ONTARIO POWER GENERATION

Report

Public Information	
Document Number: W-REP-03443-00007	Usage Classification: Information
Sheet Number: N/A	Revision: R001

Title:

2022 RESULTS OF THE ENVIRONMENTAL MONITORING PROGRAM FOR NUCLEAR SUSTAINABILITY SERVICES - WESTERN WASTE MANAGEMENT FACILITY AND RADIOACTIVE WASTE OPERATIONS SITE 1

2022 RESULTS OF THE ENVIRONMENTAL MONITORING PROGRAM FOR NUCLEAR SUSTAINABILITY SERVICES - WESTERN WASTE MANAGEMENT FACILITY AND RADIOACTIVE WASTE OPERATIONS SITE 1

W-REP-03443-00007 (R001)

2024-05-17

Order Number: N/A
Other Reference Number:

Public Information

Prepared By:

George Alipanopoulos
Technical Lead
Ecometrix Incorporated

Verified By:

Nicholas Edmunds
Project Manager
Ecometrix Incorporated

Reviewed By:

Rina Parker
Project Principal and Reviewer
Ecometrix Incorporated

Reviewed By:

Lindsay Parks
Environmental Advisor
Nuclear Environment

Reviewed By:

Dwayne Sinclair
Section Manager
Environment Support /NWMD

Reviewed By:

Cammie Cheng
Senior Manager
Environment Projects & EMP

Accepted By:

Raphael McCalla
Director
Nuclear Environment

2022 RESULTS OF THE ENVIRONMENTAL MONITORING PROGRAM FOR NUCLEAR SUSTAINABILITY SERVICES - WESTERN WASTE MANAGEMENT FACILITY AND RADIOACTIVE WASTE OPERATIONS SITE 1

REPORT PREPARED FOR:

ONTARIO POWER GENERATION INC.
700 University Avenue
Toronto, ON M5G 1X6

REPORT PREPARED BY:

Ecometrix Incorporated
www.ecometrix.ca
Mississauga, ON

Ref. 23-3209
17 May 2024

Ecometrix | Environmental INTELLIGENCE

2022 RESULTS OF THE ENVIRONMENTAL MONITORING PROGRAM FOR NUCLEAR SUSTAINABILITY SERVICES - WESTERN WASTE MANAGEMENT FACILITY AND RADIOACTIVE WASTE OPERATIONS SITE 1

George Alipanopoulos
Technical Lead

Nicholas Edmunds
Project Manager

Rina Parker
Project Principal and Senior Advisor

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
R001	2024-05-17	Revised to incorporate: • Land Acknowledgement Revised to correct typo and improve clarity in Section 2.3.7: • R000 states: Mann-Kendall testing identified that C-14 concentrations measured at passive monitor #11 significantly increased from 275,000 Bq C-14 /kgC to 282,000 Bq C-14 /kgC (p=0.0061). • R001 states: Mann-Kendall testing identified that C-14 concentrations measured at passive monitor #11 significantly increased from 123,000 Bq C-14 /kgC in Q1 of 2021 to 282,000 Bq C-14 /kgC in Q4 of 2022 (p=0.0061).
R000	2023-08-04	Initial issue.

EXECUTIVE SUMMARY

Ontario Power Generation (OPG) maintains an environmental monitoring program (EMP) at the Nuclear Sustainability Services – Western Waste Management Facility (NSS-WWMF), formerly known as the Western Waste Management Facility (WWMF). Additionally, OPG maintains the Radioactive Waste Operation Site 1 (RWOS1), 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 2022 program was implemented according to the recommended 2012 design with updates made according to recommendations from the 2019 design update Review, the 2021 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 Environmental Risk Assessments (ERAs), refine the models used, and reduce the uncertainty in the predictions made by these assessments and models.

The 2022 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 effluents from the Bruce A and B Generating Stations. For 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 (NEW) to gamma radiation near NSS-WWMF facilities was shown to be low and well below the derived dose rate limit. 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 sampling indicated that there were no significant increasing trends in radioactivity and no significant releases of radioactivity to groundwater travelling offsite. 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 has been conducted. C-14 activity in air is mainly contributed by the in-ground containers on the NSS-WWMF. 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 2022 NSS-WWMF environmental monitoring program confirm adequate protection of the public, workers, and environment.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 Introduction

Ontario Power Generation (OPG) owns and operates the Nuclear Sustainability Services — Western Waste Management Facility (NSS-WWMF), formerly known as the Western Waste Management Facility (WWMF). Additionally, OPG maintains the Radioactive Waste Operation Site 1 (RWOS1). 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) Regulatory Document – 2.9.1: Environmental Protection: Environmental Protection Policies, Program and Procedures [1]. Additionally, the OPG EMS is registered to the International Organization for Standardization (ISO) 14001 Environmental Management Systems standard.

As part of this program, each OPG Class 1 Nuclear Generating Station and Facility has an Environmental Monitoring Program (EMP), which identifies the contaminants and physical stressors which require monitoring. It also conducts 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" [2].

This report provides the results of the NSS-WWMF EMP for 2022. The report has been prepared in compliance with Clause 11.1 of CSA N288.4-10 [2], 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 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);	Section 2.3
ii) radiation doses calculated as doses to receptors where this is required;	Section 3.0
iii) an assessment of the EMP results compared with the performance indicator targets; and	Section 2.3 and 3.0

CSA N288.4-10 Clause 11.1.2	Section in EMP Report
iv) documentation and justification of any deviations from field sampling, and analytical, and data management procedures;	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	Section 6.0
e) documentation, assessment, and review of any supplementary studies that have been initiated, completed, or both.	Section 2.2.5 and 2.3.4

1.1 Program Objectives

The objectives of the NSS-WWMF EMP are to [3]:

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 μSv/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 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 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 facility 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. The RWOS 1 has not received waste since 1976 and remaining storage structures are in caretaking mode [4].

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 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, and 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 (L&ILW) radioactive waste and used fuel. The NSS-WWMF consists of the L&ILW Management Area and the Used Fuel Management Area. The L&ILW 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.

Figure 1.1: Location of Nuclear Sustainability Services – Western Waste Management Facility

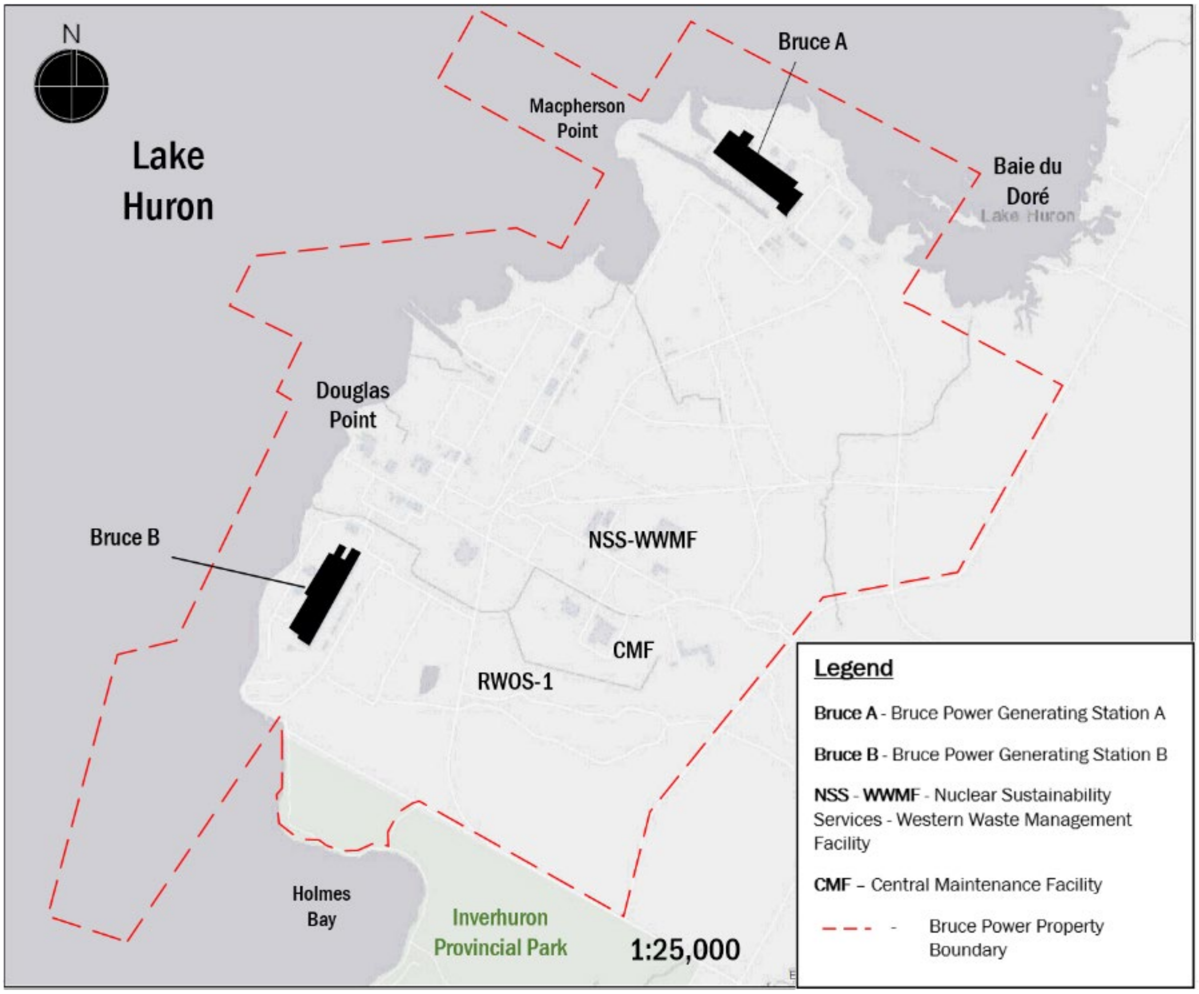


Figure 1.2: Location of Facilities on Bruce Nuclear Site

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

Figure 1.3: NSS-WWMF Aerial View

Source: AMEC, 2016 [16]

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 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 N288.4-10s standard and monitoring has been ongoing based on this design [5].

2.1.1 Facilities included in EMP

NSS-WWMF operates under a Class IB 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 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 Spent Solvent Treatment Facility (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 [5]. 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 which 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 was completed [6] in accordance with the requirements of CSA N288.6-12, Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills [7]. 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 program 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 2020-21 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 since 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 IC-18 is understood. Therefore, it is recommended that routine air monitoring 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.

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 through the groundwater monitoring program, ongoing confirmation of containment of radioactivity in the NSS-WWMF storage structures through the aging management program [8], 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 [9]. 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-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 µSv/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.

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 EGM System Overview [10]. See sections 2.3.2 and 3.3 for results of TLD measurements. Data can also be found in the quarterly reports (see [11], [12], [13], and [14]).

