	Ditch N		Ditch S	
	Tritium (Bq/L)	Gross β (Bq/L)	Tritium (Bq/L)	Gross β (Bq/L)
2024-01-09	2.51E+02	9.37E-02	1.19E+02	3.90E-02
2024-02-07	2.81E+02	1.78E-01	1.62E+02	7.35E-02
2024-03-06	2.66E+02	1.49E-01	2.04E+02	1.51E-01
2024-04-03	2.41E+02	7.27E-02	1.91E+02	6.75E-02
2024-05-06	2.47E+02	1.36E-01	2.42E+02	9.71E-02
2024-06-04	2.69E+02	1.14E-01	2.85E+02	5.17E-02
2024-07-10	2.69E+02	1.37E-01	2.65E+02	9.39E-02
2024-08-14	NS	NS	NS	NS
2024-09-13	NS	NS	NS	NS
2024-10-09	2.94E+02	7.84E-02	NS	NS
2024-11-05	1.57E+02	1.25E-01	4.18E+01	3.50E-01
2024-11-28	1.28E+02	8.36E-02	1.27E+02	1.77E-01
Annual Average	2.40E+02	1.17E-01	1.82E+02	1.22E-01
Annual Uncertainty^a	1.09E+02	6.89E-02	1.56E+02	1.93E-01

Note:

Bolded values indicate measurements under the detection limit.

NS – Indicates no sample was taken.

^a Uncertainty is given as ± 2 standard deviations.

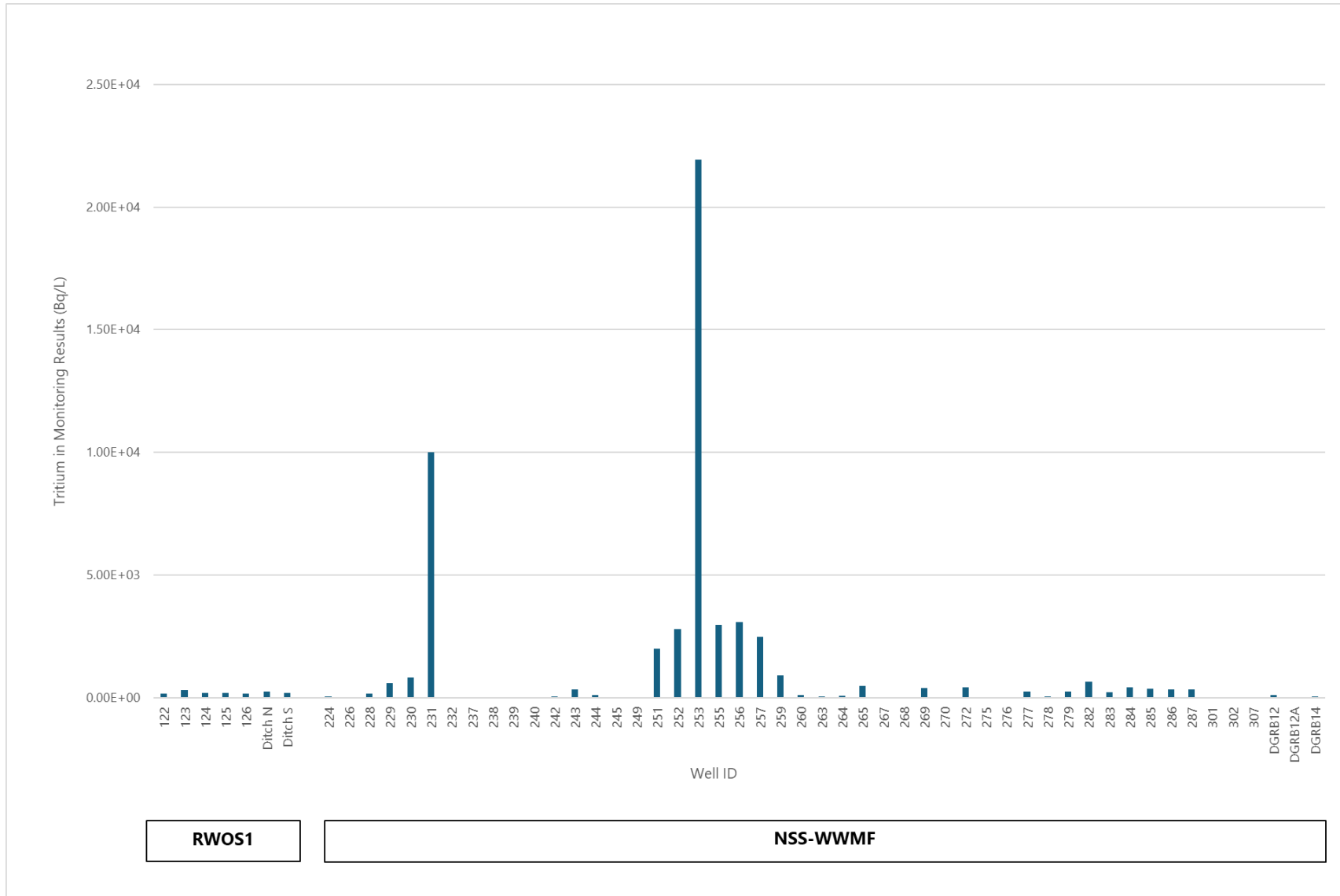


Figure 2-9: 2024 Average Annual Tritium Concentrations in Groundwater Monitoring Wells

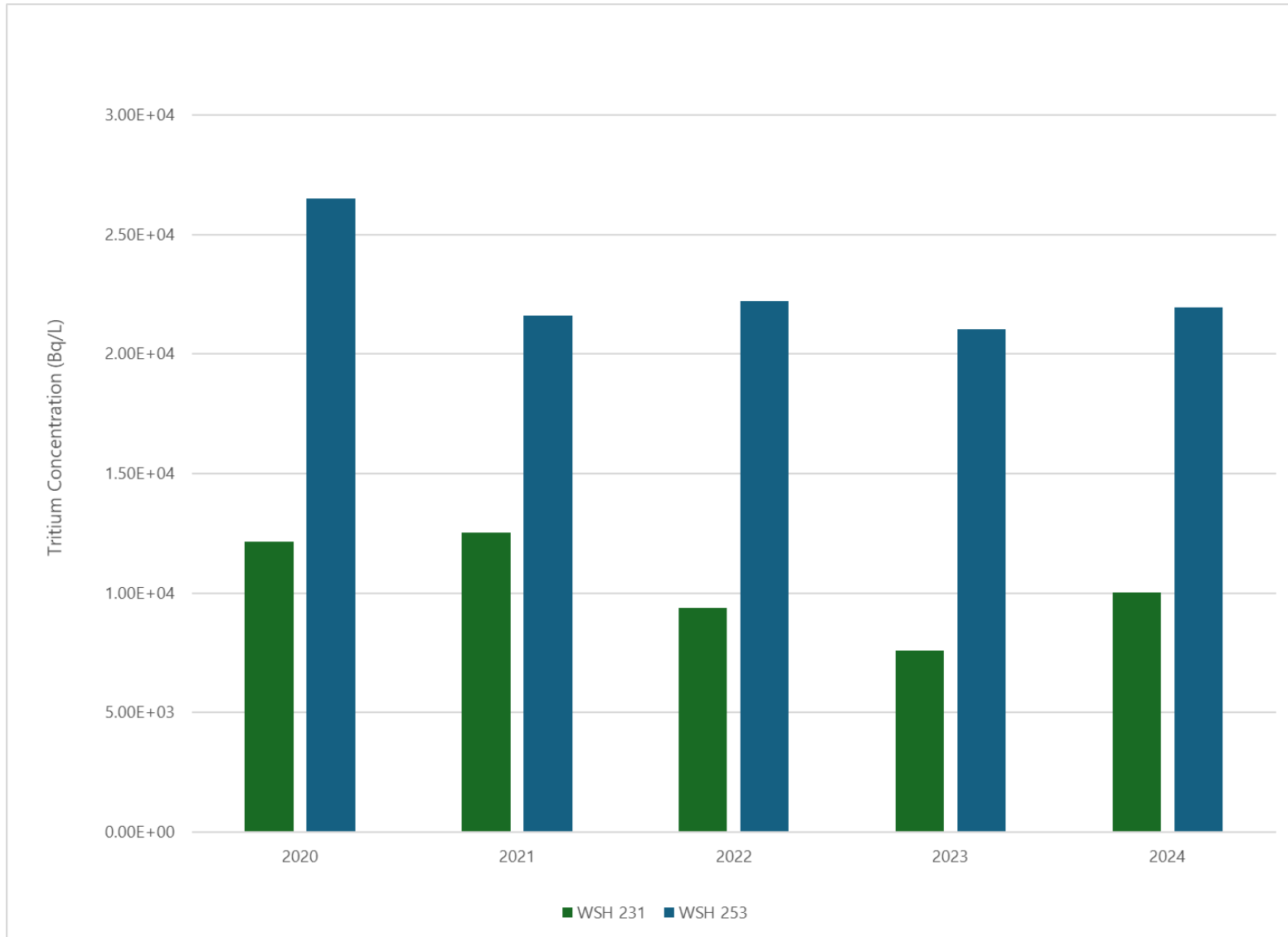


Figure 2-10: 2020 to 2024 Annual Average Tritium Concentrations in Groundwater at Well WSH231 and WSH253

2.3.4 Water in South Railway Ditch and East Stormwater Management Pond

Tritium concentrations in the SRD and East Stormwater Management Pond were measured four times (i.e., quarterly) in 2024. The mean annual concentrations at each location are shown in Table 2.5. All locations were analyzed for statistically significant trends at the 95% significance level using the Mann-Kendall Test. Using measured tritium concentrations from 2020 to 2024 a statistically significant increasing trend was detected at WOD1 ($p=0.009$), WOD2 ($p=0.027$), and WOD4 ($p=0.038$). Historically, tritium concentrations in the SRD and East Stormwater Management Pond are known to fluctuate annually and are hypothesized to be influenced by shifting degrees of surface water dilution stemming from changing weather conditions and water table levels. No other statistically significant trends were detected (Figure 2-11).

