

Report

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Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 1 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

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2023 Western Waste Management Facility Groundwater Program Results

W-REP-07294-00005-R001

January 24, 2025

Order Number: N/A

Other Reference Number: N/A

OPG Proprietary

Electronically approved via Asset Suite

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Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 2 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table of Contents

	Page
Revision Summary	5
Land Acknowledgement	6
Executive Summary	7
1.0 INTRODUCTION.....	8
1.1 Summary of Hydrogeological Characteristics at the WWMF and RWOS1	12
1.2 Subsurface Drainage System at the WWMF and Discharge Infrastructure	12
2.0 2023 PROGRAM DESIGN.....	13
2.1 Objective 1 (A)– Tritium near LLSBs, SGSB and RWCSB within the WWMF	13
2.2 Objective 1 (B) – RWOS1	14
2.3 Objective 1 (C) – Background Tritium Concentrations at WWMF	14
2.4 Objective 2 – Annual Snapshot of Hydraulic Head Measurements	14
2.5 Objective 3 – Downgradient Perimeter Groundwater Monitoring	14
3.0 2023 PROGRAM RESULTS.....	19
3.1 Objective 1 (A) Results – Tritium near SSCs at the WWMF	19
3.1.1 LLSBs #1 to #10.....	19
3.1.2 LLSBs #11 to #14, SGSB and RWCSB	25
3.1.3 Trenches, Tile Holes, ICs and Quadricells.....	28
3.2 Objective 1 (B) Results – RWOS1	38
3.3 Objective 1 (C) Results – Background Tritium	41
3.4 Objective 2 Results – Annual Snapshot of Hydraulic Head Measurements	44
3.5 Objective 3 Results – Downgradient Perimeter Groundwater Wells.....	49
4.0 2023 QUALITY ASSURANCE AND QUALITY CONTROL	52
4.1 Quality Assurance Program for Laboratories	52
4.2 Quality Control Results	52
5.0 SUPPLEMENTARY STUDIES	52
6.0 NOMENCLATURE OF SAMPLING LOCATIONS	52
7.0 ACRONYMS AND UNITS.....	53
8.0 REFERENCES.....	53
Appendix A: Tables A-1 to A-7.....	54

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 3 of 63

Title:	2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS
--------	---

List of Figures, Graphs and Table

Page

Figure 1: WWMF & RWOS1 Site Location and Boundaries	10
Figure 2: WWMF Site Buildings and Structures	11
Figure 3: 2023 Monitoring Locations – Objective 1 (A).....	15
Figure 4: 2023 Monitoring Locations – Objective 1 (B), RWOS1.....	16
Figure 5: 2023 Monitoring Locations – Objective 1 (C), Background Tritium Concentrations at the WWMF	17
Figure 6: 2023 Monitoring Locations – Objective 3, Downgradient Perimeter Wells at the WWMF	18
Figure 7: 2023 Maximum Tritium Concentrations – Objective 1 (A), LLSB #1 to #10	21
Figure 8: 2023 Maximum Tritium Concentrations – Objective 1 (A), LLSB #11 to #14, SGSB and RWCS	26
Figure 9: 2023 Maximum Tritium Concentrations – Objective 1 (A), Trenches Tile Holes, Inground Containers and Quadricells.....	31
Figure 10: 2023 Maximum Tritium Concentrations – Objective 1 (B), RWOS1	40
Figure 11: 2023 Maximum Tritium Concentrations – Objective 1 (C), Background Monitoring Wells	43
Figure 12: 2023 Shallow (HU1-3) Groundwater Contours based on May 15 th , 2023 measurements.....	45
Figure 13: 2023 MSA (HU4) Groundwater Contours based on May 15 th , 2023 measurements.....	46
Figure 14: 2023 Bedrock (HU7) Groundwater Contours based on May 15 th , 2023 measurements	47
Figure 15: 2023 Native Sand (HU 2) Groundwater Contours at RWOS1 based on May 15 th , 2023 measurements	48
Figure 16: 2023 Maximum Tritium Concentrations – Objective 3, Downgradient Perimeter Monitoring Wells	51
Graph 1: WSH237 Tritium Data	22
Graph 2: WSH253 Tritium Data	22
Graph 3: SS4B Tritium Data	23
Graph 4: WSH231 Tritium Data	23
Graph 5: WSH257 Tritium Data	24
Graph 6: WSH230 Tritium Data	24
Graph 7: SS6 Tritium Data.....	27
Graph 8: WSH269 Tritium Data	27
Graph 9: SS1 Tritium Data.....	29
Graph 10: SS2 Tritium Data	29
Graph 11: SS3 Tritium Data	30
Graph 12: WSH284 Tritium Data	33
Graph 13: WSH282 Tritium Data	33
Graph 14: WSH265 Tritium Data	34
Graph 15: WSH285 Tritium Data	34
Graph 16: WSH243 Tritium Data	35
Graph 17: WSH229 Tritium Data	36
Graph 18: WSH240 Tritium Data	37
Graph 19: WSH228 Tritium Data	37
Graph 20: WSH122 Tritium Data	39
Graph 21: WSH123 Tritium Data	39
Graph 22: WSH278 Tritium Data	42

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 4 of 63

Title:	2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS
--------	---

Graph 23: WSH249 Tritium Data50
Graph 24: WSH263 Tritium Data50

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 5 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Revision Summary

Revision Number	Date	Comments
000	2024-10-30	Initial issue.
001	2025-01-24	CNSC comments revision

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 6 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Land Acknowledgement

OPG acknowledges that the 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, 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

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: 1N/A	Revision Number: R001	Page: 7 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Executive Summary

The Western Waste Management Facility (WWMF) and the Radioactive Waste Operations Site 1 (RWOS1) have a mature and robust groundwater protection program. The groundwater monitoring aspect of the program is in place to address the following three primary goals:

- Monitor changes to on-site groundwater quality to ensure timely detection of inadvertent releases to groundwater;
- Confirm predominant on-site groundwater flow characteristics at both sites; and
- Ensure no adverse off-site impacts from groundwater beneath the WWMF and RWOS1.