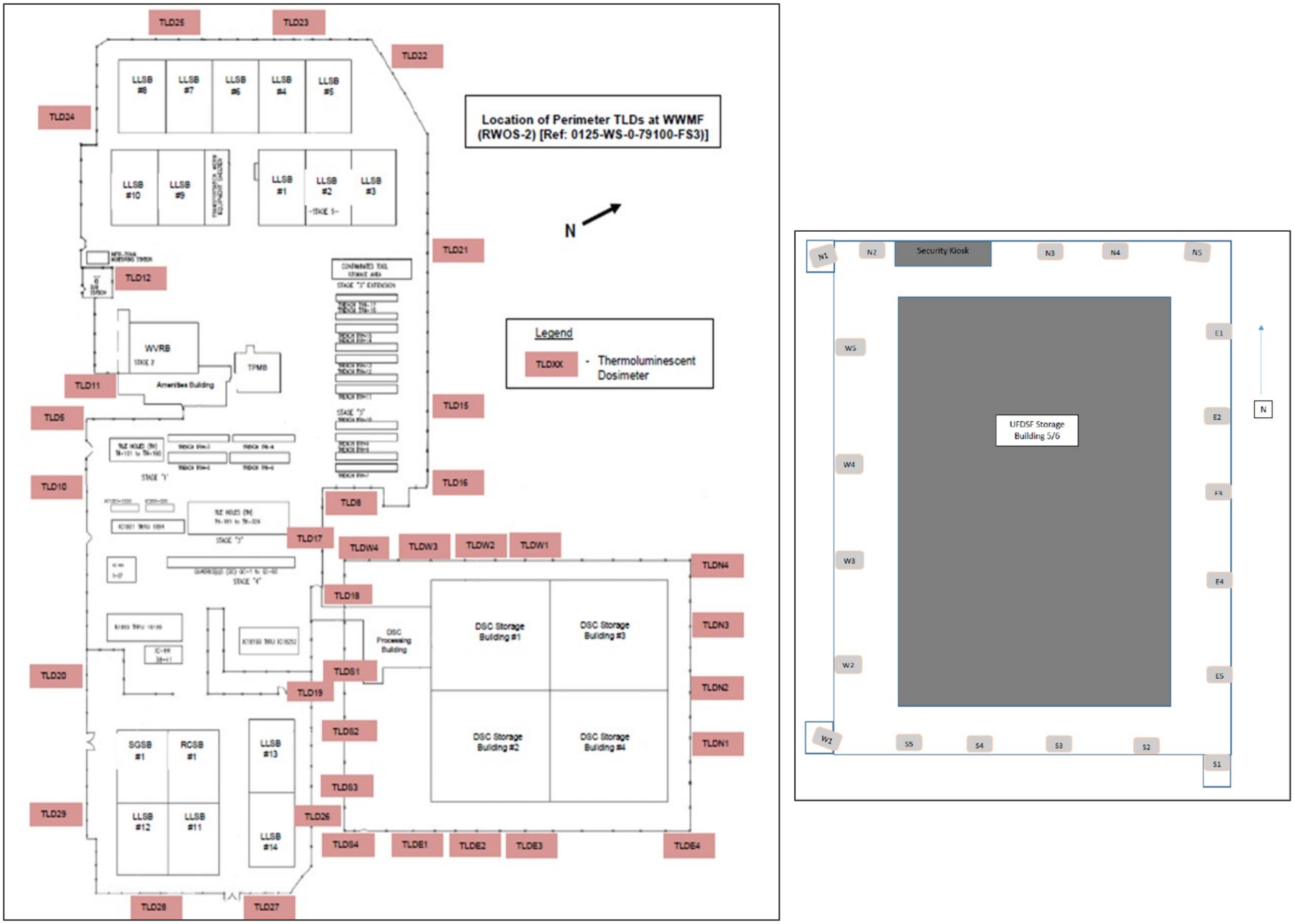


Figure 2.1: Location of TLDs at NSS-WWMF

Source: NSS-WWMF Quarterly Operations Report [11]

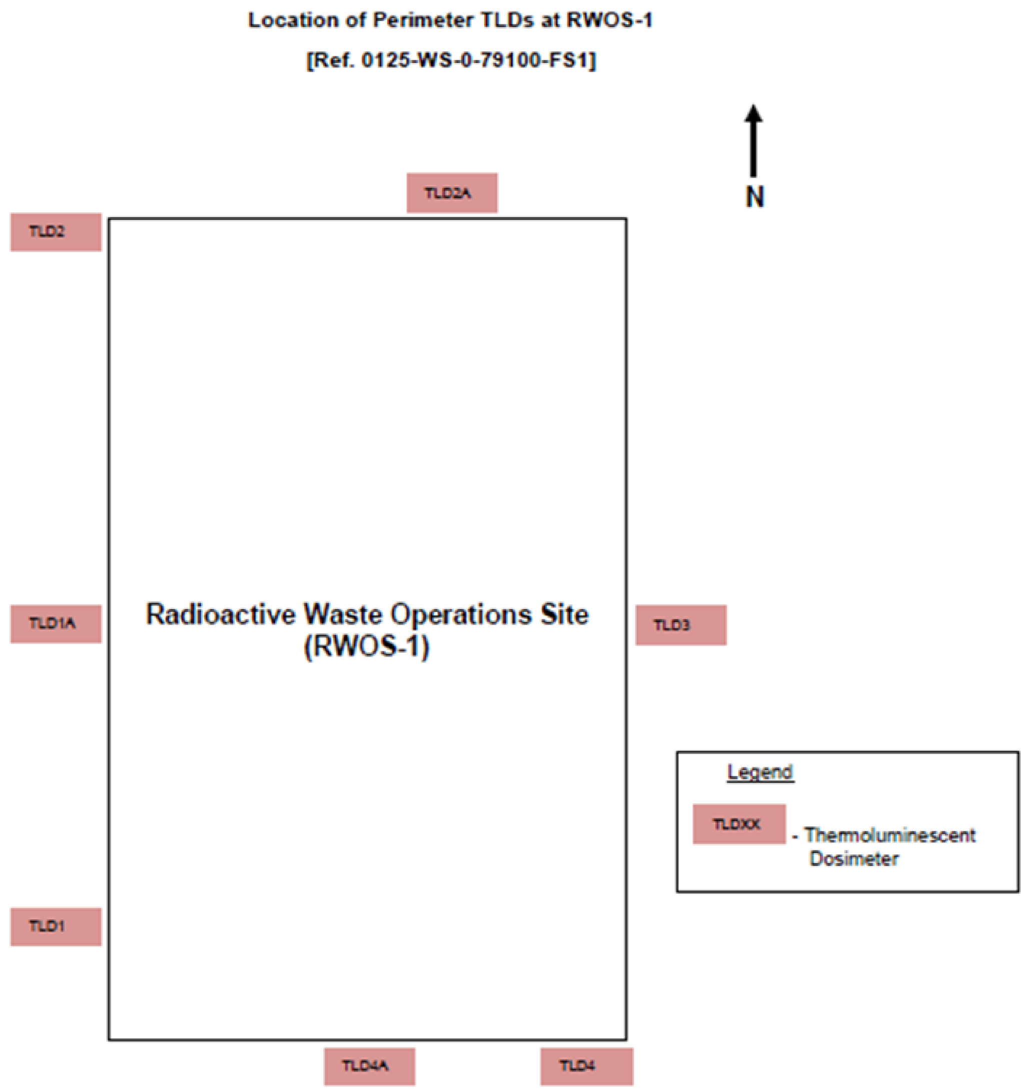


Figure 2.2: Locations of TLDs at RWOS 1

Source: NSS-WWMF Quarterly Operations Report [11]

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 proper, sealed groundwater sampling wells, but are called 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 Middle Sand Aquifer (MSA) and the deeper bedrock aquifer are monitored. Detailed procedures are followed for proper monitoring of the groundwater wells [15].

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 South Railway Ditch (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 [5]. A source term assessment and groundwater monitoring network design enhancement was completed in 2016 at 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

Based on the results of previous monitoring programs, the development of the Conceptual Site Model and Groundwater Monitoring Program identified tritium as the only contaminant of potential concern (COPC) at the site and discontinued the sampling of Gross β and Carbon-14 in groundwater in 2022. Groundwater sampling for Gross B was conducted as a supporting analysis for the purposes of general radiological trending, but was removed because it does not include tritium which is a low-energy beta. Groundwater sampling for Carbon-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 [24][25]. 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. Eight wells monitored in 2021 were also discontinued primarily due to redundancy, including WSH233, WSH 241, WSH246, WSH 248, WSH 271, WSH 127 and 20S. Section 2.3.3 provides the WSHs monitored in 2022 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 bi-annually. Results of this program are reported in section 2.3.3 of this document and are documented separately in a CSA N288.7 compliant report.

There are no specific targets or limits for radioactivity in groundwater at the NSS-WWMF or RWOS 1. However, OPG has committed to notify the CNSC if tritium levels at WSH 231 exceed 60,000 Bq/L [4]. 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 in the MSA has 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. WSH 231 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.

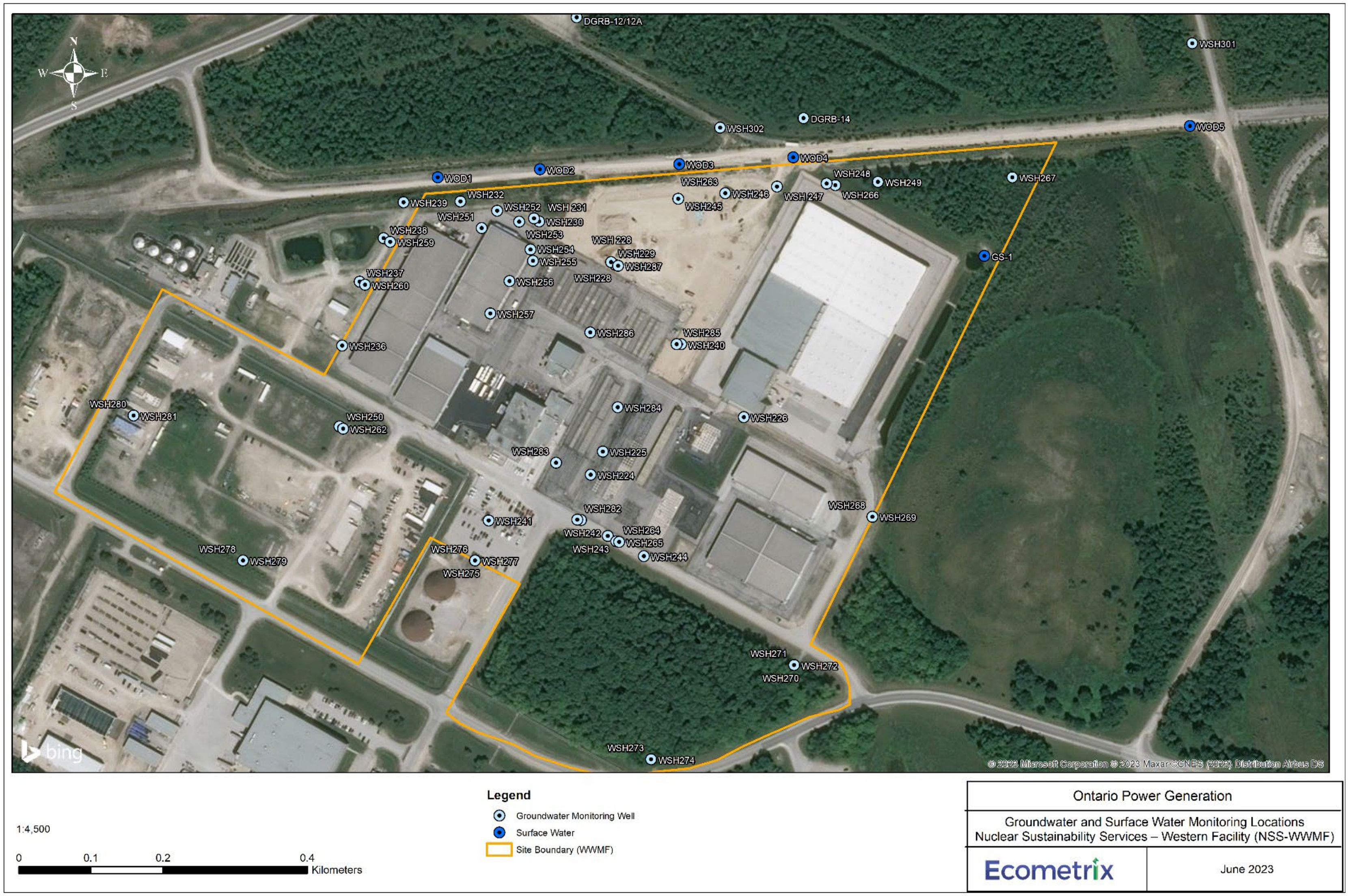


Figure 2.3: Monitoring Well Network at the NSS-WWMF

Figure 2.4: Monitoring Well Network at the RWOS 1

2.2.5 Water and Sediment in South Railway Ditch, Wetland and East Stormwater Management Pond

The EMP design report recommended a supplementary study to monitor water and sediment quality in the former grassed swale (now the East Stormwater Management Pond) and wetland at the east side of the NSS-WWMF to verify ERA predictions of no significant adverse effects. In 2013, samples of water and sediment were taken in the South Railway Ditch just north of the UFDSF (upstream of the grassed swale and wetland), in the grassed swale/wetland close to the stormwater discharge point from the east side of the NSS-WWMF site, and at the east end of the railway ditch, east of the NSS-WWMF site downstream of the wetland. Samples were taken in spring, summer, and fall. Water and sediment samples were analyzed for metals (metal scan) and gamma emitters (gamma scan). Water samples were also analyzed for HTO, C-14 and gamma emitters. In 2020 and 2021, to support the 2021 ERA update, the supplementary study was repeated, and surface water and sediment samples were collected from the South Railway Ditch, wetland and East Stormwater Management Pond for radionuclides and metals (see the 2021 NSS-WWMF ERA update for details on the sampling [6]).