In 2023, the average annual tritium concentration at WOD2 was found to have more than doubled compared with the previous annual averages calculated for 2019 to 2022. This was also seen in 2024, with the average annual tritium concentration at WOD2 (3,031 Bq/L) being comparable to the average annual concentration measured in 2023 (2,991 Bq/L). While the Q1, Q2 and Q3 tritium concentrations recorded in 2024 were found to be comparable to their respective historical quarterly averages, the tritium concentration in Q4 was measured to be 8,040 Bq/L, significantly higher than the historical average for Q4. When considering the last five years of data (2020-2024), the recent Q4 tritium concentration is flagged as a potential outlier ($p<0.05$) using Grubb's Test. While the Q3 tritium concentration in 2024 is not considered a potential outlier ($p>0.05$), both the Q3 and Q4 tritium concentrations measured in 2023 were flagged as potential statistically significant outliers in the 2023 NSS-WWMF EMP report (OPG, 2025b).

At this time, the cause of the increase in tritium at WOD2 is unknown; continued monitoring will further characterize whether the 2023 Q3 and Q4 and 2024 Q4 tritium concentrations are true outliers or within the range of seasonal variability. Beginning in April of 2025, sampling of WOD2 has increased from quarterly to monthly to better capture any variability seen in tritium concentrations throughout the year. Though the Q4 tritium concentration at WOD2 was higher than historically recorded (excluding the measurements in 2023), the conclusions made in the 2021 WWMF ERA (Ecometrix, 2022a) remain valid for tritium risk to both human health and the environment, as the measured tritium concentrations are well below the risk-based values developed for the ingestion of domestic well water and water sourced from Lake Huron that were used to assess risk in the ERA.

Table 2.5: Mean Annual Tritium Concentration in 2024 at the South Railway Ditch (WOD1 – WOD5) and East Stormwater Management Pond (SMP-1)

Location	Tritium (Bq/L)	Uncertainty ^a
WOD1	9.32E+02	1.3E+03
WOD2	3.03E+03	6.9E+03
WOD4	1.45E+03	1.4E+03
WOD5	1.03E+03	1.1E+03
SMP-1	5.30E+02	4.0E+02

^a Uncertainty is given as ± 2 standard deviations.

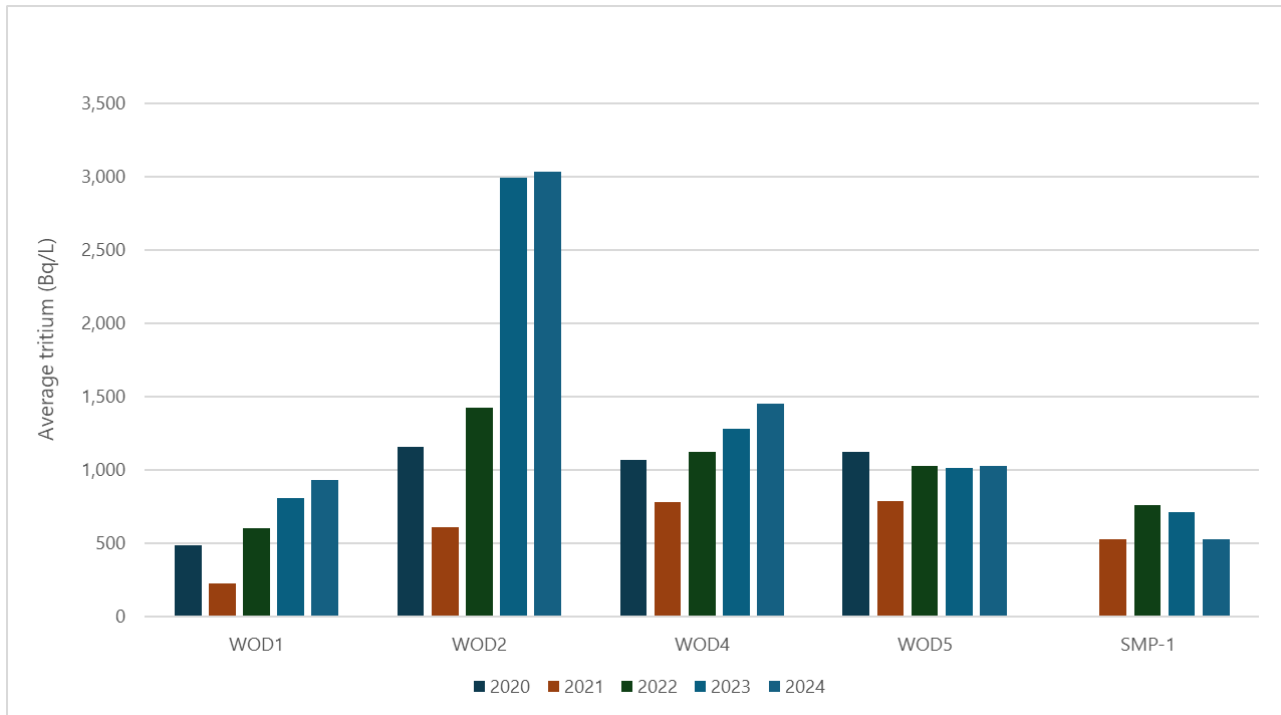


Figure 2-11: 2020-2024 Average Annual Tritium at Surface Water Sampling Locations in South Railway Ditch (WOD1-5) and East Stormwater Management Pond (SMP-1)

2.3.5 Supplementary Sampling of Water and Sediment in South Railway Ditch, West Ditch, Wetland and East Stormwater Management Pond

As previously noted in Section 2.2.6, additional sampling may occur, as required, in support of future iterations of the NSS-WWMF's environmental risk assessment (ERA). In 2024, additional water and sediment sampling was conducted within the SRD, the WD, the Wetland and the East Stormwater Management Pond. As previously noted, detailed results of these supplementary field studies will be provided in the next iteration of the NSS-WWMF ERA. For further information regarding past sampling programs conducted at these locations in support of the 2021 NSS-WWMF ERA, the reader is referred to the 2022 NSS-WWMF EMP report (OPG, 2024).

2.3.6 Passive C-14 Sampling

Twenty (20) passive monitors are used to measure C-14 in air at the NSS-WWMF on a quarterly basis. Quarterly and annual results from the passive monitors are shown in Table 2.6. Figure 2-12 shows all quarterly measurements from 2023 and 2024. All passive monitors were analyzed for statistically significant trends over the last five years (Q1 2020 – Q4 2024) at the 95% significance level using the Mann-Kendall Test (Zaiontz, 2025). The analysis did not identify any statistically significant ($p < 0.05$) upward trends for any of the passive monitors over the specified time period; however, statistically significant downward trends were identified for passive samplers #1, #2, #3, #4, #5, #8 and #12.

As the passive C-14 samplers are located near the IC-18s, results can sometimes demonstrate a high degree of variability at times when an IC is opened near a sampler; thus, to limit the influence of opened ICs on passive C-14 sample results, Figure 2-13 shows annual C-14 concentrations, averaged across each of the three distinct sampling areas, over the last five years between 2020 and 2024. Despite the elevated C-14 concentrations seen in Area 2 in 2022, which was likely attributed to the opening of numerous IC lids in Q2 of that year (OPG, 2024), average annual C-14 concentrations across the three sampling areas appear to be relatively comparable, and have decreased since 2022.