The findings in 2023 with respect to the monitoring program include the following:

- The groundwater data collected from the systems, structures and components indicate tritium concentrations are:
 - consistent with results for previous years and expected fluctuations associated with ongoing operations, or
 - where tritium concentrations have been elevated above background conditions historically, they are generally showing improvement (decreased concentrations).
 - Increases in tritium concentrations in groundwater were observed in a small number of wells; the increases are understood to be associated with historical conditions and do not represent inadvertent releases.
- The predominant groundwater flow patterns remain unchanged in 2023 from interpretations in recent years.
- Tritium concentrations within the site perimeter wells are low (at background values), stable, and far below values that would indicate potential risks to off-site water quality and use beneath the WWMF or RWOS1.

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 8 of 63

Title:	2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS
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1.0 INTRODUCTION

The Western Waste Management Facility (WWMF) and Radioactive Waste Operations Site 1 (RWOS1) are located at the Bruce Nuclear site, within the municipality of Kincardine in the County of Bruce. The WWMF and RWOS1 are each situated at an approximate distance of 1.1 km from the east shore of Lake Huron, near the Village of Tiverton between Kincardine (south) and Port Elgin (north). The WWMF is licensed by the CNSC as a class 1B Nuclear Facility to manage and store radioactive waste from Ontario Power Generation’s (OPG’s) and Bruce Power’s nuclear generating station. The RWOS1 is located approximately 660 meters southwest relative to the WWMF and operates under a Waste Nuclear Substance Licence.

OPG’s WWMF and RWOS1 have a mature and robust annual groundwater monitoring program in place. The program examines the chemical, radiological, and physical characteristics of the groundwater beneath the site.

The following objectives for the groundwater monitoring program are documented in the N288.7-compliant WWMF and RWOS1 Groundwater Protection Monitoring Program (GWPMP) (Ecometrix, 2022a):

- Objective 1:
 - A: monitor tritium concentrations in groundwater near Low-Level Storage Buildings (LLSBs), Steam Generator Storage Building (SGSB), and the Retube Waste Container Storage Building (RWCSB) within the WWMF to ensure timely detection of inadvertent releases to groundwater;
 - B: monitor tritium concentrations in groundwater beneath the RWOS1 to ensure timely detection of inadvertent releases to groundwater;
 - C: establish and monitor background tritium concentrations in groundwater at the WWMF;
- Objective 2: confirm the predominant on-site groundwater flow characteristics beneath the WWMF and RWOS1; and
- Objective 3: monitor tritium concentrations in groundwater on the perimeter of the WWMF and RWOS1 in the direction of groundwater flow (“Downgradient Perimeter”) to confirm no adverse off-site impacts to groundwater quality.

The location of the WWMF and RWOS1 are shown in Figure 1. Within the WWMF, the LLSBs, SGSB and RWCB are shown in Figure 2, along with other infrastructure including the Used Fuel Dry Storage building. Stages 1, 3 and 3E are discussed as well in this report, which pertain to the trenches, tile hole inground container and Quadricell area, which are shown in Figure 2.

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 9 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

The groundwater sampling and monitoring program conducted in 2023 followed the Sampling and Analysis Plan (SAP) for 2023 (Ecometrix, 2022c). This report presents groundwater data collected at WWMF for the period from January 1st to December 31st, 2023.

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 10 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 1: WWMF & RWOS1 Site Location and Boundaries

Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 11 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 2: WWMF Site Buildings and Structures

Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 12 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

1.1 Summary of Hydrogeological Characteristics at the WWMF and RWOS1

Seven hydrostratigraphic units (HUs) have been identified beneath the WWMF and RWOS1 through historical assessments. Of the seven HUs, three main groundwater flow systems (comprised of 5 HUs) have been identified for the site:

- HU 1-3: Perched/Shallow Water Table, comprised of fill, native sand and silt till
- HU 4: Middle Sands Aquifer (MSA)
- HU 7: Limestone/Dolostone Bedrock

Surficial fill materials at the site (HU1) are unsaturated and lie above the water table. The underlying sands (HU2) are silty and frequently contain gravel and are unsaturated or partially to fully saturated, depending on the location. Underlying the sands is a weathered till unit of clayey to sandy dense subglacial silt till with interbeds of fine to coarse sand, and fine to coarse gravel (HU3). The HU4 consists of beds of silty fine sand to well-sorted sand with occasional gravel layers and some silt till interbeds and represents an aquifer. The HU5 shares similar characteristics to HU3 but this deeper till is less weathered and more competent. The basal sand unit (HU6) is discontinuous as well and where it occurs, HU6 and HU7 form one aquifer unit.

Between HU1-3, HU4 and HU7, groundwater flow is generally vertical to subvertical, downwards, through the fine-grained till units (Ecometrix, 2022b).

At the RWOS1, overburden beneath the western portion of the site consists of till overlying dolostone bedrock, and overburden beneath the eastern portion of the site consists of sand and lesser till overlying bedrock. The monitoring wells in the eastern portion of the site are installed within the native sands, which are found to extend approximately 4-6 metres from the ground surface to bedrock. Groundwater is encountered at the sand-bedrock interface. The groundwater monitored is considered to represent a single unconfined hydrostratigraphic unit, and best aligns with HU2.

1.2 Subsurface Drainage System at the WWMF and Discharge Infrastructure

Inside the WWMF fenced area, groundwater and surface water are collected by several engineered drainage systems. The surface drainage system captures runoff from precipitation and discharges collected water to the South Railway Ditch (SRD).

The sub-surface drainage system at the WWMF includes drains and sumps associated with building foundations, tile holes or trenches. Buildings with subsurface drainage systems include the LLSBs (#2 to 10, #11 to 14), SGSB, RWCSB and the Used Fuel Dry Storage building. The LLSB #1 does not have a subsurface drainage system.