The 2021 NSS-WWMF ERA concluded that there was no risk to the majority of aquatic and riparian biota due to exposure to metals and radionuclides, but that there is a potential risk to aquatic biota such as cattails and benthic invertebrates due to metals (iron, nickel, zinc) in water and metals (chromium, copper, manganese, nickel, sodium) and dioxins/furans in sediment. However, aquatic biota in general, are not expected to be at risk in the South Railway Ditch. The elevated concentration of metals in the SRD was attributed to the existence of a former rail line within the ditch; therefore, metals could potentially be attributed to the rail ballasts or iron slag that was used to construct the railway bed. An additional potential source includes historical releases from the former SSTF upstream of SRD-1, as well as drainage culverts that may be contributing to elevated zinc concentrations in the SRD [6].

2.2.6 Water in South Railway Ditch and East Stormwater Management Pond

The South Railway Ditch 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 [4], and in 2020 and 2021 as part of the NSS-WWMF ERA update [6]. The results provided no firm conclusions about changes in tritium in the South Railway Ditch as compared with tritium levels 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 moving forward.

2.2.7 HTO in Precipitation

HTO monitoring in precipitation at NSS-WWMF was discontinued in 2022, in accordance with the recommendations of the 2021 NSS-WWMF ERA [6].

2.2.8 Fugitive Emissions of C-14

Elevated C-14 in air on the NSS-WWMF site was identified in the 2013 EMP Report [7] and an integration into routine sampling was recommended. Bruce Power nuclear site passive C-14 samplers are shown in **Figure 2.5. In 2020, 2021, and 2022 passive sampler results from Bruce Power indicated higher levels 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 [8].**

The C-14 passive samplers consist of mixed soda lime pellets to absorb CO_2 from air at a controlled rate. The CO_2 is released from the pellets in the laboratory by titration with acid, then collected and analyzed by liquid scintillation counting for C-14 content. Twenty samplers are positioned around the area of the NSS-WWMF for passive monitoring (Figure 2.6). The samples are collected and analyzed quarterly.

As a result of a review of the effluent monitoring program in 2018, elevated concentrations of C-14 were detected at the NSS-WWMF. Their source was traced to 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. During this assessment air samples were also collected from 67 ICs. An assessment of the fugitive C-14 emissions from the ICs was based on the measured levels of C-14 in the IC air and the previously measured volumes of air released from the ICs due to wind pumping. The assessment concluded that, with an estimated emission rate of 6.7E+10 Bq/week, performance monitoring of C-14 is required for ICs, as the emission estimate is >0.05% of the derived release limit (DRL).

A model has been developed to estimate fugitive emissions from the spent resin area. OPG is currently working with vendors to further review the model and methodology for accuracy. Both environmental and health physics monitoring confirm that there is no significant impact on workers, the public, or the environment.

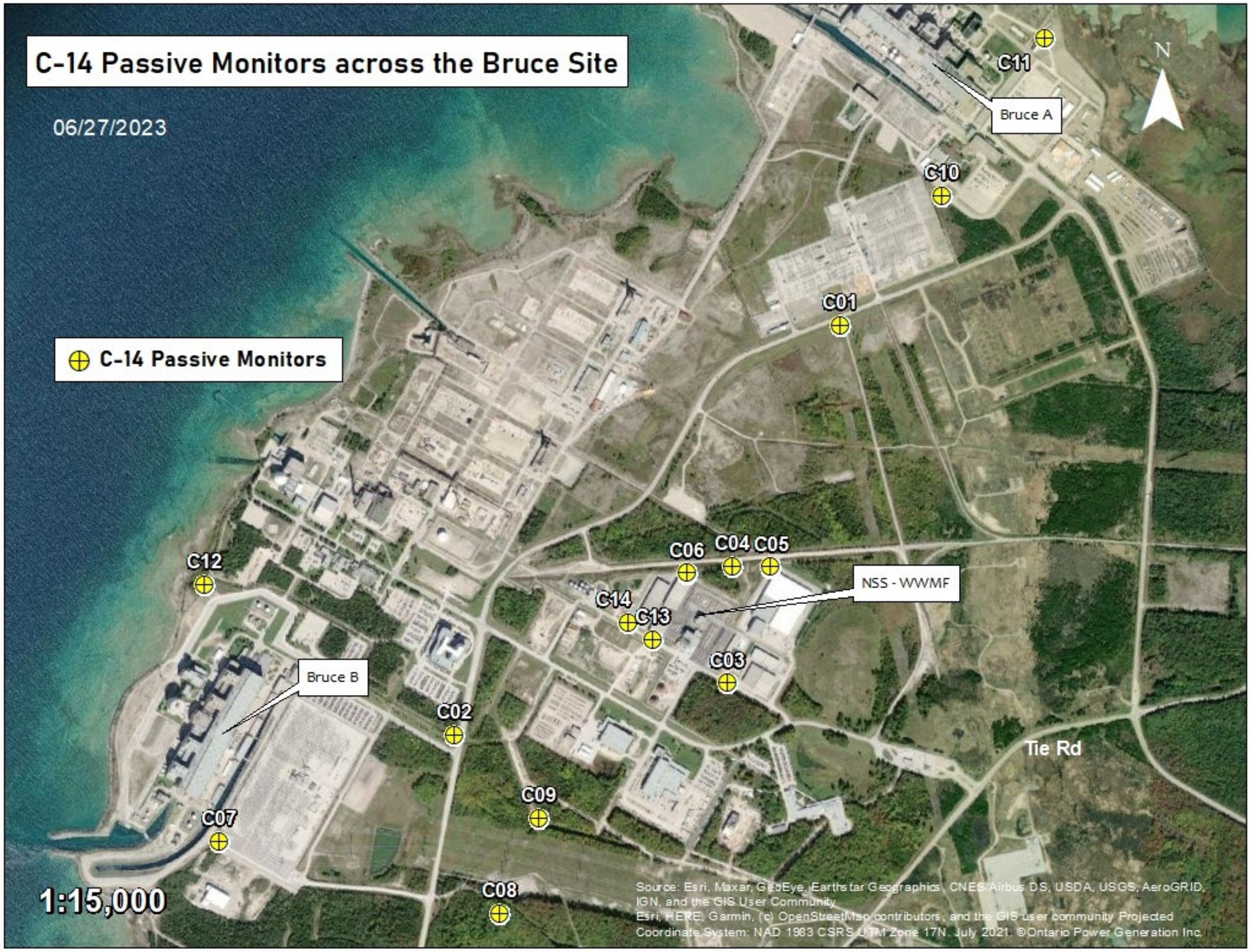


Figure 2.5: C-14 Passive Monitor Locations Across the NSS-WWMF/Bruce Power Site

Figure 2.6: Sampling Locations at the Passive Air Samplers at the NSS-WWMF

2.3 EMP Results

This section contains the 2022 results of the EMP for the NSS-WWMF and RWOS 1. Sampling methods, analyses, and QA/QC measures are identified.

2.3.1 Reporting Data and Uncertainties

Descriptive statistics such as means, and standard deviations were calculated in Excel unless the dataset contained non-detects with values specified. Statistical analysis for trends were performed using the Microsoft Excel Real Statistics package [17].

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).

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 of the quantity for which the probability of a wrong conclusion that a quantity is present exceeds a specified probability [18]. 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 [18]. The EMP uses a probability of 5%.

When reporting the analytical data, 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, in order to monitor and account for extraneous radiation dose received in transit. Additional information on the TLDs and the readout procedure can be found in the EGM System Overview [19].

The 2022 TLD gamma dose results are shown in Table 2.1. Results are given as air kerma rates (µGy/h). 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 limit of 0.5 µGy/h. A graphical representation of the 2022 results is shown in Figure 2.7.

All TLD locations were analyzed for any statistically significant trends in the last five years (2018 – 2022) at the 95% significance level using the Mann-Kendall Test [17]. Most locations did not show any appreciable changes or trends that would warrant further investigation. Only three (3) TLD locations showed statistically significant trends from 2018 to 2022 (TLDs 24, 25 and 28). TLD 24 increased from 0.063 µGy/h in Q1 of 2018, to 0.074 µGy/h in Q4 of 2022 ($p=0.002$). TLD 25 at the Western Low and Intermediate Level Waste Storage Facility (WLILWSF) increased from 0.054 µGy/h in Q1 of 2018 to 0.082 µGy/h in Q4 of 2022 ($p=0.005$). TLD 28 decreased from 0.088 µGy/h in Q1 of 2018 to 0.085 µGy/h in Q4 of 2022 ($p<0.0133$) (Figure 2.7). As noted, all TLD gamma dose results are below the dose rate limit of 0.5 µGy/h.

Table 2.1: 2022 TLD Average Air Kerma Rates

TLD - Average Air Kerma Rates (µGy/h)						
TLD Location	**Q1**	**Q2**	**Q3**	**Q4**	**Annual Average**	**2*SD(3)**
RWOS 1						
1	0.048	0.051	0.055	0.052	0.052	0.006
1A	0.051	0.057	0.053	0.057	0.055	0.006
2	0.052	0.051	0.055	0.059	0.054	0.007
2A	0.051	0.055	0.053	0.058	0.054	0.006
3	0.047	0.048	0.050	0.053	0.050	0.005
4	0.046	0.049	0.050	0.051	0.049	0.004
4A	0.045	0.053	0.053	0.053	0.051	0.008
WLILWSF(1)						
5	0.049	0.049	0.049	0.056	0.051	0.007
8	0.059	0.059	0.058	0.066	0.061	0.007
10	0.051	0.05	0.055	0.057	0.053	0.007
11	0.061	0.063	0.058	0.07	0.063	0.010
12	0.060	0.062	0.062	0.068	0.063	0.007
15	0.058	0.064	0.06	0.065	0.062	0.007
16	0.060	0.066	0.065	0.069	0.065	0.007
17	0.056	0.055	0.058	0.065	0.059	0.009
18	0.056	0.061	0.061	0.062	0.060	0.005
19	0.059	0.060	0.061	0.063	0.061	0.003
20	0.057	0.063	0.065	0.062	0.062	0.007
21	0.052	0.058	0.057	0.057	0.056	0.005
22	0.050	0.054	0.054	0.055	0.053	0.004
23	0.067	0.069	0.072	0.074	0.071	0.006
24	0.065	0.074	0.072	0.074	0.071	0.009
25	0.080	0.082	0.076	0.082	0.080	0.006
26	0.070	0.078	0.076	0.078	0.076	0.008
27	0.066	0.072	0.073	0.07	0.070	0.006
28	0.081	0.083	0.08	0.085	0.082	0.004
29	0.063	0.070	0.067	0.067	0.067	0.006
UFDSF Buildings 1-4(2)						
DFSN-1	0.082	0.079	0.08	0.082	0.081	0.003
DFSN-2	0.085	0.089	0.085	0.092	0.088	0.007
DFSN-3	0.086	0.08	0.077	0.086	0.082	0.009
DFSN-4	0.062	0.06	0.059	0.063	0.061	0.004
DFSS-1	0.064	0.068	0.066	0.072	0.068	0.007
DFSS-2	0.067	0.067	0.067	0.073	0.069	0.006

TLD - Average Air Kerma Rates (µGy/h)						
TLD Location	**Q1**	**Q2**	**Q3**	**Q4**	**Annual Average**	**2*SD(3)**
DFSS-3	0.069	0.07	0.07	0.073	0.071	0.003
DFSS-4	0.064	0.064	0.062	0.069	0.065	0.006
DFSE-1	0.064	0.066	0.06	0.068	0.065	0.007
DFSE-2	0.084	0.082	0.077	0.083	0.082	0.006
DFSE-3	0.084	0.084	0.077	0.083	0.082	0.007
DFSE-4	0.060	0.061	0.063	0.065	0.062	0.004
DFSW-1	0.082	0.084	0.083	0.087	0.084	0.004
DFSW-2	0.081	0.082	0.081	0.08	0.081	0.002
DFSW-3	0.078	0.078	0.073	0.078	0.077	0.005
DFSW-4	0.059	0.057	0.056	0.06	0.058	0.004
UFDSF Buildings 5-6						
DFSB56-N1	-(4)	0.062	0.065	0.059	0.062	0.006
DFSB56-N2	-	0.065	0.064	0.063	0.064	0.002
DFSB56-N3	-	0.064	0.058	0.069	0.064	0.011
DFSB56-N4	-	0.062	0.063	0.063	0.063	0.001
DFSB56-N5	-	0.055	0.060	0.060	0.058	0.006
DFSB56-E1	-	0.056	0.057	0.054	0.056	0.003
DFSB56-E2	-	0.056	0.063	0.064	0.061	0.009
DFSB56-E3	-	0.067	0.081	0.080	0.076	0.016
DFSB56-E4	-	0.076	0.092	0.090	0.086	0.017
DFSB56-E5	-	0.070	0.069	0.074	0.071	0.005
DFSB56-W1	-	0.071	0.074	0.076	0.074	0.005
DFSB56-W2	-	0.137	0.168	0.163	0.156	0.033
DFSB56-W3	-	0.192	0.286	0.284	0.254	0.107
DFSB56-W4	-	0.085	0.155	0.148	0.129	0.077
DFSB56-W5	-	0.068	0.078	0.079	0.075	0.012
DFSB56-S1	-	0.063	0.065	0.064	0.064	0.002
DFSB56-S2	-	0.071	0.077	0.077	0.075	0.007
DFSB56-S3	-	0.101	0.118	0.112	0.110	0.017
DFSB56-S4	-	0.115	0.125	0.125	0.122	0.012
DFSB56-S5	-	0.125	0.124	0.130	0.126	0.006