The elevated concentrations of C-14 at IC-18s are attributed to the storage of spent moderator ion exchange (IX) resin and are subsequently investigated separately. C-14 concentration in air is highest in Area 1 (samplers 1-9), and in Area 2 (samplers 10-15). The highest C-14 concentrations (Figure 2-12) measured between 2023 and 2024 occurred in Area 1 at samplers #6 and #9 (see Figure 2-6). Between April and May 2024, spacers and scrubbers were installed at three IC-18s located between samplers #6 and #9. Another two IC-18s were opened in late May to accommodate the storage of additional resin liners. The opening of IC-18 units is associated with the increase in C-14 measured in Q2 of 2024; furthermore, the addition of resin liners contributes to the temporary elevated release of C-14 in the immediate area of the #6 and #9 samplers.

Figure 2-14 shows C-14 concentrations from the Bruce Power passive air sampler located closest to the IC-18s (i.e., B#3) and one representing background (i.e., B#13) for comparison. Between

2020 and 2024, no statistically significant trends were noted with the Mann-Kendall Test based on the annual averages of C-14 at the NSS-WWMF for samplers B#3 (Near IC-18) and B#13 (background). In Figure 2-14, the average annual C-14 concentration at sampler B#3 appears elevated due to an abnormally high measurement of 71,200 Bq/Kg C during Q3 of 2024. This measurement was noted to not correlate with results at the nearby Stage 6 IC-18s (Area 2). To investigate further, grass and weeds were sampled near sampler B#3 in Q3 2024 and the C-14 concentration was measured to be 26,972 Bq/Kg C, a result that is more in line with historic results. Therefore, the Q3 2024 measurement recorded for sampler B#3 is suspected to be an error. However, no QA/QC issues were reported during sampling or laboratory analysis, so OPG cannot verify this claim. In response, an additional sampler has been placed beside B#3 to act as a duplicate starting in Q2 2025.

Table 2.6: 2024 C-14 Passive Air Sampling Results

Location	Q1 (Bq C-14 /kgC)	Q2 (Bq C-14 /kgC)	Q3 (Bq C-14 /kgC)	Q4 (Bq C-14 /kgC)	Annual Average (Bq C-14 /kgC)	Uncertainty ^a (Bq C-14 /kgC)	Annual Average (Bq/m ³)	Uncertainty ^a (Bq/m ³)
Area 1 : Phase I-III								
#1	4.96E+04	3.35E+04	1.17E+04	2.41E+04	2.97E+04	3.20E+04	6.54E+00	7.03E+00
#2	6.22E+04	3.90E+04	1.55E+04	4.71E+04	4.10E+04	3.90E+04	9.01E+00	8.58E+00
#3	3.80E+04	3.62E+04	1.25E+04	1.92E+04	2.65E+04	2.52E+04	5.82E+00	5.54E+00
#4	5.66E+04	4.65E+04	1.44E+04	3.13E+04	3.72E+04	3.68E+04	8.18E+00	8.10E+00
#5	3.23E+04	8.19E+04	1.73E+04	1.73E+04	3.72E+04	6.13E+04	8.18E+00	1.35E+01
#6	1.58E+05	7.87E+05	2.81E+04	7.03E+04	2.61E+05	7.10E+05	5.74E+01	1.56E+02
#7	1.16E+05	8.06E+04	2.68E+04	8.52E+04	7.72E+04	7.41E+04	1.70E+01	1.63E+01
#8	6.63E+04	7.30E+04	1.95E+04	5.26E+04	5.29E+04	4.76E+04	1.16E+01	1.05E+01
#9	1.67E+05	9.99E+05	3.34E+04	5.74E+04	3.14E+05	9.20E+05	6.91E+01	2.02E+02
Area 2 : Stage 6								
#10	3.59E+05	1.59E+05	5.95E+04	2.13E+05	1.98E+05	2.50E+05	4.35E+01	5.50E+01
#11	6.42E+04	8.60E+04	1.46E+04	1.72E+04	4.55E+04	7.07E+04	1.00E+01	1.55E+01
#12	2.68E+05	1.37E+05	5.31E+04	8.15E+04	1.35E+05	1.91E+05	2.97E+01	4.19E+01
#13	1.71E+05	5.54E+04	1.64E+04	6.98E+04	7.82E+04	1.32E+05	1.72E+01	2.90E+01
#14	3.79E+04	1.04E+04	3.67E+03	1.46E+04	1.66E+04	2.97E+04	3.66E+00	6.54E+00
#15	1.63E+05	1.11E+05	5.79E+04	1.03E+05	1.09E+05	8.62E+04	2.39E+01	1.90E+01
Area 3 : Batch 5								
#16	8.21E+03	5.34E+03	2.66E+03	6.23E+03	5.61E+03	4.61E+03	1.23E+00	1.01E+00
#17	8.03E+03	3.31E+03	4.97E+03	5.37E+03	5.42E+03	3.91E+03	1.19E+00	8.60E-01
#18	4.42E+03	3.26E+03	2.22E+03	4.71E+03	3.65E+03	2.28E+03	8.04E-01	5.03E-01
#19	8.17E+03	3.72E+03	2.29E+03	3.95E+03	4.53E+03	5.07E+03	9.97E-01	1.11E+00
#20	3.62E+03	2.67E+03	1.49E+03	3.21E+03	2.75E+03	1.85E+03	6.04E-01	4.07E-01

Note: ^a Uncertainty is given as ±2 standard deviations.

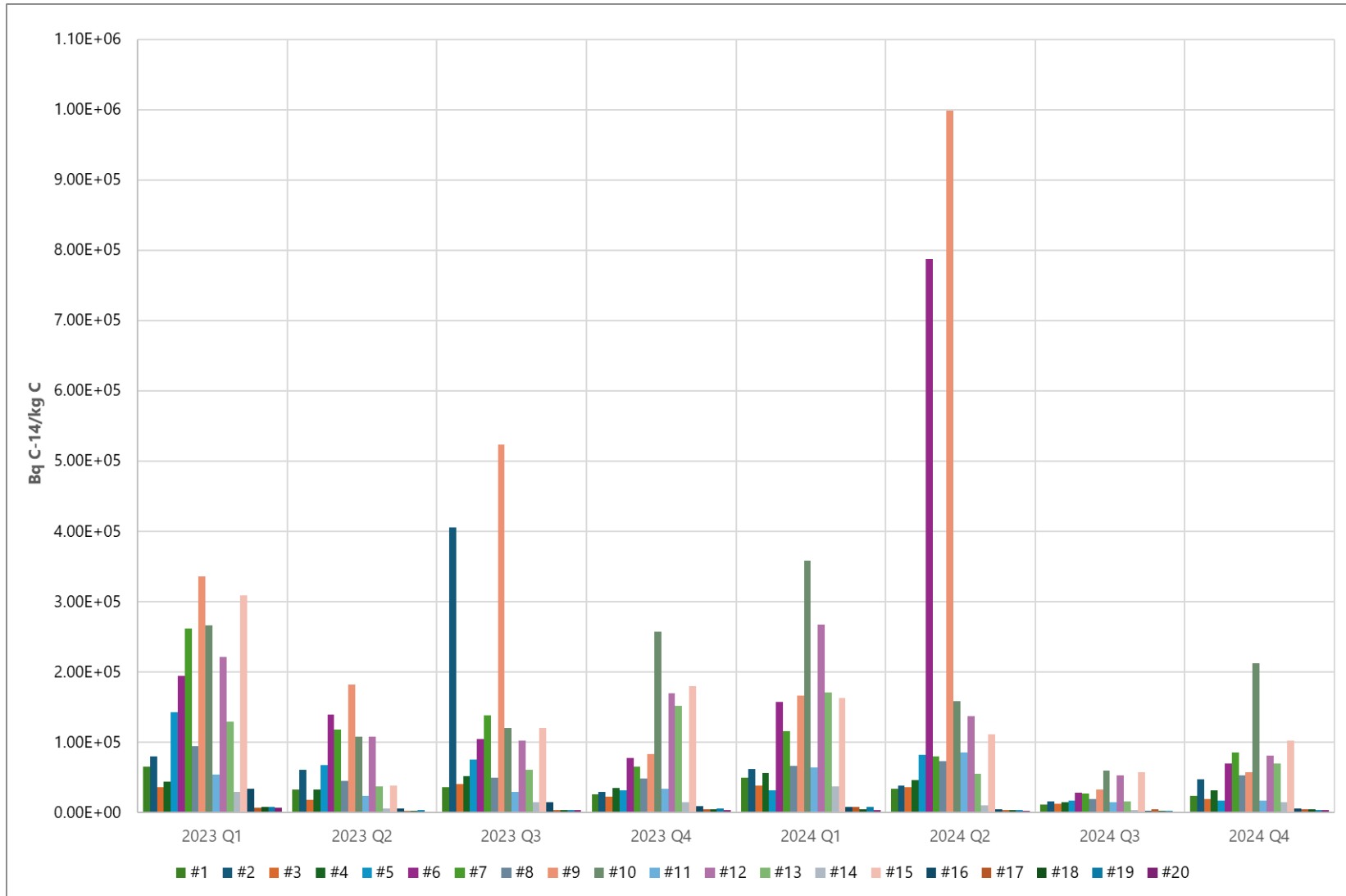


Figure 2-12: 2023 and 2024 C-14 Concentration at the Passive Air Samplers by Quarter