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 13 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Water collected by the subsurface drainage systems is directed to either the SRD or the stormwater management pond. The SRD and stormwater management pond are shown in Figure 2. Monitoring of the groundwater quality collected by the subsurface drainage is part of the GWPMP for the WWMF, Objective 1.

2.0 2023 PROGRAM DESIGN

The groundwater monitoring program design is detailed in the WWMF GWPMP (Ecometrix, 2022a). The N288.7-compliant 2023 SAP (Ecometrix, 2022c) was developed to meet the relevant components of the objectives listed above.

In 2023, as per the SAP, groundwater samples were collected from fifty-three (53) sampling locations in total, including groundwater monitoring wells and subsurface drainage structures. Sample results of the groundwater quality monitoring are provided in Appendix A.

The 2023 SAP specified the sampling locations and the frequency of sampling tritium concentrations in groundwater at each location (e.g., semi-annually or annually).

Water levels were measured before the collection of groundwater samples for analysis of tritium concentrations by OPG technicians. Following measurement of the water level and prior to sample collection, each monitoring well was purged to remove standing water, ensuring that groundwater representative of the conditions in the HUs was sampled. Collected samples were analyzed for tritium concentrations by the Bruce Power Health Physics Laboratory.

The groundwater data generated from the sampling program was subsequently analyzed to support previous conclusions, identify trends, reflect improvements and/or to demonstrate no significant change in tritium concentrations concerning historical values. Refer to Section 6.0 of this report for details on the sampling naming/location nomenclature used in the groundwater program.

2.1 Objective 1 (A)– Tritium near LLSBs, SGSB and RWCSB within the WWMF

Included within Objective 1 (A) are the following areas of the site and systems, structures and components (SSCs):

- LLSBs #1 to #10;
- LLSBs #11 to #14, SGSB and RWCSB; and
- Trenches, Tile Holes, Quadricells and Inground Containers (ICs).

Figure 3 shows the locations of groundwater wells and subsurface structures in which groundwater quality was monitored for Objective 1 (A).

Sample results for tritium concentrations related to Objective 1 (A) are presented in Appendix A (Table A-1a, Table A-1b, Table A-2a, Table A-2b, Table A-3a and Table A-3b).

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 14 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

2.2 Objective 1 (B) – RWOS1

In 2023, groundwater quality was monitored in five groundwater monitoring wells at the RWOS1. Figure 4 shows the locations of the wells monitored for this objective. Sample results for tritium concentrations in groundwater related to Objective 1 (B) are presented in Appendix A (Table A-4).

2.3 Objective 1 (C) – Background Tritium Concentrations at WWMF

In 2023, six locations were monitored to establish background tritium concentrations in groundwater at the WWMF. Figure 5 shows the groundwater wells monitored for this objective. Sample results for tritium concentrations in groundwater related to Objective 1 (C) are presented in Appendix A (Table A-5).

2.4 Objective 2 – Annual Snapshot of Hydraulic Head Measurements

Groundwater flow interpretations for the WWMF and RWOS1 were developed in the WWMF GWPMP (Ecometrix, 2022c). On an annual basis, the GWPMP requires that a set of water levels be collected from all wells at RWOS1 and a subset of the wells in the groundwater well network at the WWMF over a short period of time (days). This “snapshot” program intends to verify that groundwater flow conditions, which are the basis for interpreting the migration of constituents in groundwater, have not changed and that OPG continues to have a sound understanding of groundwater flow patterns at the site.

The water level readings collected on May 15, 2023 were used to calculate the groundwater elevation at each monitoring well and generate water elevation contours, from which groundwater flow directions are inferred. Groundwater flow directions are interpreted to be perpendicular to and downgradient across the contour lines.

2.5 Objective 3 – Downgradient Perimeter Groundwater Monitoring

In 2023, groundwater quality was monitored in seven groundwater wells located on the perimeter of the WWMF. Locations monitored for this objective are shown in Figure 6. Sample results of groundwater tritium concentrations for Objective 3 are presented in Appendix A (Table A-6).

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 15 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 3: 2023 Monitoring Locations – Objective 1 (A)

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 16 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 4: 2023 Monitoring Locations – Objective 1 (B), RWOS1

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 17 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 5: 2023 Monitoring Locations – Objective 1 (C), Background Tritium Concentrations at the WWMF

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 18 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 6: 2023 Monitoring Locations – Objective 3, Downgradient Perimeter Wells at the WWMF

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 19 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

3.0 2023 PROGRAM RESULTS

3.1 Objective 1 (A) Results – Tritium near SSCs at the WWMF

In 2023, the groundwater data collected from the areas surrounding SSCs at the WWMF indicate that tritium concentrations in groundwater have remained, overall, consistent with results for previous years and within the ranges of expected fluctuations resulting from ongoing routine operations or represent the expected movement of well characterized and understood tritium releases to groundwater. Further discussion is provided in the sections below.

The frequency of sampling of the subsurface drainage is monthly. The frequency of sampling of groundwater monitoring wells has been specified based on groundwater conditions at the locations being sampled. Semi-annual sampling is the most frequent and biennial sampling is the least frequent.

3.1.1 LLSBs #1 to #10

Within the LLSB #1 to #10 area, the primary point source (or, SSC) of tritium to groundwater is tritiated water vapour that originates from the stored waste within the LLSBs. Tritium that condenses on the internal and external surfaces of the LLSBs and surrounding asphalt surfaces has the potential to migrate to the subsurface via sumps or pervious surfaces. In recent years, and including in 2023, conditions with respect to tritium concentrations in groundwater in this area are, for the most part, decreasing over time or are stable and not showing changes over time.

Maximum tritium concentrations in groundwater, in all HUs beneath the LLSB #1 to #10 area, in 2023 are shown in Figure 7. Tritium concentrations are highest to the north of LLSBs #3, specifically in the monitoring well WSH253, and in the subsurface drainage, SS4B.