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.
   Ld = 0.7 µGy.
4) TLDs at UFDSF Buildings 5-6 were installed in Q2 2022

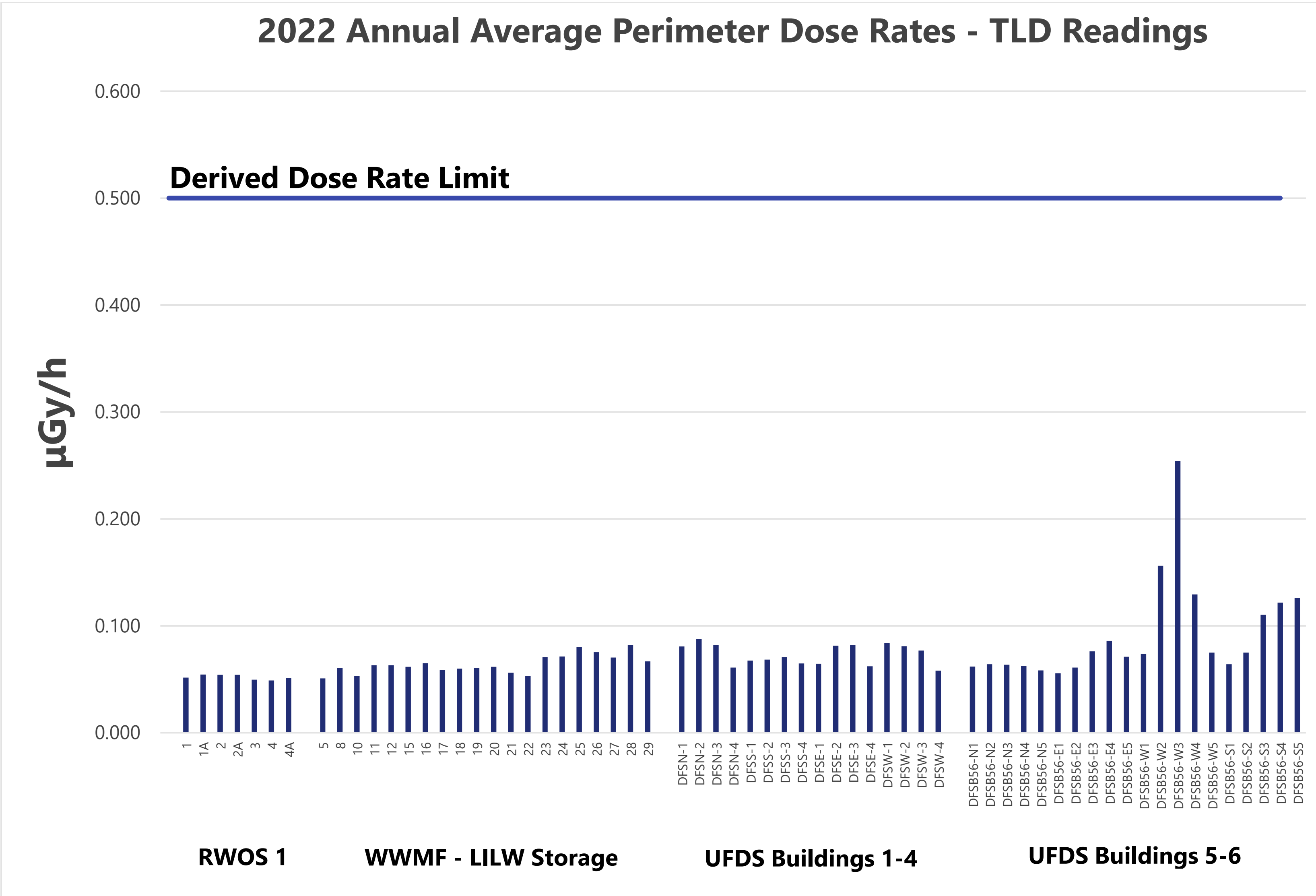


Figure 2.7: 2022 TLD Results

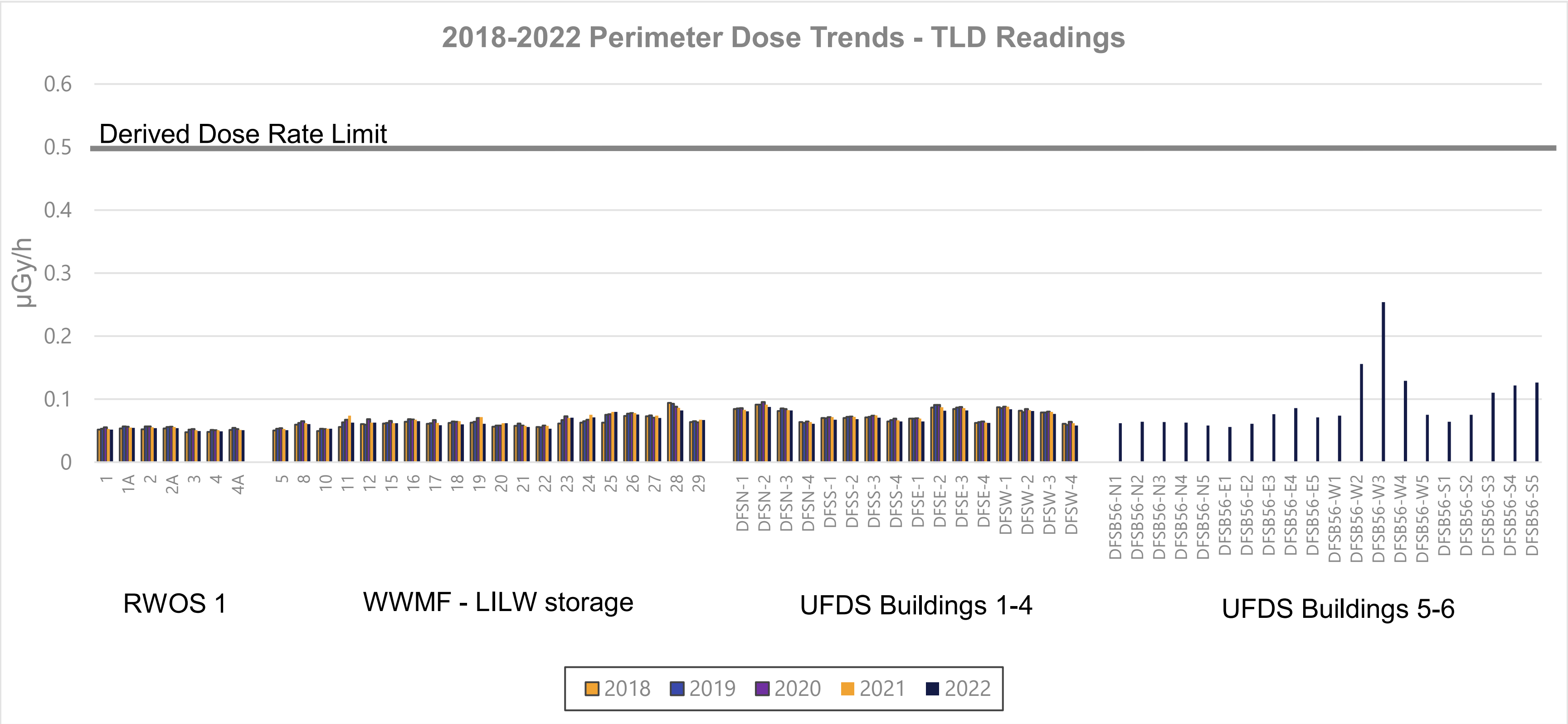


Figure 2.8: 2018-2022-TLD Results

2.3.3 Groundwater Monitoring Results

Of the 49 wells monitored in 2022 at the NSS-WWMF in the bedrock and the MSA, 19 wells are monitored for tritium activity bi-annually and 30 are monitored annually (for a total of 49 wells monitored in 2022). Of these, seven historical stations were re-established in 2022 including WSH 245, WSH 252, WSH 256, WSH 267, WSH 275, WSH 276, WSH 277, and six stations were newly established, including WSH 301, WSH 302, WSH 307, DGRB12, DGRB12A and DGRB14. Monitoring of WSH 233, WSH 241, WSH246, WSH 248 and WSH 271 was discontinued at the NSS-WWMF in the first quarter of 2022. Analysis results for all wells sampled on a bi-annual basis are shown in Table 2.2. Wells that are monitored annually are shown in Table 2.3. At RWOS 1 the bedrock aquifer is monitored for tritium activity semi-annually in five wells, and monthly for tritium and gross β at two surface water locations (Ditch N, Ditch S), shown in Table 2.2 and Table 2.4 respectively, Monitoring of WSH 127 and WSH 20S was discontinued at RWOS 1 in the first quarter of 2022.

In 2022, all of the RWOS 1 wells and 39 of the 49 NSS-WWMF wells measured had annual average tritium concentrations in groundwater below 500 Bq/L. Wells with average tritium concentrations higher than 500 Bq/L include WSH 231 (9,370 Bq/L), WSH 251 (1,680 Bq/L), WSH 252 (17,900 Bq/L), WSH 253 (22,200 Bq/L), WSH 255 (2,800 Bq/L), WSH 256 (2,790 Bq/L) and WSH 257 (3,490 Bq/L), WSH 259 (1,110 Bq/L), WSH 269 (504 Bq/L) and WSH 282 (647 Bq/L). Tritium in WSH 231, which characterizes the MSA, averaged 9,370 Bq/L over the year, and never exceeded the level of 60,000 Bq/L at which OPG has committed to notify the CNSC [7]. A negative trend was identified for tritium concentrations at WSH 231 ($p<0.001$), indicating that tritium is steadily decreasing at this station over time. The highest tritium concentrations were measured at WSH 253, located close to WSH 231 with an annual average of 22,200 Bq/L. Monitoring of this well started in 2017 and no statistically significant trend had been identified. The 2022 average tritium concentrations in groundwater for all WSHs are shown in Figure 2.9.

In 2022 gross β levels at RWOS 1 were only measured in surface water at the Ditch N and Ditch S locations. Ditch N averaged 0.124 Bq/L and ranged from 0.075 Bq/L to 0.188 Bq/L. Ditch S averaged 0.090 Bq/L and ranged from 0.044 Bq/L to 0.139 Bq/L (Table 2.4). Examination of gross β in groundwater across the site was discontinued at the end of 2021 based on the results of the Conceptual Site Model and the Groundwater Protection and Monitoring Program development per CSA N288.7 [24][25].

Historic data for tritium activity in the WSHs of both sites from 2018 to 2022 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 statistical increasing or decreasing trend at the 95% confidence level. The results of the trend analyses for tritium in the NSS-WWMF wells indicated that WSH 229 and WSH 230 showed an increasing trend, however increases are minor, and concentrations of tritium remain well below the level of 60,000 Bq/L at which OPG has committed to notify the CNSC. Of the remaining NSS-WWMF wells, nine had a decreasing tritium trend (WSH 226, WSH 228, WSH 231, WSH 238, WSH 251, WSH 263, WSH 265, WSH 283, WSH 284) and the remainder had no statistically significant trend.

From 2018 to 2022, in RWOS 1, only Ditch N and Ditch S showed significant trends in tritium or gross β levels, with Ditch N ($p=0.007$) and Ditch S ($p=0.046$) (Note that Ditch N and Ditch S are considered surface water samples).