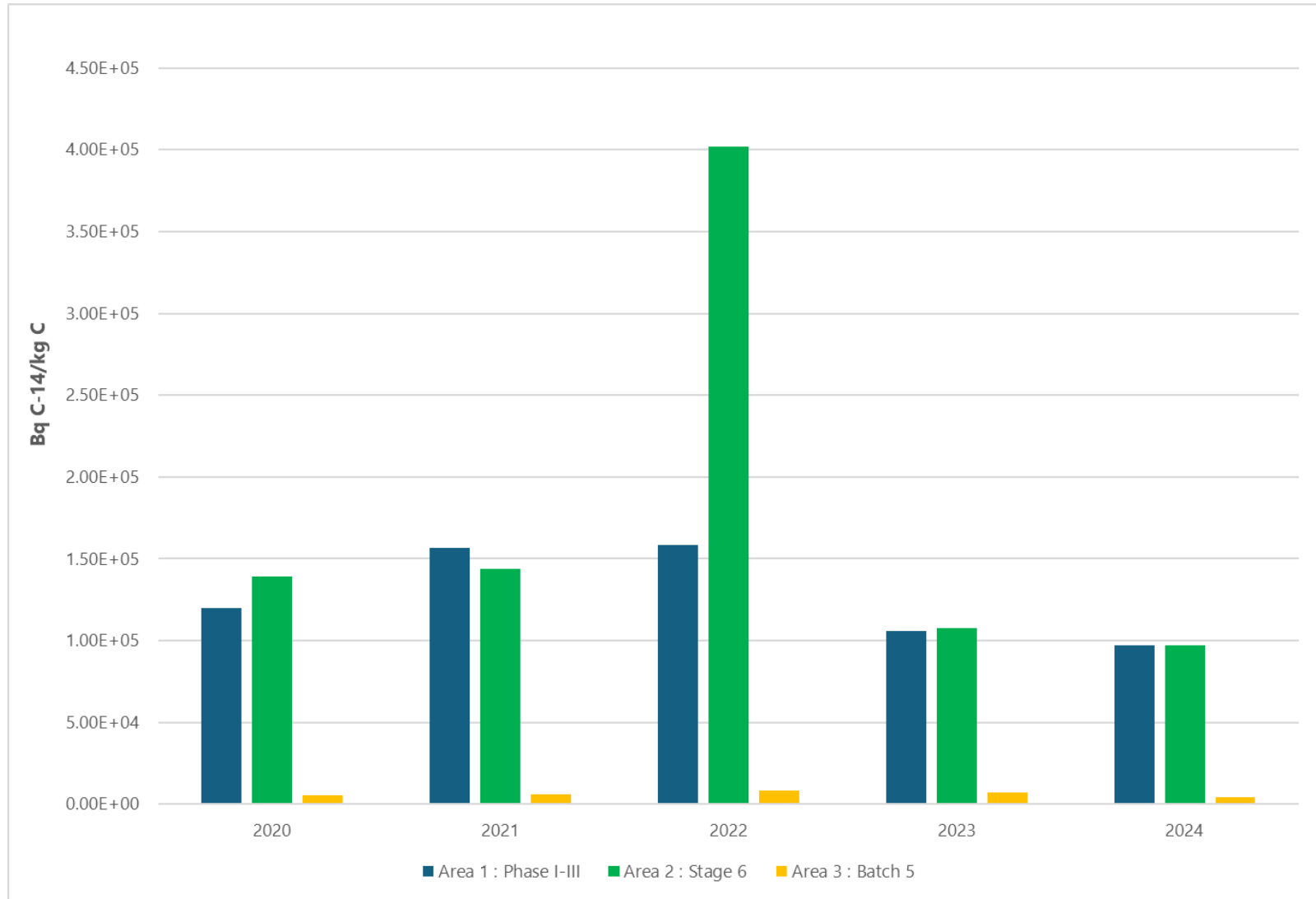


Figure 2-13: Annual Average C-14 Concentration by Sampling Area (2020-2024)

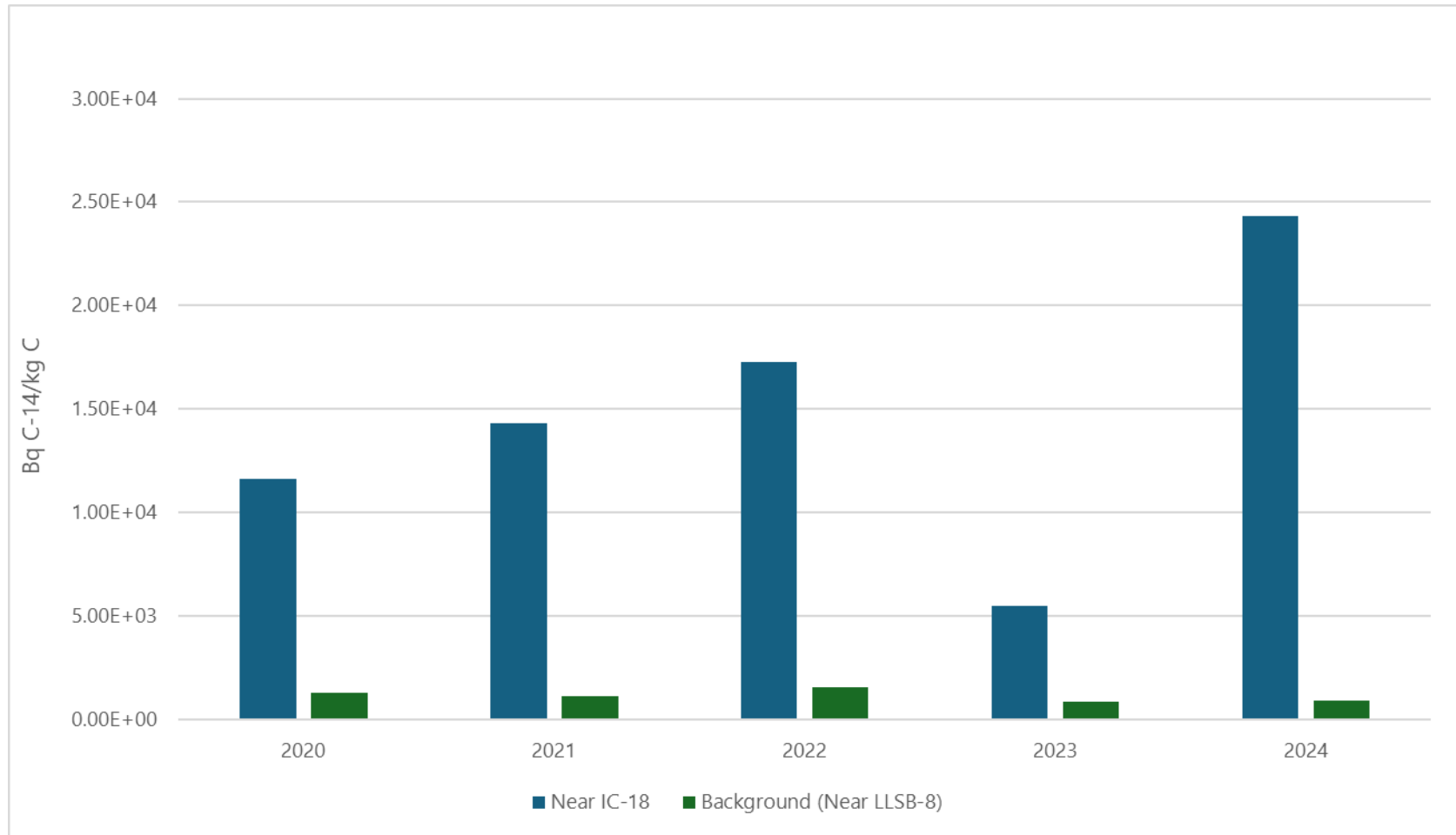


Figure 2-14: 2020-2024 C-14 Average Annual Concentration at NSS-WWMF for Samplers B#3 (Near IC-18) and B#13 (Background)

3.0 Radiological Dose to the Public

One NSS-WWMF EMP objective is to demonstrate that the radiological risk to the public from the operation of NSS-WWMF is low and any potential dose to the public is below the regulatory dose limit of 1 mSv/a. Non-NEWs on site may be exposed to direct/in-direct radiation from NSS-WWMF facilities or RWOS 1. The regulatory dose limit for these workers is the same as for members of the public. OPG has also committed to keeping levels of tritium in drinking water, due to operation of OPG facilities, below 100 Bq/L on an annual average basis at nearby WSPs.

3.1 Public Radiological Dose Estimation Results

As discussed in Section 2.2.1, the calculated public radiological dose based on measurements of radioactivity in environmental media outside the Bruce nuclear site is the result of public exposure to the combined emissions of all facilities on the Bruce nuclear site.