Tritium concentrations in groundwater to the west of the LLSBs #1 to #10, in monitoring wells WSH237, WSH238 and WSH239 (all in HU7), are stable, decreasing or demonstrate no trend, as shown in Graph 1 for WSH237. These wells are located in the inferred upgradient groundwater flow direction to the LLSBs #1 to #10 (see Objective #4, Section 2.4) and tritium concentrations in these wells represent background conditions in those HUs within this area of the site.

North and east of LLSBs #1 to #5, maximum concentrations of tritium in groundwater are measured in the subsurface drainage, monitored at SS4B. Tritium concentrations in SS4B have decreased over time and stabilized to values between approximately 10,000-20,000 Bq/L in the past five years, as shown in Graph 3. In 2023, tritium concentrations in SS4B ranged from 8,490 Bq/L (October) to 66,600Bq/L (January), with an annual average concentration of about 16,500 Bq/L (Graph 3 and Table A-1b). The elevated reading of tritium

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 20 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

concentration (January H3=66,600 Bq/L) is considered an outlier when compared to the upper bound (40,925 Bq/L) and the lower bound (11,800 Bq/L) of the dataset averaged over the last ten years. This reading was still included in the analysis, since it is still below the administrative levels (98,000 Bq/L), and the measurements return to the average concentrations in the following months starting February 2023 (13,900 Bq/L).

Tritium concentrations above background values are observed in the shallow till/fill material (HU1-3) and in the MSA (HU4), which is encountered at relatively shallow depths within the LLSBs #1 to #10 area. Maximum tritium concentrations in groundwater within the shallow fill/till were 6,390 Bq/L in 2023 (WSH252). Within the MSA, maximum tritium concentrations were observed in WSH253 (20,700 Bq/L) in 2023, as they have been historically; tritium concentrations in this well have been stable in recent years (Graph 2). Further downgradient, tritium concentrations in WSH231 are decreasing steadily (Graph 4). To the west of the LLSBs, tritium concentrations are approximately 3,000 Bq/L in monitoring wells WSH255, WSH256, and WSH257, as shown in Graph 5 for WSH257.

Tritium concentrations in the underlying unweathered till (HU5) and bedrock aquifer (HU7) to the northeast of LLSBs #1 to #5 show tritium concentrations above background levels, reflecting natural downward vertical gradients between the MSA and the deeper groundwater units across the WWMF (Ecometrix, 2022b). In bedrock (HU7), monitoring well WSH230 is clustered with MSA well WSH231 (HU4). Tritium concentrations in the bedrock hydrostratigraphic unit at WSH230 are increasing, as shown in Graph 6, with a maximum concentration of 748 Bq/L in 2023 which is approximately one order of magnitude lower than the concentrations in the overlying MSA at WSH231 (maximum concentration in 2023 of 9,390 Bq/L; Figure 7). Low levels of tritium are migrating to the northwest in the groundwater in bedrock (HU7). This increase is expected as part of the migration of tritium in groundwater originating from beneath the LLSBs #1 to #5, primarily, and migrating downwards from the MSA into deeper till and the bedrock aquifer.

The extent of migration of tritium further downgradient in HU7 is being monitored in wells WSH302 and DGRB-12. Tritium concentrations in well WSH302 are at background levels based on 2022 data. Tritium concentrations were only available for DGRB-12 in 2022. The measured tritium value of 110 Bq/L is elevated to a limited extent above expected background concentrations in HU7 beneath the LLSBs #1 to #10.

The data in 2023 confirms that groundwater conditions continue to improve overall, with respect to tritium concentrations north and east of LLSBs #1 and #5. Tritium continues to migrate downwards in groundwater from shallow groundwater to the bedrock hydrostratigraphic unit. The extent of tritium migration in HU7 will continue to be monitored. Monitoring of additional downgradient perimeter wells as part of Objective 3 (Section 2.5) demonstrates that tritium concentrations in the perimeter wells remain substantively below groundwater evaluation criteria.

Groundwater quality in this area will continue to be monitored.

Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 21 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