These results indicate that there are no elevated radionuclide concentrations in groundwater leaving the NSS-WWMF in the bedrock aquifer. However, the localized elevated tritium in WSH 231 and WSH 253 indicate that there was 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 [20]. Remedial actions have been taken since 2007, which included resealing of select LLSB sumps and regular pump-outs of Electrical Manholes to prevent downgradient migration of tritiated groundwater. Additionally, the tritium inventory in this area continues to decrease due to decay and off-gassing. As stated above, tritium levels in WSH 231 showed a statistically significant decreasing trend over the 2018 to 2022 period ($p<0.01$). WSH 231 and the neighbouring WSH 253 annual averages over this period are plotted in Figure 2.10.

Table 2.2: 2022 Groundwater Monitoring Results (Bq/L)

WSH	Q2 HTO	Q4 HTO	Annual Average	
			HTO	Uncertainty (1)
RWOS 1				
122	2.28E+02	1.22E+02	1.75E+02	1.50E+02
123	6.99E+02	1.44E+02	4.22E+02	7.85E+02
124	1.60E+02	1.71E+02	1.66E+02	1.56E+01
125	1.34E+02	1.33E+02	1.34E+02	1.41E+00
126	1.38E+02	1.49E+02	1.44E+02	1.56E+01
NSS-WWMF				
226	**9.13E+00**	**9.67E+00**	9.40E+00	7.64E-01
228	1.59E+02	1.56E+02	1.58E+02	4.24E+00
229	1.30E+03	8.91E+02	1.10E+03	5.78E+02
230	6.56E+02	6.78E+02	6.67E+02	3.11E+01
231	9.28E+03	9.46E+03	9.37E+03	2.55E+02
240	**1.02E+01**	**1.03E+01**	1.03E+01	1.41E-01
242	4.85E+01	3.90E+01	4.38E+01	1.34E+01
243	2.70E+02	2.80E+02	2.75E+02	1.41E+01
253	2.11E+04	2.33E+04	2.22E+04	3.11E+03
255	3.11E+03	2.49E+03	2.80E+03	8.77E+02
265	4.28E+02	5.03E+02	4.66E+02	1.06E+02
269	5.51E+02	4.56E+02	5.04E+02	1.34E+02
276	3.05E+01	1.14E+01	2.10E+01	2.70E+01
282	6.93E+02	6.00E+02	6.47E+02	1.32E+02
283	1.12E+02	1.20E+02	1.16E+02	1.13E+01
284	3.36E+02	3.52E+02	3.44E+02	2.26E+01
285	2.99E+02	4.23E+02	3.61E+02	1.75E+02
286	2.69E+02	3.16E+02	2.93E+02	6.65E+01
287	2.87E+02	3.16E+02	3.02E+02	4.10E+01

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

Table 2.3: Annual Tritium in Yearly Monitored Groundwater Wells (Bq/L)

WSH	Q4 HTO
NSS-WWMF	
224	5.22E+01
232	**8.40E+00**
237	**1.07E+01**
238	**1.06E+00**
239	**1.05E+01**
244	4.14E+01
245	**8.34E+00**
249	8.31E+00
251	1.68E+03
252	1.79E+04
256	2.79E+03
257	3.49E+03
259	1.11E+03
260	1.67E+01
263	5.62E+01
264	5.36E+01
267	**8.21E+00**
268	9.98E+00
270	**8.48E+00**
272	2.95E+02
275	**8.40E+00**
277	3.11E+02
278	3.62E+01
279	1.74E+02
301	**9.62E+00**
302	**9.88E+00**
307	**9.58E+00**
DGRB12	1.10E+02
DGRB12A	**9.41E+00**
DGRB14	4.86E+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: 2022 Groundwater Monitoring Results RWOS 1 Surface Water (Bq/L)

Date	Discharge HTO Ditch (N)		Discharge HTO Ditch (S)	
	Tritium (Bq/L)	Gross β (Bq/L)	Tritium (Bq/L)	Gross β (Bq/L)
2022-01-05	1.82E+02	1.38E-01	2.24E+02	7.05E-02
2022-02-10	1.93E+02	1.29E-01	1.65E+02	1.12E-01
2022-03-10	1.93E+02	**7.52E-02**	1.98E+02	**6.61E-02**
2022-04-05	1.87E+02	1.42E-01	2.02E+02	1.29E-01
2022-05-10	2.38E+02	8.77E-02	2.77E+02	7.55E-02
2022-06-08	2.32E+02	8.91E-02	2.54E+02	5.28E-02
2022-07-11	2.43E+02	1.88E-01	2.61E+02	1.14E-01
2022-08-10	2.21E+02	8.17E-02	2.50E+02	8.81E-02
2022-09-12	2.19E+02	1.25E-01	NS	NS
2022-10-04	2.41E+02	1.14E-01	1.59E+02	1.01E-01
2022-11-09	2.17E+02	1.51E-01	2.03E+02	1.39E-01
2022-12-06	2.63E+02	1.62E-01	2.03E+02	4.42E-02
Annual Average	2.19E+02	1.24E-01	2.18E+02	9.02E-02

Note:
Bolded values indicate measurements under the detection limit.
NS – Indicates no sample was taken.

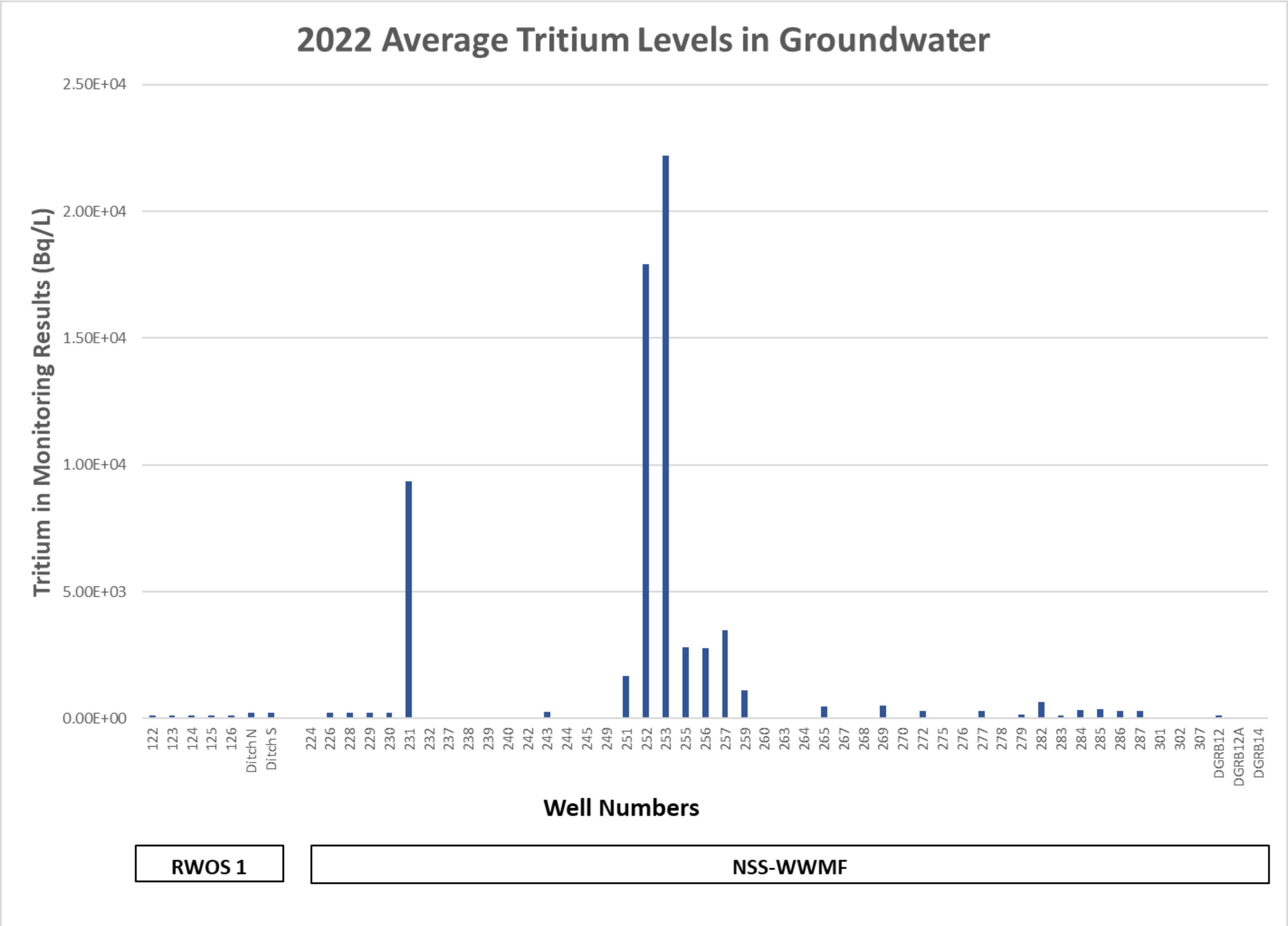


Figure 2.9: 2022 Average Annual Tritium Levels in Groundwater Monitoring Wells

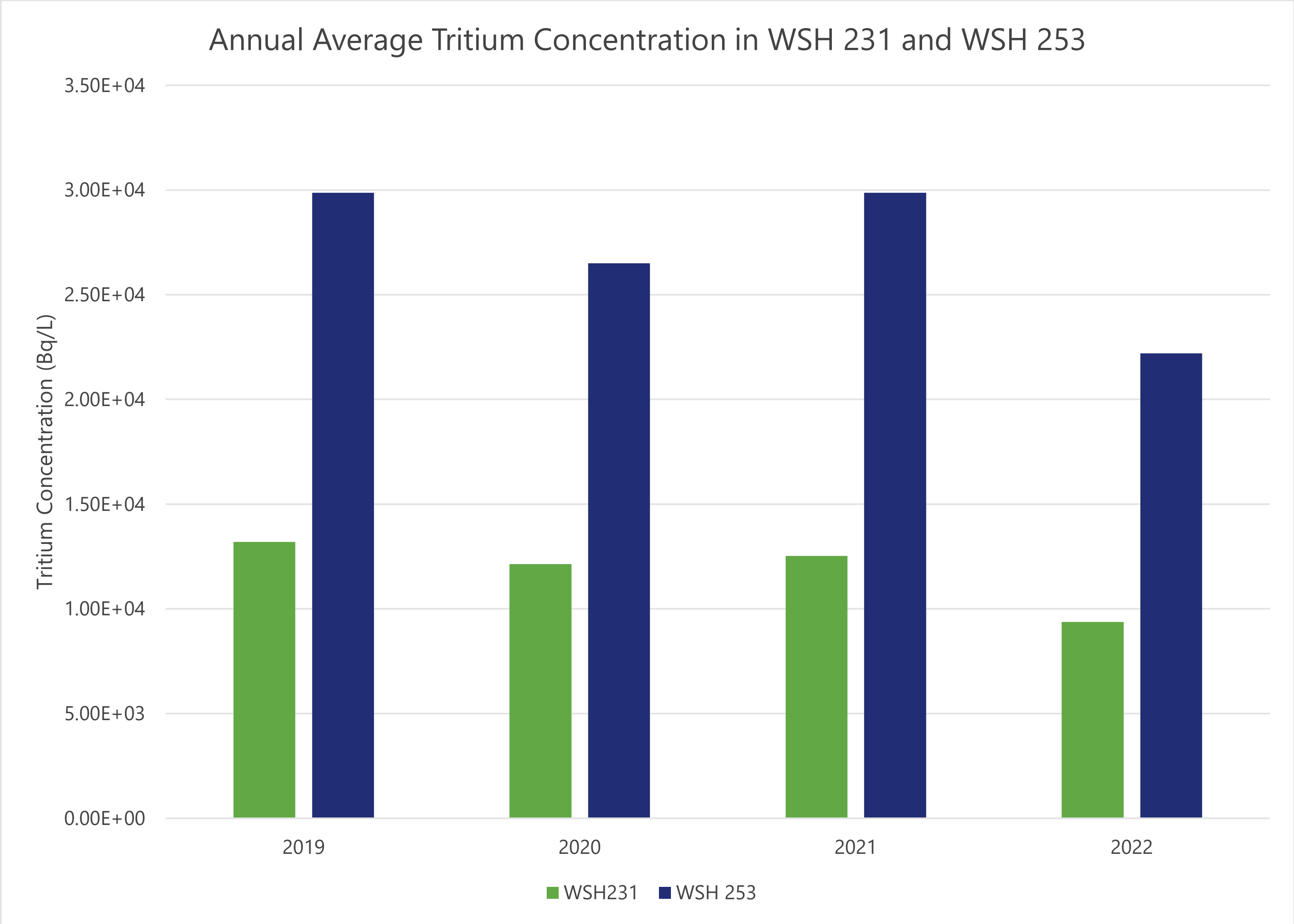


Figure 2.10: Annual Average Concentration of Tritium in Groundwater at Well WSH 231 and WSH 253

2.3.4 Water and Sediment in South Railway Ditch, East Stormwater Management Pond, and Wetland

Surface water samples were collected in 2020-2021 in the fall, winter, spring, and summer and analyzed for metals and inorganic parameters, dioxins and furans, C-14, tritium, and gamma scan. Sediment samples were collected in 2020-2021 in the fall, spring, and summer and analyzed for metals, moisture, total organic carbon (TOC), dioxins and furans, C-14, and gamma scan. Cattails were also collected in the fall from the South Railway Ditch and wetland and analyzed for C-14, moisture, and metals. Analytical results are presented in Appendix F of the 2021 NSS-WWMF ERA [6].