3.1.1 Basis for Calculation of Dose to Members of the Public

Bruce Power calculates the public radiological dose to the various surrounding population groups most likely to receive the highest doses. These groups are referred to as the potential critical groups. The methodology used follows the guidance provided in CSA N288.1-20 (BP, 2025). Public dose is calculated using mostly measured concentrations of radionuclides in the environment, exposure pathways for the identified potential critical groups, and critical group characteristics. Important pathways and group characteristics were determined by a pathways analysis and a site-specific survey. Further information on how Bruce Power determines public dose can be found in Bruce Power's annual environmental report (BP, 2025).

3.1.2 Public Dose from NSS-WWMF Operations

Bruce Power reported the maximum annual public dose to be 1.1 μ Sv to the Bruce Subsistence Farmer (Adult) in 2024 based on results from their 2024 EMP (BP, 2025). This is approximately three orders of magnitude below the public dose limit of 1 mSv/a (or 1,000 μ Sv/a). The public dose arising from NSS-WWMF operations is a portion of the 1.1 μ Sv value. Thus, the dose to members of the public from NSS-WWMF operations is well below the regulatory limit.

3.2 Tritium Levels at Nearby Water Supply Plants

The WSPs influenced by NSS-WWMF emissions are the same as those monitored by Bruce Power in their EMP; that is, the Kincardine WSP and the Southampton WSP. For 2024, Bruce Power reported that the annual average tritium in drinking water at these WSPs was 3.8 Bq/L at the Kincardine WSP and 12.6 Bq/L at the Southampton WSP (BP, 2025). These values are well below the Ontario Drinking Water Standard (ODWS) for tritium of 7,000 Bq/L, and meet OPG's commitment to keep these levels below 100 Bq/L on an annual average basis.

3.3 Direct Gamma Radiation Exposure

The NSS-WWMF facilities, including the UFDSF and RWOS 1 are relatively far from the Bruce nuclear site boundaries. Gamma radiation and skyshine from the NSS-WWMF facilities is attenuated to a very large degree at and beyond the site boundaries and does not contribute significantly to public dose. The gamma dose and skyshine were measured at the RWOS 1 and NSS-WWMF facility boundaries (see Section 2.3.2) to ensure that non-NEWs did not receive doses that exceed the regulatory limit. The TLD measurements for 2024 showed that doses at all locations around the facility boundaries were around 0.1 $\mu\text{Gy/h}$, compared to the derived dose rate target of 0.5 $\mu\text{Gy/h}$.

3.4 Radiation Dose from C-14 in Air

Dose related to C-14 emissions is expected to be negligible for human and non-human receptors. Using an average C-14 concentration in air at the IC-18s (Figure 2-14) from 2024 of 2.43×10^4 Bq/kg-C, the dose in a worst-case scenario to a non-NEW worker at the fence line of the NSS-WWMF can be estimated. In the case of 8-hour occupancy year-round, the expected dose due to C-14 inhalation is estimated to be 0.08 $\mu\text{Sv/a}$. This is well below the dose limit for a non-NEW of 1,000 $\mu\text{Sv/a}$.

Sampling close to the IC-18s found that the concentration of C-14 in grass is comparable to the concentration in air on a Bq/kg-C basis. From this, the dose to non-human biota (grasses) in the immediate vicinity of the C-14 emission was estimated. Calculated dose rates to grasses were determined to be 1.65×10^{-3} mGy/day, well below the terrestrial dose benchmark of 2.4 mGy/day (CSA, 2012; UNSCEAR, 2008).

3.5 Discussion of Results

All direct and indirect estimations of radiological dose to members of the public, including non-NEWs on-site, produced results well below regulatory limits. Additionally, the tritium levels at WSPs were well below the OPG commitment level of 100 Bq/L. These results indicate that the NSS-WWMF is meeting its EMP objectives in these areas. Radiological airborne emissions and liquid effluent releases from facilities situated on the Bruce Nuclear site were obtained from the 2024 Bruce Power EMP (BP, 2025), and are presented below in Table 3.1.

Table 3.1: 2024 Radiological Emissions from Bruce Nuclear Site Facilities (Bq/year)

Parameter	Bruce A	Bruce B	CMF	CSF	NSS-WWMF ^b	CNL	Kinectrics KI ^c	Total	% NSS-WWMF
Airborne Emissions (Bq/year)									
Tritium Oxide	3.2E+14	3.7E+14	3.9E+09	1.8E+12	1.4E+13	4.0E+11	1.6E+11	7.1E+14	2.0%
Noble Gas (Bq-MeV/yr)	6.2E+13	2.5E+13	NA	NA	NA	NA	NA	8.7E+13	NA
Iodine-131	1.4E+05	1.5E+05	0.0E+00	NA	4.5E+03	NA	NA	2.9E+05	1.5%
Particulate Beta/Gamma^a	2.0E+06	7.4E+06	0.0E+00	0.0E+00	1.8E+03	1.2E+05	NA	9.5E+06	0.02%
Particulate-Gross Alpha	1.3E+04	3.7E+04	4.0E+02	NA	NA	NA	NA	5.0E+04	NA
Carbon-14	1.2E+12	9.2E+11	NA	NA	5.3E+09	NA	NA	2.1E+12	0.25%
Waterborne Effluent (Bq/year)									
Tritium Oxide	3.5E+14	1.1E+15	NA	NA	NA	2.4E+10	NA	1.5E+15	NA
Carbon-14	1.2E+10	4.9E+09	NA	NA	NA	NA	NA	1.7E+10	NA
Gross Beta/Gamma	1.4E+09	3.9E+09	NA	NA	NA	NA	NA	5.3E+09	NA
Gross Beta	NA	NA	NA	NA	NA	1.5E+07	NA	1.5E+07	NA
Gross Alpha	2.4E+05	3.3E+05	NA	NA	NA	1.2E+07	NA	1.2E+07	NA

Notes:

- a) Naturally occurring radionuclide material detected in gamma spectrum analysis is not reported.
- b) Beginning in January 2021, waterborne emissions from the NSS-WWMF are no longer reported under the effluent monitoring program since surface discharge is stormwater and subsurface discharge is groundwater. Effluent from the NSS-WWMF is not released into the stormwater system – any tritium in stormwater is from atmospheric deposition.
- c) This is the net airborne emission from KI North Facility for the period of December 31, 2023 to December 30, 2024.
- d) Beginning in January 2021, waterborne emissions from the NSS-WWMF are no longer reported under the effluent monitoring program since surface discharge is stormwater and subsurface discharge is groundwater. Effluent from the NSS-WWMF is not released into the stormwater system – any tritium in stormwater is from atmospheric deposition.

<Ld = less than limit of detection

NA = Emissions not reported for the specified parameter and facility

4.0 Quality Assurance and Performance

The NSS-WWMF EMP design report recommends that a QA/QC program for the NSS-WWMF EMP be implemented and that it should be based on OPG's existing EMP QA manual (for Darlington and Pickering EMPs) (OPG, 2016), with adjustments for the specific characteristics of the NSS-WWMF site and operations. The program would encompass all activities including field sample collection, laboratory analysis, laboratory quality control, and external laboratory intercomparison. The objectives would include ensuring that EMP samples are representative, and their analytical results are accurate, as well as complying with procedures and program quality requirements. This section provides an overview of quality assurance activities.

4.1 Laboratory Quality Assurance and Quality Control

The OPG HPL has a QA/QC program that includes measurement of environmental TLDs. The system uses TLD-100H LiF dosimeters capable of measuring gamma dose down to ambient environmental levels. These are suitable for the intended purpose. Part of the QA program includes sending sixteen (16) dosimeters every quarter to the National Research Council of Canada (NRCC), where they are irradiated to two known and different levels of exposure and must achieve a mean relative bias less than $\pm 30\%$ and a coefficient of variation less than 0.35. In addition, the sum of the mean relative bias (as a fraction) and the coefficient of variation is required to be less than 0.50. For 2024, the OPG EGM system met these accuracy and precision requirements. Results of the HPL QA testing for 2024 were satisfactory and are documented in its annual QA report (OPG, 2025c).

The OPG HPL has a commitment to perform a minimum of one annual independent audit of the quality system used for dosimetry and environmental measurement services. These may not always be related to the EMPs. In 2024, an HPL QA audit was conducted on the Health Physics Laboratory's ISO 17025 accredited Gross Alpha/Beta in Water Method. The audit involved a review of relevant documentation, HPL staff interviews, and work performance observations.

The Health Physics Laboratory identified no significant adverse conditions through the audit. However, the audit identified five (5) recommendations and three (3) findings which will be addressed by updating procedures, performing further assessments, and implementing process improvements. The findings of the audit are tracked via Station Condition Record (SCR) N-2025-01384 and AR 28272574.