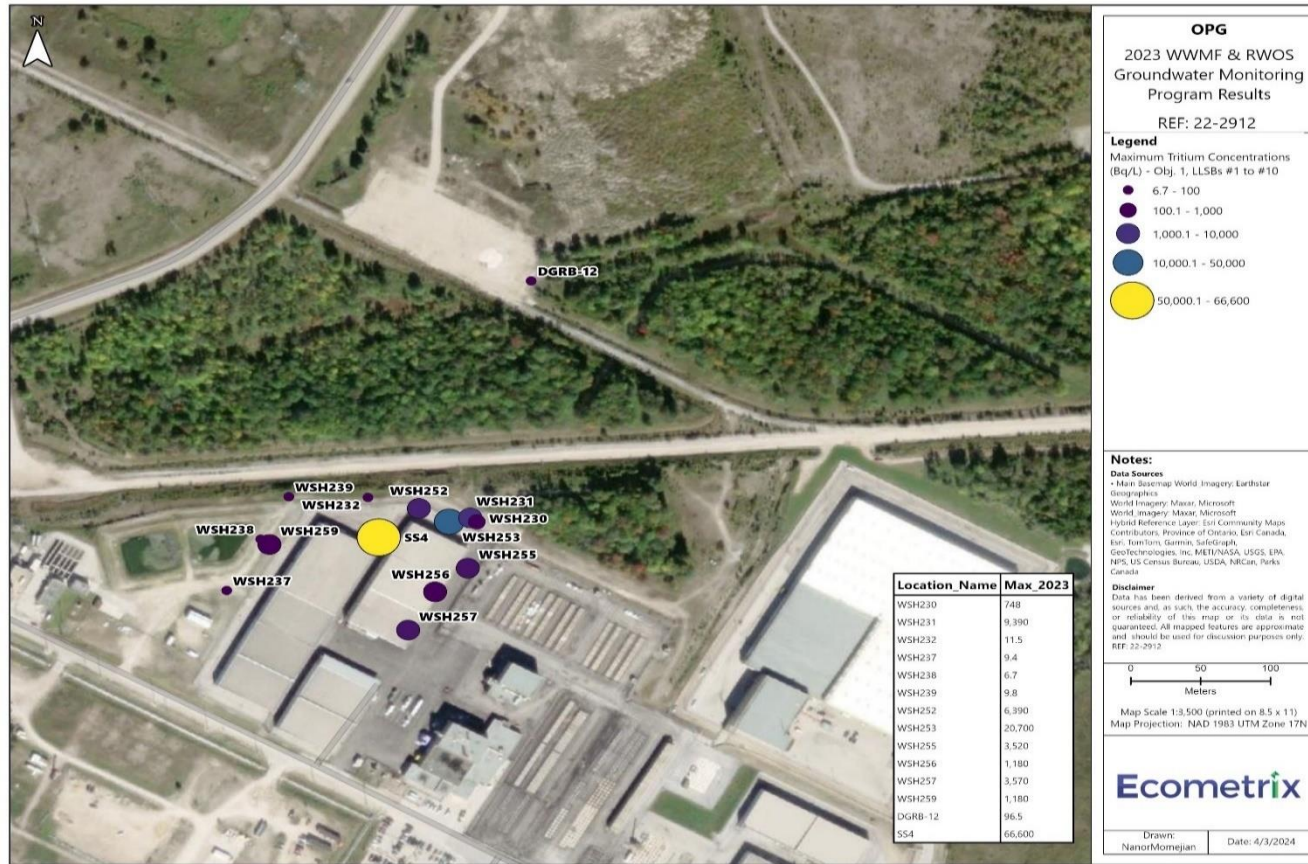


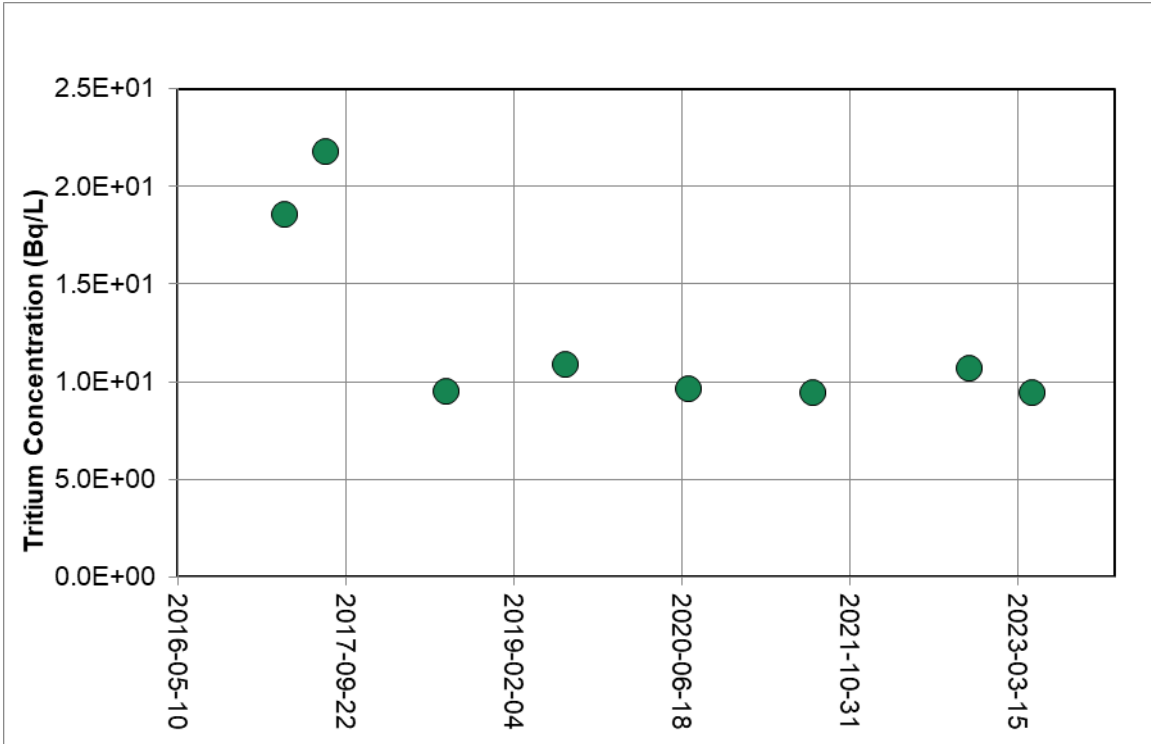
Figure 7: 2023 Maximum Tritium Concentrations – Objective 1 (A), LLSB #1 to #10

Report

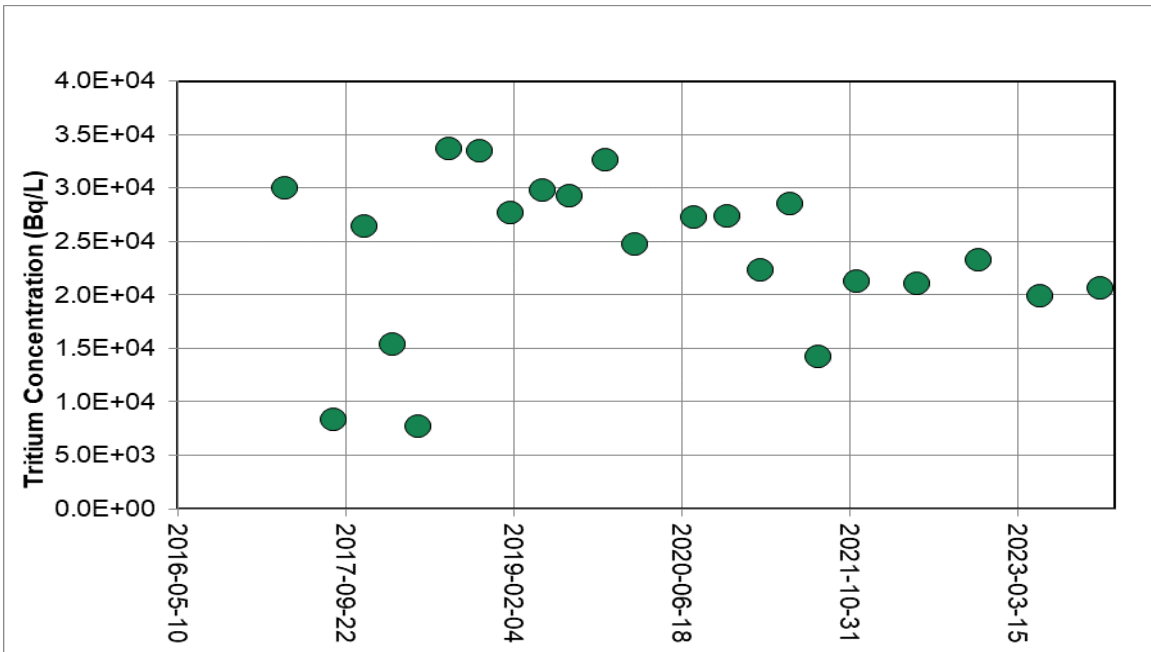
OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 22 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 1: WSH237 Tritium Data