Based on the results of the data collected, the following conclusions were made in the 2021 NSS-WWMF ERA update.

South Railway Ditch (including East Stormwater Management Pond)

Fish and herpetofauna in the South Railway Ditch and East Stormwater Management Pond are not at toxicological risk from NSS-WWMF operations. Cattails may be exposed to concentrations of iron, nickel and zinc above their toxicity reference values; however, the cattail population is not expected to be at risk in the South Railway Ditch.

Some individual benthic invertebrates may be impacted through exposure to concentrations of metals and dioxins/furans in water and sediment which exceed applicable toxicity reference values; however, the benthic invertebrate community as a whole is not expected to be at risk in the South Railway Ditch.

Wetland

The wetland receives drainage from multiple sources, including the South Railway Ditch, East Stormwater Management Pond and Construction Landfill 1. The majority of constituent concentrations were higher in the South Railway Ditch than in the wetland indicating that concentrations are largely originating from the South Railway Ditch prior to discharge into the wetland. However, elevated concentrations of strontium were observed in the wetland that were not observed in the South Railway Ditch. While the maximum strontium concentration in surface water in the wetland may be an outlier, it is possible that the location where the maximum strontium concentration was measured is representative of one of the other sources that discharge into the wetland, i.e., the Construction Landfill 1. Considering that the source of inputs to the wetland is generally understood, ongoing monitoring of the wetland is not considered necessary. However, strontium levels in the wetland will be monitored to support the next ERA update to determine if conditions are stable or have changed.

2.3.5 Water in South Railway Ditch and East Stormwater Management Pond

Tritium concentrations in the South Railway Ditch and East Stormwater Management Pond were measured four times in 2022. 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 2018 to 2022 no statistically significant trends were detected (Figure 2.11).

Table 2.5: Mean Annual Tritium Concentration in 2022 at the South Railway Ditch (WOD1-5) and East Stormwater Management Pond (SMP-1)

	HTO (Bq/L)	Uncertainty *
WOD1	6.06E+02	1.05E+03
WOD2	1.42E+03	1.49E+03
WOD4	1.12E+03	6.47E+02
WOD5	1.03E+03	6.55E+02
SMP-1	7.58E+02	1.02E+03

*Uncertainty is given as ± 2 standard deviations.

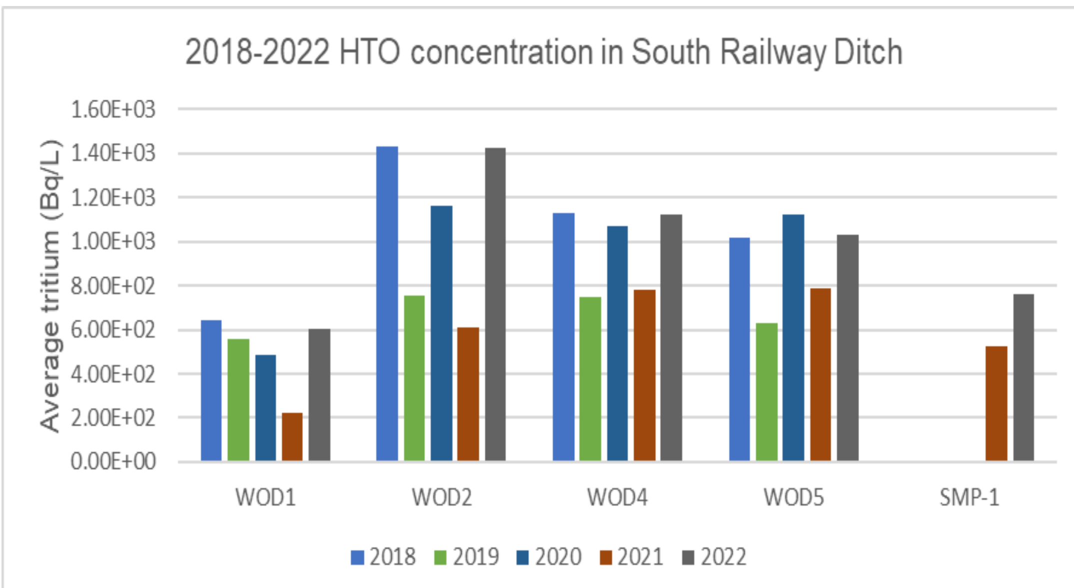


Figure 2.11: 2018-2022 Average Annual Tritium at Surface Water Sampling Locations in South Railway Ditch (WOD1-5) and East Stormwater Management Pond (SMP-1)

2.3.6 HTO in Precipitation

As of 2022, tritium is no longer monitored in precipitation at the NSS-WWMF, as per the recommendations in the 2021 NSS-WWMF ERA update.

2.3.7 Passive C-14 Sampling

Twenty 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 2021 and 2022. Mann-Kendall testing identified that C-14 concentrations measured at passive monitor #11 significantly increased from 123,000 Bq C-14 /kgC in Q1 of 2021 to 282,000 Bq C-14 /kgC in Q4 of 2022 ($p=0.0061$). No other statistically significant trends were noted.

The elevated concentrations of C-14 at IC-12s and IC-18s are attributed to the storage of spent moderator ion exchange (IX) resin, and are subsequently investigated separately. As a result, C-14 concentration in air is highest in Area 1 (samplers 1-9) where IC-12s and IC-2s are located, and in Area 2 (samplers 10-15) at the location of the IC-18s. The highest concentration in Area 2 is noted for sampler #12 located at the center of the IC-18s (Figure 2.12). Sampler #12 is located beside an in-ground storage container (IC) known to contain the highest concentration of C-14. A number of IC lids in the area were opened in May of 2022, likely causing the large increase in C-14 concentrations in that sampler during Q2 2022.

Figure 2.13 shows C-14 concentrations from the Bruce Power passive air sampler located closest to the IC-18s (i.e., B#3, Figure 2.13) and one representing background (i.e., B#13, Figure 2.13) for comparison. 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).

Table 2.6: 2022 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 (Bq C-14 /kgC)	Annual Average (Bq/m^3)	Uncertainty (Bq/m^3)
			Area 1: Phase I-III				**Area 1: Phase I-III**	
#1	7.77E+04	7.25E+04	4.70E+04	5.20E+04	6.23E+04	3.01E+04	1.37E+01	6.63E+00
#2	8.06E+04	1.08E+05	1.07E+05	8.99E+04	9.64E+04	2.68E+04	2.12E+01	5.90E+00
#3	1.13E+05	1.18E+05	2.43E+05	3.65E+04	1.28E+05	1.71E+05	2.81E+01	3.76E+01
#4	9.83E+04	8.45E+04	1.03E+05	5.14E+04	8.43E+04	4.66E+04	1.85E+01	1.03E+01
#5	9.94E+04	1.09E+05	8.07E+04	1.13E+05	1.01E+05	2.88E+04	2.21E+01	6.33E+00
#6	2.00E+05	2.69E+05	2.17E+05	2.45E+05	2.33E+05	6.09E+04	5.12E+01	1.34E+01
#7	1.96E+05	3.34E+05	4.15E+05	4.19E+05	3.41E+05	2.09E+05	7.50E+01	4.59E+01
#8	1.14E+05	1.03E+05	1.33E+05	9.54E+04	1.11E+05	3.27E+04	2.45E+01	7.18E+00
#9	2.02E+05	2.61E+05	2.07E+05	4.11E+05	2.70E+05	1.95E+05	5.95E+01	4.29E+01
			Area 2: Stage 6				**Area 2: Stage 6**	
#10	2.96E+05	4.71E+05	1.01E+05	1.42E+05	2.53E+05	3.36E+05	5.56E+01	7.40E+01
#11	1.95E+05	2.04E+05	2.28E+05	2.82E+05	2.27E+05	7.81E+04	5.00E+01	1.72E+01
#12	5.36E+05	4.90E+06	3.51E+05	9.63E+04	1.47E+06	4.59E+06	3.24E+02	1.01E+03
#13	9.73E+04	5.01E+05	8.16E+04	4.90E+04	1.82E+05	4.27E+05	4.01E+01	9.39E+01
#14	4.19E+04	7.95E+04	2.48E+04	1.33E+04	3.99E+04	5.78E+04	8.77E+00	1.27E+01
#15	1.86E+05	-	3.27E+05	4.29E+04	1.85E+05	2.84E+05	4.08E+01	6.25E+01
			Area 3: Batch 5				**Area 3: Batch 5**	
#16	1.91E+04	1.35E+04	2.35E+04	9.38E+03	1.64E+04	1.24E+04	3.60E+00	2.73E+00
#17	7.42E+03	6.09E+03	5.44E+03	6.16E+03	6.28E+03	1.66E+03	1.38E+00	3.64E-01
#18	6.34E+03	4.67E+03	4.95E+03	5.63E+03	5.40E+03	1.49E+03	1.19E+00	3.28E-01
#19	1.88E+04	6.29E+03	5.56E+03	7.66E+03	9.58E+03	1.24E+04	2.11E+00	2.73E+00
#20	6.31E+03	4.84E+03	5.14E+03	4.63E+03	5.23E+03	1.50E+03	1.15E+00	3.30E-01

Note: *Uncertainty is given as ±2 standard deviations.

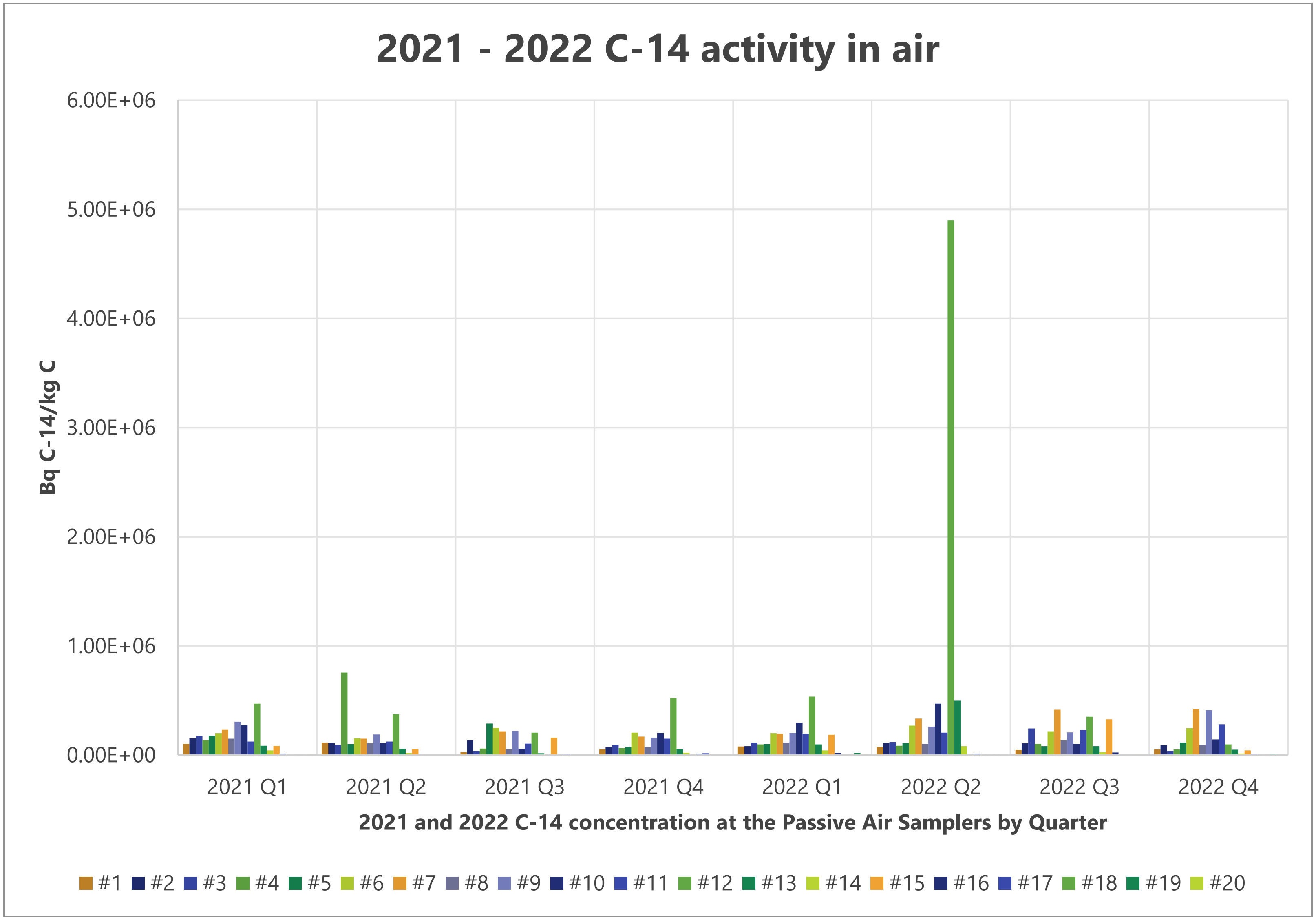


Figure 2.12: 2021 and 2022 C-14 concentration at the Passive Air Samplers by Quarter