In 2024, the MECP performed Drinking Water Licence Inspections of OPG's HPL between the 15th and 18th of June (unannounced), and between the 21st and 30th of October (announced). There were no non-compliant findings during either of the inspections, and final inspection ratings of 100% were given in both cases. The details of the unannounced June inspection can be reviewed under N-CORR-03443-00004, and details of the announced October inspection can be viewed under N-CORR-03443-1424935 (OPG, 2025c).

In 2023, the Canadian Association of Laboratory Accreditation (CALA) conducted an audit of the HPL between the 14th and 16th of November to assess accreditation of analyses performed for the EMP (see N-CORR-03443-1348108). As this audit runs on a 2-year cycle, there was no CALA audit performed in 2024.

Environmental tritium and gross β analysis in water samples are performed for the NSS-WWMF by the Bruce Power Health Physics laboratory. The Bruce Power Health Physics Lab operates a comprehensive QA program in accordance with ISO 14001, which includes quality control samples, blank/background samples, process control samples and externally generated proficiency testing samples. QA/QC results for testing relevant to the groundwater and surface water sample analyses, that is, HTO and gross β activity in water, met all requirements, including accuracy and precision requirements as per external laboratory testing.

4.2 Program Quality Assurance

EMP QA includes self-assessments and audits as per the requirements of CSA N288.4-10 (CSA, 2010) and OPG procedures. In 2024, OPG's Nuclear Oversight group conducted an audit of the NSS-WWMF, Darlington Nuclear, and Pickering Nuclear EMPs.

The audit of the EMP identified that the managed system controls are "Generally Effective". Furthermore, the audit identified one narrowly focused concern (Finding #1) related to the NSS-WWMF EMP; specifically, it was determined that the Nuclear Environment EMP did not fully incorporate NSS-WWMF's EMP processes into several Nuclear Environment documents. It was noted that the potential cause of Finding #1 may relate to inadequate reinforcement of change management processes and insufficient incorporation of the NSS-WWMF EMP processes into the established documentation framework to ensure the integration was fully completed. This deficiency was found to have no impact on NSS-WWMF deliverables or reporting, but represents a weakness in governance of the NSS-WWMF EMP which, if unresolved, may potentially lead to non-conformance with CSA N288.4 requirements. Follow up actions to address Finding #1 are being tracked through AR 28267922.

Additionally, the audit identified six (6) insights which are being tracked under ARs 28267537 and 28267407.

4.2.1 Self-assessments

4.2.1.1 Performance Assessment

The most recent self-assessment was completed for the 2023 NSS-WWMF EMP Annual Performance Assessment (NO25-000072-SA). The assessment confirmed that all EMP design objectives were met and the results of the 2023 NSS-WWMF EMP indicated adequate protection

of the public, workers, and the environment. No necessary revisions to the NSS-WWMF EMP were identified.

4.3 Program Performance

4.3.1 Sample Unavailability

Table D.1 (Appendix D) provides a summary of samples collected, the monitoring period and deviations from the Plan during the 2024 EMP for all media.

TLD deployment and analysis and groundwater sampling and analysis are done on a planned schedule. All data were examined to determine the unavailability for 2024. Unavailability is the fraction of the total planned samples that were missed or produced invalid results. The NSS-WWMF does not currently have unavailability targets for EMP samples.

A total of 252 TLD samples were planned for 2024, consisting of quarterly samples at seven locations at RWOS 1, quarterly samples at 20 locations at the NSS-WWMF/LILW storage area, quarterly samples at 16 locations at the NSS-WWMF/UFDSF Buildings 1-4 and 20 quarterly samples (starting in Q2 2022) at the UFDSF Buildings 5-6. All but one of the 252 results were obtained and valid, producing an overall unavailability of 0.4% (1 missing reading out of a planned 252 readings). In Q1 of 2024, no reading was recorded for TLD 28 located at the WLILWSF as this TLD was reported to be damaged (OPG, 2025a).

Table E.1 (Appendix E) shows the numbers of planned and actual samples and analyses for the groundwater and ditch surface water monitoring components of the EMP, and the unavailability for these. The 2024 groundwater monitoring plan collected 110 of the planned 110 samples and had an overall unavailability of 0%.

A total of 80 C-14 samples were planned for 2024, consisting of quarterly samples at 20 locations at the NSS-WWMF. 80 of the planned 80 results were obtained and valid (see Table 2.6), producing an overall unavailability of 0%.

5.0 Overall Summary of EMP

An EMP detailed design was developed for the NSS-WWMF in 2012 (AMEC, 2012) with updates made in 2019 (OPG, 2019). All objectives of the EMP concerning public and worker safety and demonstrating containment of radioactivity were met in 2024. Operation of the NSS-WWMF resulted in extremely low public dose, well below regulatory limits. The potential exposure of non-NEWs near NSS-WWMF facilities to gamma radiation and skyshine was low and well within the derived dose rate target. Concentrations of tritium at nearby WSPs were below 100 Bq/L on an annual average basis (Objectives 1 and 6).

Measurements of TLDs around the NSS-WWMF and RWOS 1 (Objective 2) are below the derived dose rate target of 0.5 $\mu\text{Gy/h}$. Despite an increasing trend in eight locations, the highest dose rate measured was 0.275 $\mu\text{Gy/h}$ and no effects are expected due to this exposure.

Bedrock aquifer groundwater sampling (Objective 3) indicated that there were no significant releases of radioactivity to groundwater travelling offsite. Eight (8) wells at the NSS-WWMF showed statistically significant increasing trends in tritium. Of these wells, WSH230 (annual average 819 Bq/L) and WSH282 (annual average 632 Bq/L) had concentrations above 500 Bq/L, the value used for comparative purposes to highlight groundwater wells with tritium concentrations that are outside the range of what is typically expected across the NSS-WWMF and RWOS 1 sites.

Previously elevated tritium levels in one area of the MSA have steadily decreased since 2009. Remedial measures taken to reduce tritium in groundwater have been effective. A statistically significant decrease in tritium concentrations in groundwater at WSH 231 was identified for the period 2020 to 2024. Comparing to the Ontario Drinking Water Quality Standards for tritium (7,000 Bq/L), there is currently no evidence of unacceptable levels of radioactivity leaving the site either in surface water or groundwater. The groundwater monitoring program has been updated to meet CSA N288.7 and implementation was initiated in 2022. Results of this program have been reported in this document and are additionally reported in a separate NSS-WWMF Annual Groundwater Report, which is compliant with CSA N288.7.

Monitoring in the SRD (Objective 4) is completed as part of routine sampling. Surface water in the SRD and East Stormwater Management Pond is monitored quarterly. The supplementary study conducted in 2013, concluded that the NSS-WWMF runoff/groundwater has a negligible influence on tritium concentrations and found no statistically significant trends. A statistically significant increasing trend in tritium concentrations was detected at WOD1, WOD2, and WOD4 between 2020 and 2024. However, tritium concentrations in the SRD and East Stormwater Management Pond are known to fluctuate annually; this is hypothesized to occur because of changes in surface water dilution from differing weather conditions and water table levels. No other statistically significant trends were observed in the monitored locations for 2020-2024.

Additional water and sediment sampling was conducted in the SRD, the WD, Wetland and East Stormwater Management Pond areas of the NSS-WWMF (Objective 5) in 2024 in support of the

upcoming NSS-WWMF ERA update. Details of previously completed sampling programs can be found in the 2022 NSS-WWMF EMP report (OPG, 2024).

Increasing C-14 concentration in air at the NSS-WWMF has been attributed to moderator exchange resin stored in Area 1. Scrubbers were installed in select ICs in 2021, 2022, 2023 and 2024 to reduce the amount of fugitive emissions to help mitigate this trend. Despite these emissions, both environmental and health physics monitoring confirm that there is no significant impact on workers, the public, or the environment (Objective 7). OPG will continue monitoring and reporting C-14 concentrations using the existing C-14 passive samplers.

Overall, the results of the 2024 NSS-WWMF EMP indicate confirmation of adequate protection of the public, on-site workers, and the surrounding environment.

6.0 Outlook for EMP

Ongoing implementation of the EMP design will be continued. Some additional work to address existing areas of uncertainty will also be planned. Areas that will be addressed are:

- **Surface Water:** The SRD routine and supplementary studies indicated little impact from the NSS-WWMF, with levels remaining within the range of findings in previous years. The routine tritium sampling in the SRD and East Stormwater Management Pond will continue. A supplementary study to collect water and sediment data for non-radionuclides was completed in 2020-2021 in support of the 2021 NSS-WWMF ERA update and is currently being repeated in advance of the 2026 ERA update. Additionally, the sampling frequency for tritium at WOD2 has been increased from quarterly to monthly.
- **Wetland sampling:** The East Wetland was sampled in 2020-2021 as part of supplementary studies to support the 2021 NSS-WWMF ERA and is currently being repeated in advance of the 2026 ERA update.
- **C-14 monitoring in air:** C-14 monitoring will continue indefinitely into the future, with a focus on investigating the upward trend close to the IC-18s. Scrubbers were installed in select ICs in 2021, 2022, 2023 and 2024. Subsequent results should indicate if this mitigation is sufficient to address the recently observed upward trend. Furthermore, as of Q2 2025, an additional sampler has been placed beside B#3 to act as a duplicate sample to further investigate the validity of the elevated C-14 measurement recorded in Q2 2024.