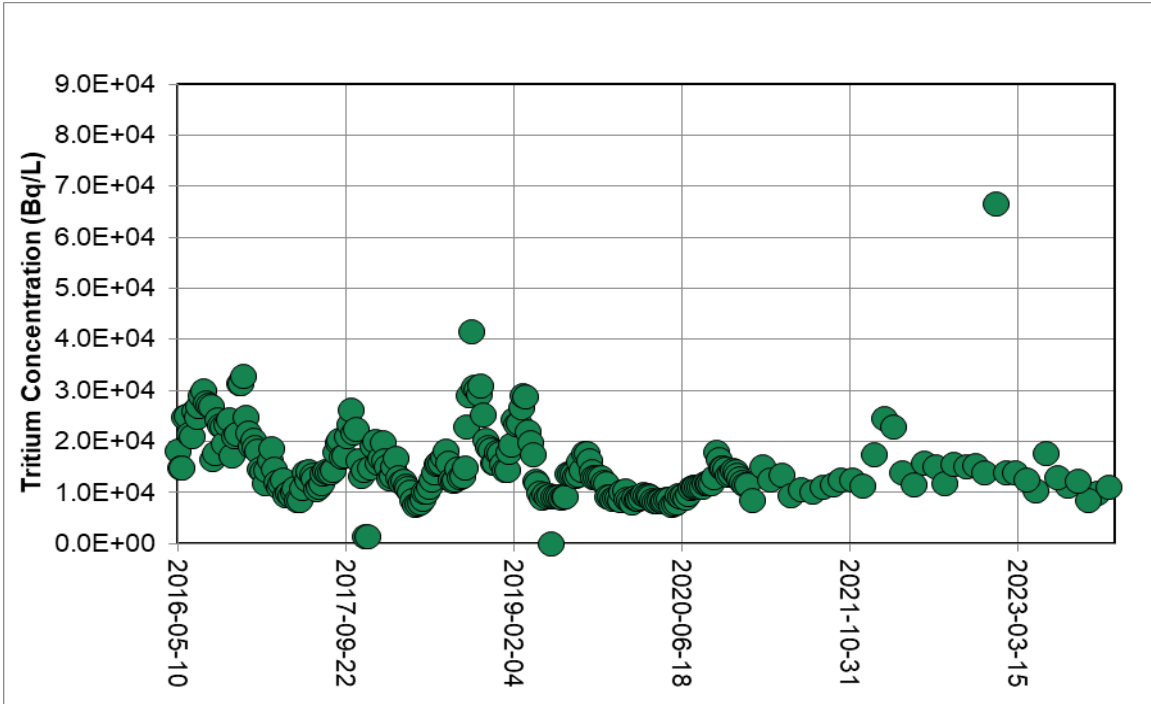
Graph 2: WSH253 Tritium Data

Report

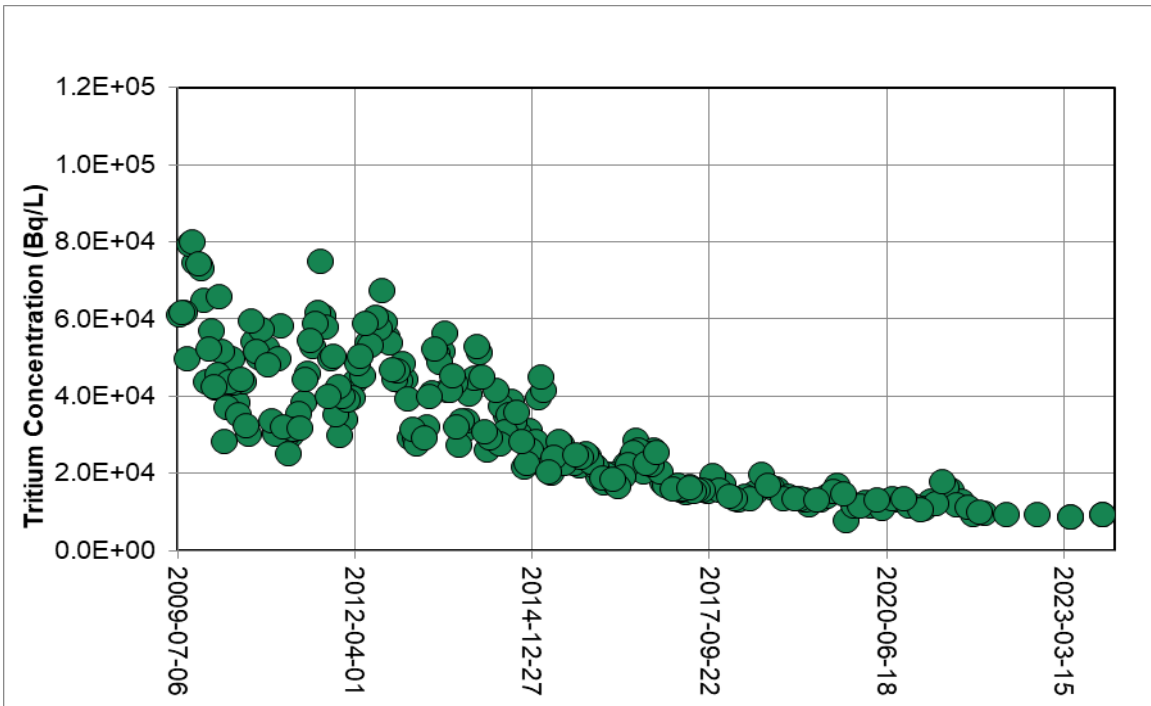
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Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 23 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 3: SS4B Tritium Data