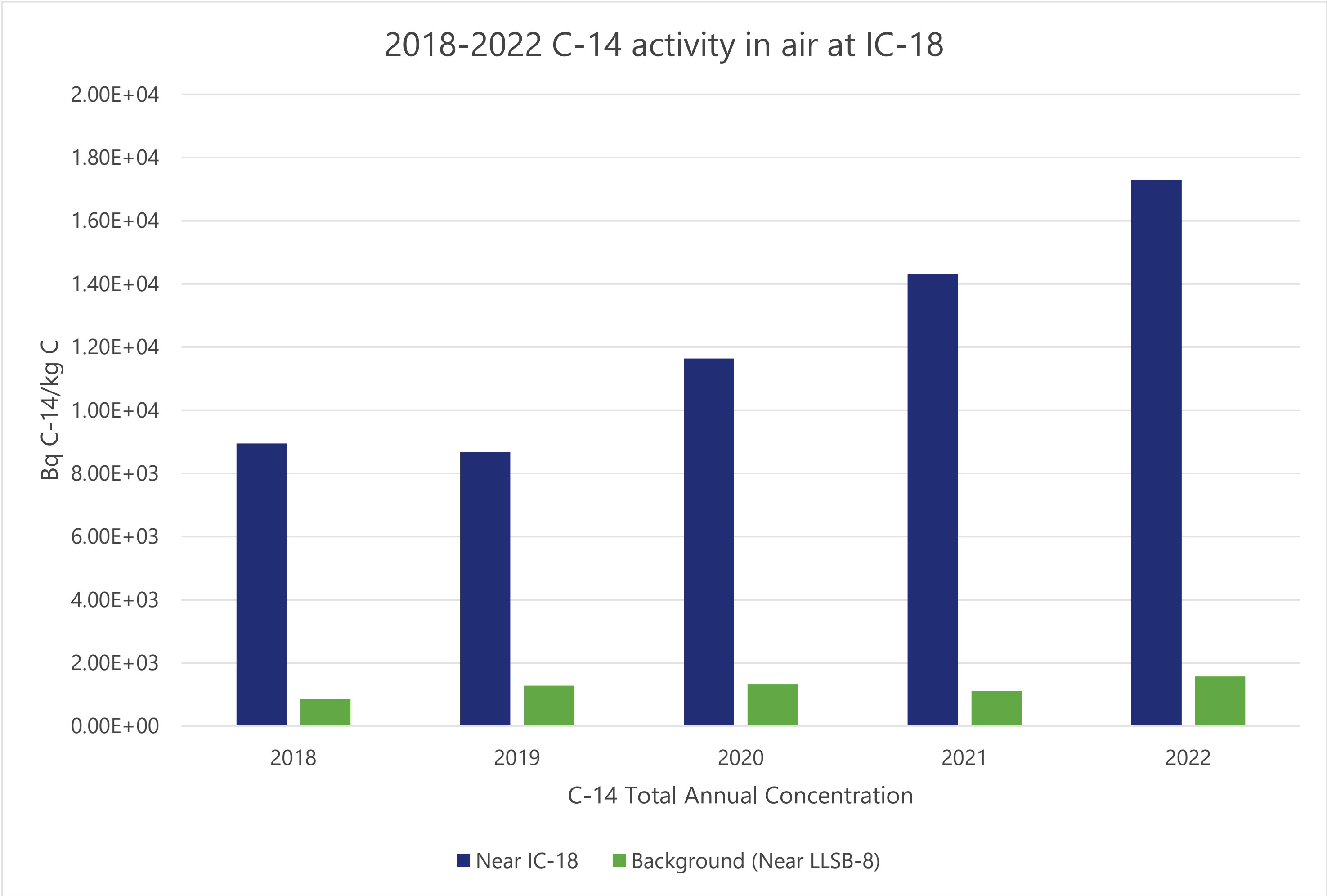


Figure 2.13: 2018-2022 C-14 Average Annual Concentration at NSS-WWMF for Samplers B#3 (Near IC-18) and B#13 (Background)

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 N288.1-14 [21]. 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 [9].

3.1.2 Public Dose from NSS-WWMF Operations

Bruce Power reported the annual public dose to be 2.4 µSv to the Bruce Subsistence Farmer (infant) in 2022 based on results from their 2022 EMP [9]. This is approximately three orders of magnitude below the public dose limit of 1 mSv/a. The public dose arising from NSS-WWMF operations is a portion of the 2.4 µSv 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 2022, Bruce Power reported that the annual average tritium in drinking water at these WSPs was 3.95 Bq/L at the Kincardine WSP and 10.4 Bq/L at the Southampton WSP [9]. These are well below the Ontario Drinking Water Standard 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 2022 showed that doses at all locations around the facility boundaries were around 0.1 µGy/h, compared to the derived dose rate limit of 0.5 µGy/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 average C-14 concentration in air at the IC-18s (Figure 2.13) from 2022 of 1.73E+04 Bq/kgC, 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 0.06 µSv/a. This is well below the dose limit for a non-NEW of 1,000 µSv/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/kgC 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 1.18E-03 mGy/day, well below the terrestrial dose benchmark of 2.4 mGy/day [22] [7].

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.

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

	Bruce A	Bruce B	CMF	CSF	NSS-WWMF(c)	CNL	Kinectrics KI(b)	Total	%NSS-WWMF(b)
					Airborne Emissions (Bq/year)				
Tritium Oxide	1.7E+15	3.7E+14	3.2E+09	1.4E+11	1.4E+13	2.4E+11	2.2E+11	2.1E+15	0.68%
Noble gas (Bq-MeV/yr)	8.1E+13	4.1E+13	N/A	N/A	N/A	N/A	N/A	1.2E+14	N/A
I-131	6.8E+08	4.0E+06	0.0E+00	N/A	5.2E+03	N/A	N/A	6.8E+08	0.00%
Particulate Beta/Gamma (a)	2.6E+06	6.3E+06	0.0E+00	0.0E+00	0.0E+00	1.2E+05	N/A	9.1E+06	0.00%
Particulate-Gross Alpha	2.1E+04	7.5E+04	4.4E+02	N/A	N/A	N/A	N/A	9.6E+04	N/A
C-14	2.5E+12	8.6E+11	N/A	N/A	5.2E+09	N/A	N/A	3.4E+12	0.16%
					Waterborne Emissions (Bq/year)				
Tritium Oxide	2.8E+14	5.7E+14	-	-	N/A	2.4E+10	N/A	8.5E+14	N/A
C-14	6.9E+08	9.0E+08	-	-	N/A	N/A	N/A	1.6E+09	N/A
Gross β/ γ	1.7E+09	1.5E+09	-	-	N/A	N/A	N/A	3.2E+09	N/A
Gross β	N/A	N/A	-	-	N/A	8.6E+06	N/A	8.6E+06	N/A
Gross α	<Ld	<Ld	-	-	N/A	5.7E+06	N/A	5.7E+06	N/A

a) Naturally occurring radionuclide material detected in gamma spectrum analysis is not reported.

b) This is the net airborne emission from KI North Facility for the period of December 31, 2021 to December 29, 2022. There were no waterborne emissions in 2022 for Kinectrics KI

c) 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

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) [18], 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 is to read out eight dosimeters every quarter that were irradiated to known environmental exposures by the National Research Council Canada and achieve a mean relative bias less than ±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 2022, the OPG EGM system met these accuracy and precision requirements. Results of its HPL QA testing for 2022 were satisfactory and are documented in its annual QA report [23].

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 2022, an HPL QA audit was conducted on the Tritium in Water Duty Area of the Health Physics Laboratory.

The Tritium in Water Duty Area of the Health Physics Laboratory identified eight recommendations and zero findings. The eight recommendations are being addressed through AR 28255294, 'Actions from Self Assessment RF22-000096-SA 2022 Audit Tritium in Water'. There were no significant non-conformances affecting quality of results, recommendations represent opportunities for improvement or clarity of areas where further review is warranted.

The MECP performed Drinking Water Licence Inspections of the HPL in June and November 2022. In June there was one finding indicating that the lab was unable to identify the start time of instrumentation for Tritium analysis at the time of the inspection. To address this finding, HPL implemented the changes to identify each sample's start and end times on instrument data printout. MECP was satisfied that the implemented changes have met all regulatory requirements relating to the required actions (N-CORR-03443-1216770). The Final Inspection Rating was 100% In November, there were no non-compliant findings. Overall, the final inspection ratings for both audits were 100% [23].

The Canadian Nuclear Safety Commission (CNSC) completed a Type II inspection of the Environmental Monitoring Program beginning November 7, 2022. The inspection report was not provided at the time of the 'Annual Summary 2022 – HPL Environmental Measurement QA Program' report.

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, surface water, and precipitation sample analyses, that is, HTO and gross β activity in water, met all requirements, including accuracy and precision requirements as per external laboratory testing.

Bruce Power had one external audit in 2022, performed by the Canadian Standards Association International Organization for Standardization 14001 Environmental Management System Standard [9]. No non conformances and five opportunities for improvement were identified. Opportunities for improvement are for consideration to further enhance the environmental management system and environmental performance. The audit confirmed the following:

- Bruce Power continues to effectively implement a management system that meets the International Organization for Standardization 14001:2015 standard for the scope of registration identified in the report.
- Bruce Power ensures the management system remains effective considering internal and external changes.
- Bruce Power demonstrates a commitment to maintain the effectiveness and improve the management system in order to enhance overall performance.
- Bruce Power operates the management system to ensure the achievement of the slated policies and objectives.

4.2 Program Quality Assurance

EMP program QA includes self-assessments and audits as per the requirements of CSA N288.4-10 [2] and OPG procedures. There were no assessments or audits of the EMP program in 2022. The most recent internal audit was conducted in 2019.

4.2.1 Self-assessments

<u>Performance Assessment</u>

Self-assessment COE22-000106-SA was completed for the 2020 EMP Annual Performance Assessment. The assessment confirmed that all EMP design objectives were met and the results of the 2020 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 2022 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 2022. 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 232 TLD samples were planned for 2022, 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 232 results were obtained and valid, producing an overall unavailability of 0%.

As per the recommendation of the 2021 ERA tritium monitoring in precipitation was discontinued in 2022.

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 2022 groundwater monitoring plan collected 110 of the planned 110 samples and had an overall unavailability of 0.0%.

Sampling of C-14 in groundwater was discontinued in 2022 based on the results of the Conceptual Site Model and the Groundwater Protection and Monitoring Program development per CSA N288.7.

5.0 Overall Summary of EMP

An EMP detailed design was developed for the NSS-WWMF in 2012 [5] with updates made in 2019 [3]. All objectives of the EMP concerning public and worker safety and demonstrating containment of radioactivity were met in 2022. 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 limit. Concentrations of tritium at nearby WSPs were below 100 Bq/L on an annual average basis (Objectives 1 and 7).