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Appendix A Radiological Units and Conversions

Absorbed Dose

1 gray (Gy) = 1 joule/kg

Effective Dose

1 sievert (Sv) = 100 rem
1 millisievert (mSv) = 100 millirem (mrem)
1 microsievert (μ Sv) = 0.1 millirem (mrem)

Quantity of Radionuclide

1 becquerel (Bq) = 1 disintegration per second
1 curie (Ci) = 3.7×10^{10} Bq
1 mCi/(km²·month) = 37 Bq/(m²·month)

Appendix B Glossary of Acronyms and Symbols

Radionuclides and Units of Measure

C-14	Carbon-14
HTO	Tritium Oxide
Gross α	Gross Alpha
Gross β	Gross Beta
μ Gy	microgray
μ Sv	microsievert
Bq	becquerel
Gy	Gray
kg	kilogram
L	Litre
mGy	milligray
mSv	millisievert
Sv	Sievert

Acronyms and Abbreviations

AECL	Atomic Energy of Canada Limited
CMF	Central Maintenance Facility
CNL	Canadian Nuclear Laboratories
CNSC	Canadian Nuclear Safety Commission
COPC	Contaminant of Potential Concern
CSA	Canadian Standards Association
CSF	Central Storage Facility
DPWF	Douglas Point Waste Facility
DRL	Derived Release Limit
EGM	Environmental Gamma Monitors
EMP	Environmental Monitoring Program
EMS	Environmental Management System
EPA	Environmental Protection Agency
ERA	Environmental Risk Assessment
HPL	OPG Health Physics Laboratory
HU	Hydrostratigraphic Unit
IAEA	International Atomic Energy Agency
ICs	In-ground storage containers
IC-12	12 m ³ capacity ICs
IC-18	18 m ³ capacity ICs
ISO	International Organization for Standardization

KM	Kaplan-Meier Estimation Method
Lc	Critical Level
Ld	Limit of Detection
LILW	Low and Intermediate Level Waste
LLSB	Low Level Storage Building
MECP	Ontario Ministry of the Environment, Conservation and Parks
MSA	Middle Sand Aquifer
NEW	Nuclear Energy Worker
NGS	Nuclear Generating Station
NRCC	National Research Council of Canada
NSS-WWMF	Nuclear Sustainability Services – Western Waste Management Facility
ODWS	Ontario Drinking Water Standards
OPG	Ontario Power Generation
QA	Quality Assurance
QC	Quality Control
QOR	Quarterly Operations Report
RCSB	Retube Component Storage Building
RWOS 1	Radioactive Waste Operations Site 1
SCR	Station Condition Record
SD	Standard Deviation
SGSB	Steam Generator Storage Building
SMP-1	East Stormwater Management Pond
SRD	South Railway Ditch
SSTF	Spent Solvent Treatment Facility
TLD	Thermoluminescent Dosimeter
TOC	Total Organic Carbon
TPMB	Transportation Package Maintenance Building
UFDSF	Used Fuel Dry Storage Facility
WD	West Ditch
WLILWSF	Western Low and Intermediate Level Waste Storage Facility
WSH	Water Sampling Hole
WSP	Water Supply Plant
WVRB	Waste Volume Reduction Building

Appendix C Tritium in Groundwater 2020-2024

This appendix contains the plots of tritium with statistically significant increases over the 5-year period 2020-2024. All datasets were analyzed for the presence of statistically significant trends using the Mann-Kendall test in the Microsoft Excel Real Statistics package. The results of the trend analyses are reported in Section 2.3.3.

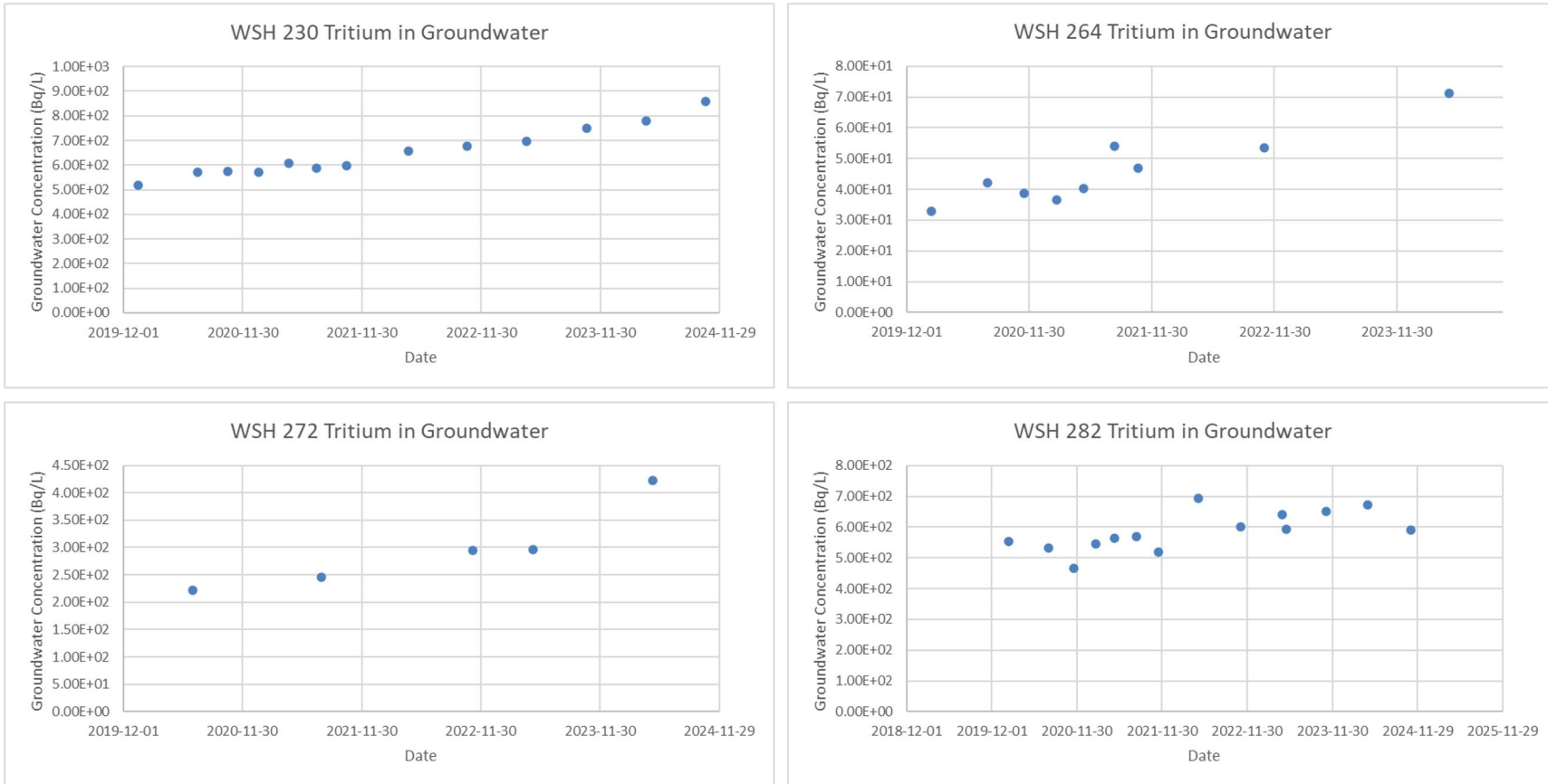


Figure C-1: Measured Tritium in Groundwater Wells with Statistically Significant Increasing Trends