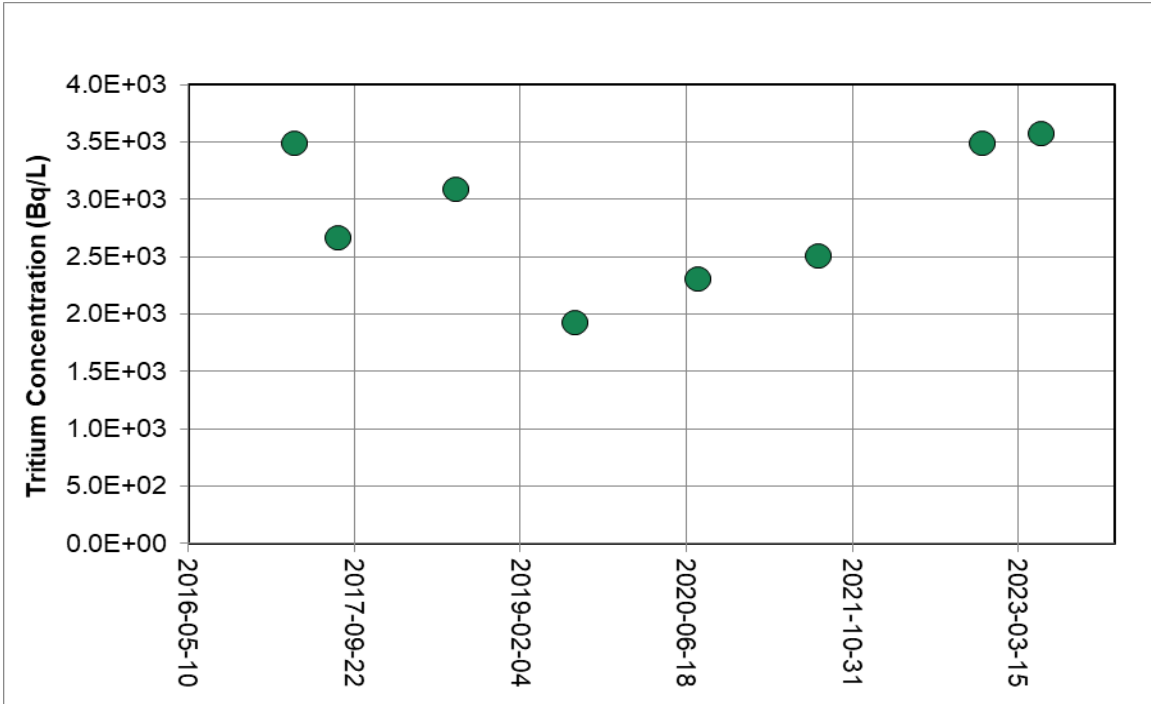
Graph 4: WSH231 Tritium Data

Report

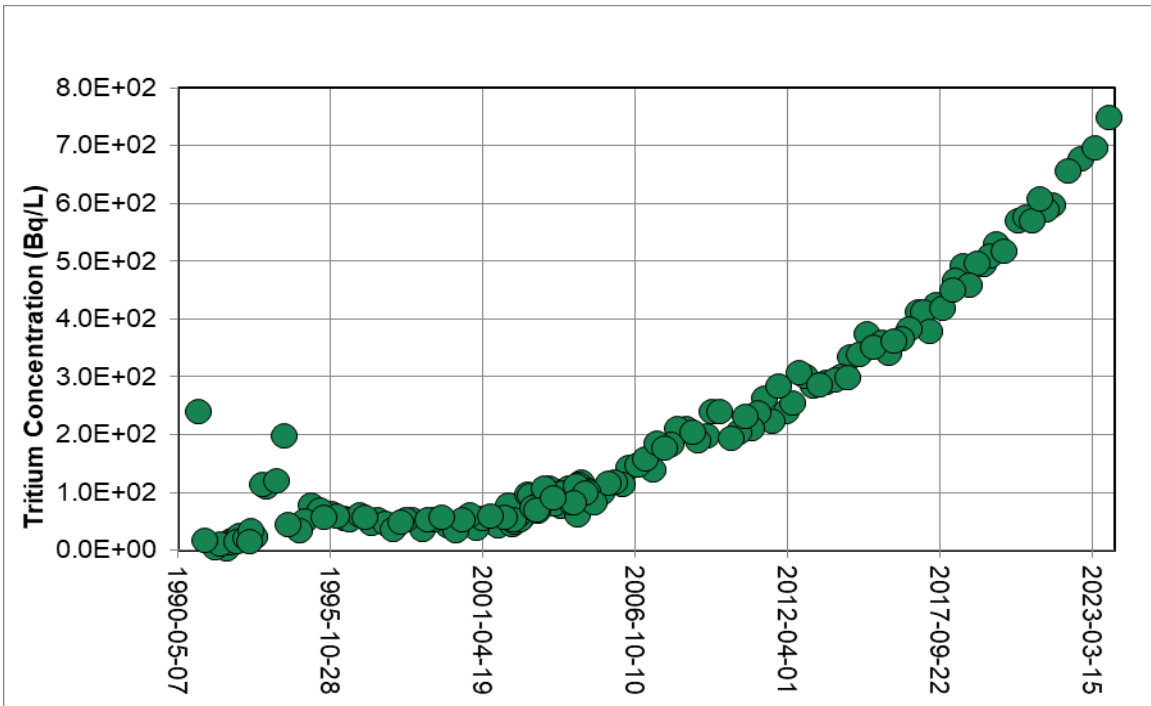
OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 24 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 5: WSH257 Tritium Data