Measurements of TLDs around the NSS-WWMF and RWOS 1 (Objective 2) are below the derived dose rate limit of 0.5 µGy/h. Despite an increasing trend in three locations, no TLD exceeded 0.286 µGy/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. Two wells at the NSS-WWMF showed statistically significant increasing trends in tritium, however they remain well below the level of 60,000 Bq/L at which OPG has committed to notify the CNSC. Of these wells, WSH 230 (annual average 667 Bq/L) and WSH 229 (annual average 1,100 Bq/L) had concentrations above 500 Bq/L.

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 2018 to 2022. 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-W Annual Groundwater Report and the supplementary Addendum NSS-W Annual Groundwater Report which are compliant with CSA N288.7. These reports are currently in progress for 2022.

Monitoring of HTO in precipitation (previously objective 4) was discontinued in 2022.

Monitoring in the South Railway Ditch (Objective 4) is completed as part of routine sampling. Surface water in the South Railway Ditch 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. No statistically significant trends were observed in the monitored locations for 2018- 2022.

Sediment and water in the SRD, wetland, and East Stormwater Management Pond areas of the NSS-WWMF (Objective 5) were monitored in a supplementary study conducted in 2013-2014 and used in the 2016 ERA [16]. Sediment and water samples were also collected in the SRD, wetland, and East Stormwater Management Pond areas in 2020-2021 to support the NSS-WWMF ERA update. The 2021 NSS-WWMF ERA concluded no risk to the majority of aquatic biota due to exposure to metals and radionuclides. Risk was identified to benthic invertebrates in the SRD due to exposure to nickel and zinc in water and multiple metals (chromium, copper, manganese, nickel, sodium) and dioxins/furans in sediment. The wetland was assessed with the SRD and East Stormwater Management Pond since the wetland receives drainage from multiple sources including the SRD, East Stormwater Management Pond, and a construction landfill. Elevated concentrations of strontium in the wetland appear to be coming from another source other than the SRD, such as a construction landfill. Strontium will be monitored in the wetland as part of the next ERA update to determine if this is an emerging trend.

Increasing C-14 concentration in air at the NSS-WWMF has been attributed to moderator exchange resin stored in Area 1. A fugitive emissions reassessment has been completed to address this finding. OPG has reviewed the estimating methodology and is working with the contractor to further refine the prediction instrument. Scrubbers were installed in select ICs in 2021 and 2022 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.

Overall, the results of the 2022 NSS-WWMF EMP indicate confirmation of adequate protection of the public, the workers, and the 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 South Railway Ditch 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 South Railway Ditch and East Stormwater Management Pond will continue. A supplementary study to collect water and sediment data for non-radionuclides was completed in 2020-21 in support of the 2021 NSS-W ERA update and should be repeated prior to the next ERA update.
- Wetland sampling: The East Wetland was sampled in 2020-21 as part of supplementary studies to support the 2021 NSS-WWMF ERA and should be repeated prior to the next ERA update.
- C-14 monitoring in air: Currently implemented with a focus on the upward trend close to IC-18. Scrubbers were installed in select ICs in 2021 and 2022. Subsequent results should indicate if this mitigation is sufficient to address the recently observed upward trend.

7.0 References

[1] Canadian Nuclear Safety Commission (CNSC), "Environmental Protection: Environmental Principles, Assessments and Protection Measures, REGDOC-2.9.1, Version 1.1," 2016.

[2] Canadian Standards Association (CSA), "Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills, CSA N288.4-10," May 2010.

[3] Ontario Power Generation (OPG), "Western Waste Management Facility Environmental Monitoring, W-MAN-03443-00001-R001," 2019.

[4] Ontario Power Generation (OPG), "2013 Results of the Environmental Monitoring Program for Western Waste Management Facility. OPG Assigned Document Number W-REP-03443-00001-NA-R000," 2014.

[5] Amec Foster Wheeler (AMEC), "Detailed Design of Environmental Monitoring Program for OPG's Western Waste Management Facility. OPG Report No. W-REP-07002," July 2012.

[6] Ecometrix, "Environmental Risk Assessment 2021 Update - Western Waste Management Facility," December 2021.

[7] Canadian Standards Association (CSA), "Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills, CSA N288.6-12," June 2012.

[8] Ontario Power Generation (OPG), "Nuclear Sustainability Services Western In-Ground Storage Structures Aging Management Plan, OPG Report, 01098-PLAN-01060-00005-R002," 2022.

[9] Bruce Power, "2021 Environmental Protection Report, BP Assigned Document No. B-REP-07000-00014," April 2022.

[10] Ontario Power Generation (OPG), "EGM System Overview. Procedure N-HPP-03443.4-10099-EGM-01-R001," November 2013.

[11] Ontario Power Generation (OPG), "Nuclear Waste Management Western Waste Quarterly Operations Report First Quarter 2021. W-REP-00531.1-00099," 2021.

[12] Ontario Power Generation (OPG), "Nuclear Waste Management Western Waste Quarterly Operations Report Second Quarter 2021. W-REP-00531.1-00100," 2021.

[13] Ontario Power Generation (OPG), "Nuclear Waste Management Western Waste Quarterly Operations Report Third Quarter 2021. W-REP-00531.1-00101," 2021.

[14] Ontario Power Generation (OPG), "Nuclear Waste Management Western Waste Quarterly Operations Report Fourth Quarter 2021. W-REP-00531.1-00102," 2021.

[15] Ontario Power Generation (OPG), "WWMF and RWOS1 Radiological Sampling of Groundwater and Inground Storage Structures. 0125-OP-79017-00001-R017," 2018.

[16] Amec Foster Wheeler (AMEC), "Environmental Risk Assessment for the Western Waste Management Facility. OPG Report No. 01098-REP-07701-00011-R001," October 2016.

[17] C. Zaiontz, "Real Statistics Using Excel.," [Online]. Available: www.real-statistics.com.

[18] Ontario Power Generation (OPG), "Environmental Monitoring Programs Quality Assurance Manual, N-MAN-03443-10005-R002," 2016.

[19] Ontario Power Generation (OPG), "EGM System Overview. Procedure N-HPP-03443.4-10099-EGM-01-R001," November 2013.

[20] CH2M Hill (CH2M), "Ontario Power Generation Western Waste Management Facility – Groundwater Monitoring Well Network Assessment. OPG Report No. W-REP-0125-REP-79100-00034.," November 2016.

[21] Canadian Standards Association (CSA), "Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities, CSA N288.1-14," 2014.

[22] United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), "United Nations Scientific Committee on Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. UNSCEAR 2008 Report to the General Assembly with Scientific Annexes. Annex E. Effects of Ionizing Radiation on Non-human Biota," 2008.

[23] Ontario Power Generation (OPG), "Annual Summary 2022 – Health Physics Laboratory Environmental Measurement Quality Assurance Program, OPG Report, N-REP-03443.8-10016," February 2022.

[24] Kinectrics, "2019 Certificate of Accreditation: Analytical and Environmental Services Laboratory," 2019.

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 (µSv)	=	0.1 millirem (mrem)

Quantity of Radionuclide

1 becquerel (Bq)	=	1 disintegration per second
1 curie (Ci)	=	3.7 x 10^{10} Bq
1 mCi/(km^2·month)	=	37 Bq/(m^2·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
μGy	microgray
μSv	microsievert
Bq	becquerel
Gy	Gray
kg	kilogram
L	Litre
mGy	milligray
mSv	millisievert
Sv	Sievert

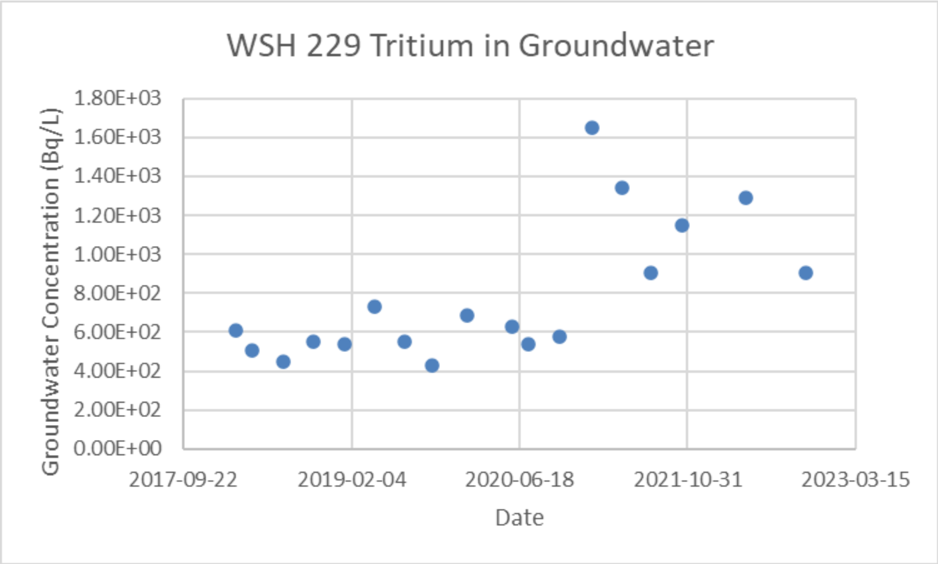
Acronyms and Abbreviations

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
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 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
NRC	National Research Council of Canada
NSS-WWMF	Nuclear Sustainability Services – Western Waste Management Facility
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
SD	Standard Deviation
SGSB	Steam Generator Storage Building
SMP-1	East Stormwater Management Pond
SRD	South Railway Ditch
SSTF	Spent Solvent Treatment Facility
TLD	Thermo Luminescent 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 2018-2022

This appendix contains the plots of tritium with statistically significant increases over the 5-year period 2018-2022. 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.



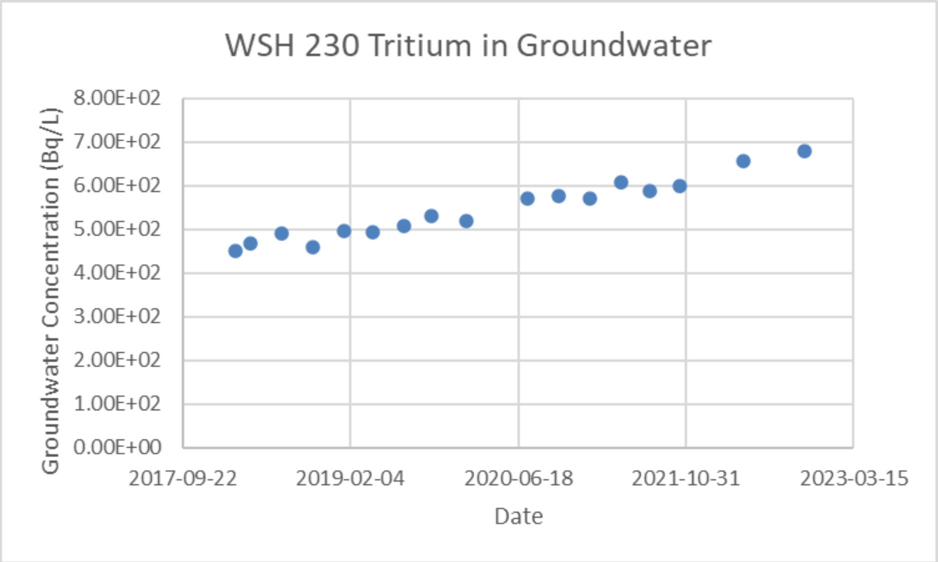


Figure C.1: Measured Tritium in Groundwater Wells with Significant Trends

Appendix D Summary of Samples Collected

Table D.1: Summary of Samples Collected, Monitoring Period and Deviation from the Plan during the 2022 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 2022	No	2022, trend analysis: 2018 - 2022
Groundwater Monitoring	Yes	2022 (wells monitored either annually or bi-annually)	No	2022, trend analysis: 2018 - 2022
SRD	Yes – (presented average and 2 sigma for each measurement station consistent with the 2021 EMP). Raw data is not provided in the EMP Report.	2022	No	2022, trend analysis 2018 - 2022
C-14 in air	Yes	2022	No (79 of the 80 planned samples were obtained)	2022, trend analysis 2018 - 2022

Appendix E Groundwater and Ditch Surface Sample Unavailability

Table E.2: 2022 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 Bi-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

	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

	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	-	-	-	-	4	4	0.0