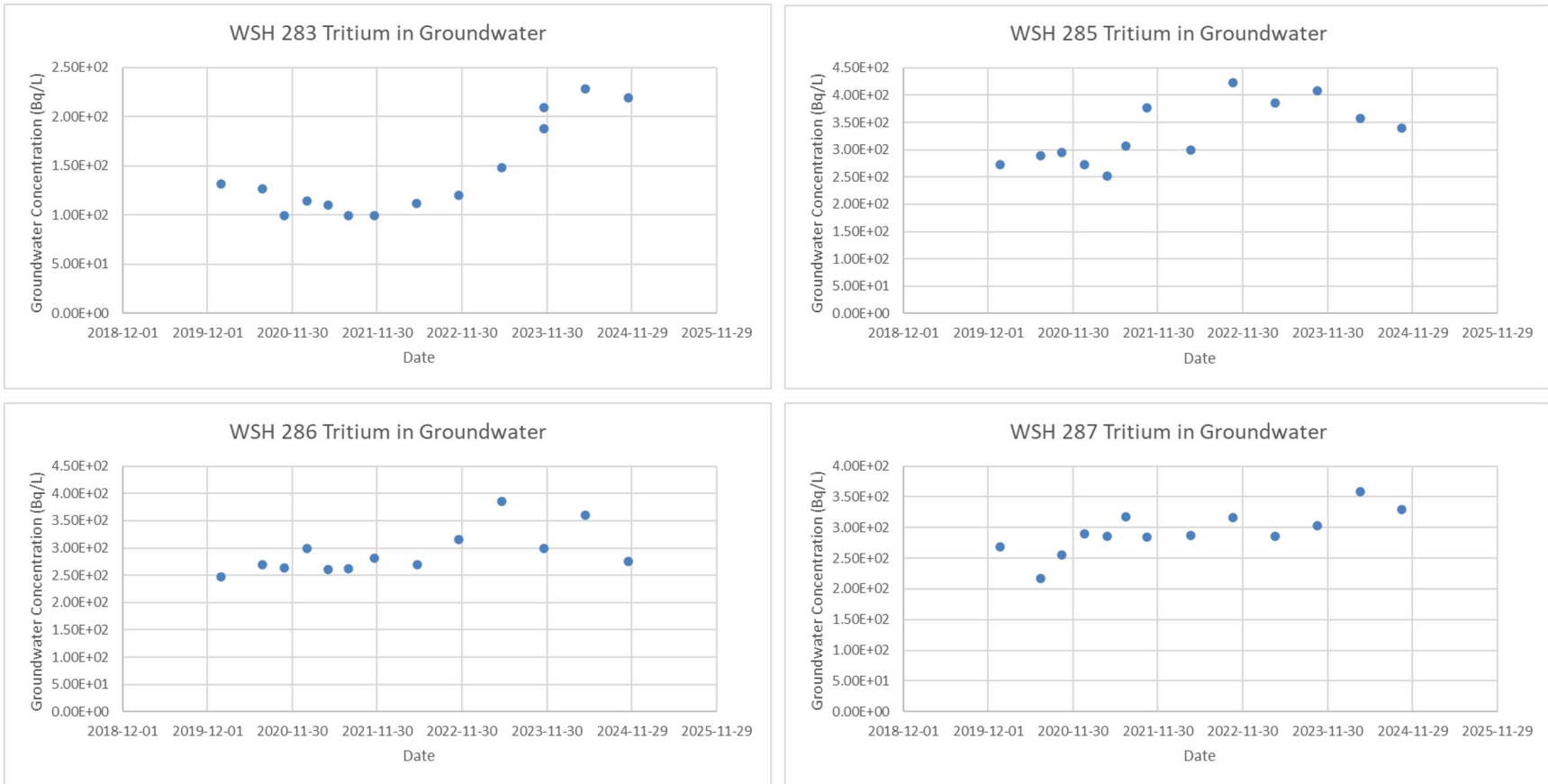


Figure C-2: Measured Tritium in Groundwater Wells with Statistically Significant Increasing Trends (Con't)

Appendix D Summary of Samples Collected

Table D.1: Summary of Samples Collected, Monitoring Period and Deviation from the Plan during the 2024 EMP

Sampling Program	Monitoring Results Presented in EMP (all raw data)	Monitoring Period	Deviations from Monitoring Period	Assessment Period
Gamma Radiation Monitoring	Yes	4 quarters of 2024	No (251 of 252 planned readings were obtained)	2024, trend analysis: 2020 - 2024
Groundwater Monitoring	Yes	2024 (wells monitored either annually or bi-annually)	No	2024, trend analysis: 2020 - 2024
SRD	Yes – (presented average and 2 sigma for each measurement station consistent with the 2021, 2022 and 2023 EMP). Raw data is not provided in the EMP Report.	2024	No	2024, trend analysis 2020 - 2024
C-14 in air	Yes	2024	No (80 of the 80 planned samples were obtained)	2024, trend analysis 2023 - 2024

Appendix E Groundwater and Ditch Surface Sample Unavailability

Table E.2: 2024 Planned and Actual Samples and Analyses for Groundwater and Ditch Surface Water at NSS-WWMF

	Planned Samples								Total Planned	Total Actual	% Unavailability
	HTO				Gross β						
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4			
RWOS 1											
122	-	1	-	1	-	-	-	-	2	2	0.0
123	-	1	-	1	-	-	-	-	2	2	0.0
124	-	1	-	1	-	-	-	-	2	2	0.0
125	-	1	-	1	-	-	-	-	2	2	0.0
126	-	1	-	1	-	-	-	-	2	2	0.0
NSS-WWMF Semi-Annual											
226	-	1	-	1	-	-	-	-	2	2	0.0
228	-	1	-	1	-	-	-	-	2	2	0.0
229	-	1	-	1	-	-	-	-	2	2	0.0
230	-	1	-	1	-	-	-	-	2	2	0.0
231	-	1	-	1	-	-	-	-	2	2	0.0
240	-	1	-	1	-	-	-	-	2	2	0.0
242	-	1	-	1	-	-	-	-	2	2	0.0
243	-	1	-	1	-	-	-	-	2	2	0.0
253	-	1	-	1	-	-	-	-	2	2	0.0
255	-	1	-	1	-	-	-	-	2	2	0.0
265	-	1	-	1	-	-	-	-	2	2	0.0
269	-	1	-	1	-	-	-	-	2	2	0.0
276	-	1	-	1	-	-	-	-	2	2	0.0
282	-	1	-	1	-	-	-	-	2	2	0.0

2024 RESULTS OF THE ENVIRONMENTAL MONITORING PROGRAM FOR NUCLEAR SUSTAINABILITY SERVICES – WESTERN WASTE MANAGEMENT FACILITY AND RADIOACTIVE WASTE OPERATIONS SITE 1

Appendices

	Planned Samples								Total Planned	Total Actual	% Unavailability
	HTO				Gross β						
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4			
283	-	1	-	1	-	-	-	-	2	2	0.0
284	-	1	-	1	-	-	-	-	2	2	0.0
285	-	1	-	1	-	-	-	-	2	2	0.0
286	-	1	-	1	-	-	-	-	2	2	0.0
287	-	1	-	1	-	-	-	-	2	2	0.0
NSS-WWMF Annual											
224	-	-	-	1	-	-	-	-	1	1	0.0
232	-	-	-	1	-	-	-	-	1	1	0.0
237	-	-	-	1	-	-	-	-	1	1	0.0
238	-	-	-	1	-	-	-	-	1	1	0.0
239	-	-	-	1	-	-	-	-	1	1	0.0
244	-	-	-	1	-	-	-	-	1	1	0.0
245	-	-	-	1	-	-	-	-	1	1	0.0
249	-	-	-	1	-	-	-	-	1	1	0.0
251	-	-	-	1	-	-	-	-	1	1	0.0
252	-	-	-	1	-	-	-	-	1	1	0.0
256	-	-	-	1	-	-	-	-	1	1	0.0
257	-	-	-	1	-	-	-	-	1	1	0.0
259	-	-	-	1	-	-	-	-	1	1	0.0
260	-	-	-	1	-	-	-	-	1	1	0.0
263	-	-	-	1	-	-	-	-	1	1	0.0
264	-	-	-	1	-	-	-	-	1	1	0.0
267	-	-	-	1	-	-	-	-	1	1	0.0
268	-	-	-	1	-	-	-	-	1	1	0.0
270	-	-	-	1	-	-	-	-	1	1	0.0

2024 RESULTS OF THE ENVIRONMENTAL MONITORING PROGRAM FOR NUCLEAR SUSTAINABILITY SERVICES – WESTERN WASTE MANAGEMENT FACILITY AND RADIOACTIVE WASTE OPERATIONS SITE 1

Appendices

	Planned Samples								Total Planned	Total Actual	% Unavailability
	HTO				Gross β						
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4			
272	-	-	-	1	-	-	-	-	1	1	0.0
275	-	-	-	1	-	-	-	-	1	1	0.0
277	-	-	-	1	-	-	-	-	1	1	0.0
278	-	-	-	1	-	-	-	-	1	1	0.0
279	-	-	-	1	-	-	-	-	1	1	0.0
301	-	-	-	1	-	-	-	-	1	1	0.0
302	-	-	-	1	-	-	-	-	1	1	0.0
307	-	-	-	1	-	-	-	-	1	1	0.0
DGRB12	-	-	-	1	-	-	-	-	1	1	0.0
DGRB12A	-	-	-	1	-	-	-	-	1	1	0.0
DGRB14	-	-	-	1	-	-	-	-	1	1	0.0
South Railway Ditch and East Stormwater Management Pond											
WOD1	1	1	1	1	1	1	1	1	8	8	0.0
WOD2	1	1	1	1	1	1	1	1	8	8	0.0
WOD4	1	1	1	1	1	1	1	1	8	8	0.0
WOD5	1	1	1	1	1	1	1	1	8	8	0.0
SMP-1	1	1	1	1	1	1	1	1	8	8	0.0