Graph 6: WSH230 Tritium Data

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 25 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

3.1.2 LLSBs #11 to #14, SGSB and RWCSB

LLSBs #11 to #14, SGSB and RWCSB are in the southeast corner of the WWMF. Maximum tritium concentrations are shown spatially in Figure 8. The MSA is not present beneath this portion of the WWMF. The groundwater monitoring network includes monitoring wells installed in shallow groundwater (HU1-3), and bedrock (HU7). Subsurface drainage collected in this area is monitored at SS6. Historical results in this area suggest that uncontrolled releases of tritium from the LLSBs #11 to #14, the SGSB or the RWCSB to groundwater have not occurred (Ecometrix, 2022b).

Tritium concentrations in groundwater and subsurface drainage in this area in 2023 are summarized in Tables A2-a and A2-b, respectively.

Tritium concentrations in the subsurface drainage, measured at SS6, have fluctuated since the LLSBs were put into service in 2010, and are considered to result from operational activities (e.g., waste loadings, sump pump outs, etc.). Maximum tritium concentrations in subsurface drainage at SS6 were observed in October 2023, with concentrations remaining stable in recent years (Graph 7). In 2023, tritium concentrations in SS6 ranged from 3,410 Bq/L (March) to 9,020 Bq/L (October) with an average annual value of 4,505 Bq/L (Appendix A, Table A-2b).

In 2023, groundwater flow conditions (Section 2.4) were consistent with historical conditions, from south to north in HU7. Tritium concentrations are at background levels upgradient of the SSCs in both HU1-3 (WSH272) and HU7 (WSH270). Tritium concentrations in HU7 are at background levels downgradient of the SSCs. Tritium concentrations in groundwater near the SSCs are measured in HU1-3 WSH269. In well WSH269, tritium concentrations are elevated above background levels, with a maximum tritium concentration in 2023 of 435 Bq/L in Q4. Tritium concentrations fluctuate in WSH269 (Graph 8) in this area. In the deeper bedrock (WSH270), concentrations are at background levels. Groundwater quality in this area will continue to be monitored.

Tritium that condenses on the internal and external surfaces of the LLSBs and surrounding asphalt surfaces has the potential to migrate to the subsurface via sumps or pervious surfaces. The temporal behaviour of tritium in WSH269 indicates that routine operational activities associated with the LLSBs #11 to #14 are influencing water quality near the SSCs to a limited extent, but an uncontrolled release has not occurred. Groundwater quality in the deeper groundwater is not influenced by operational activities.

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 26 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

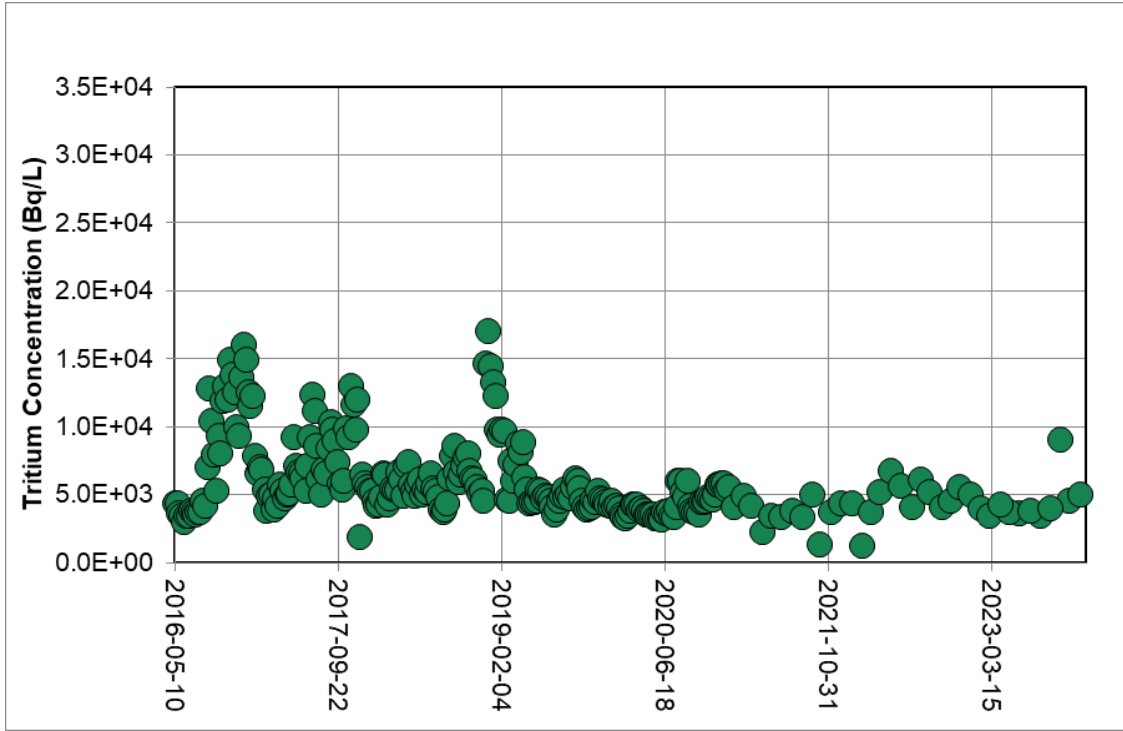


Figure 8: 2023 Maximum Tritium Concentrations – Objective 1 (A), LLSB #11 to #14, SGSB and RWCS

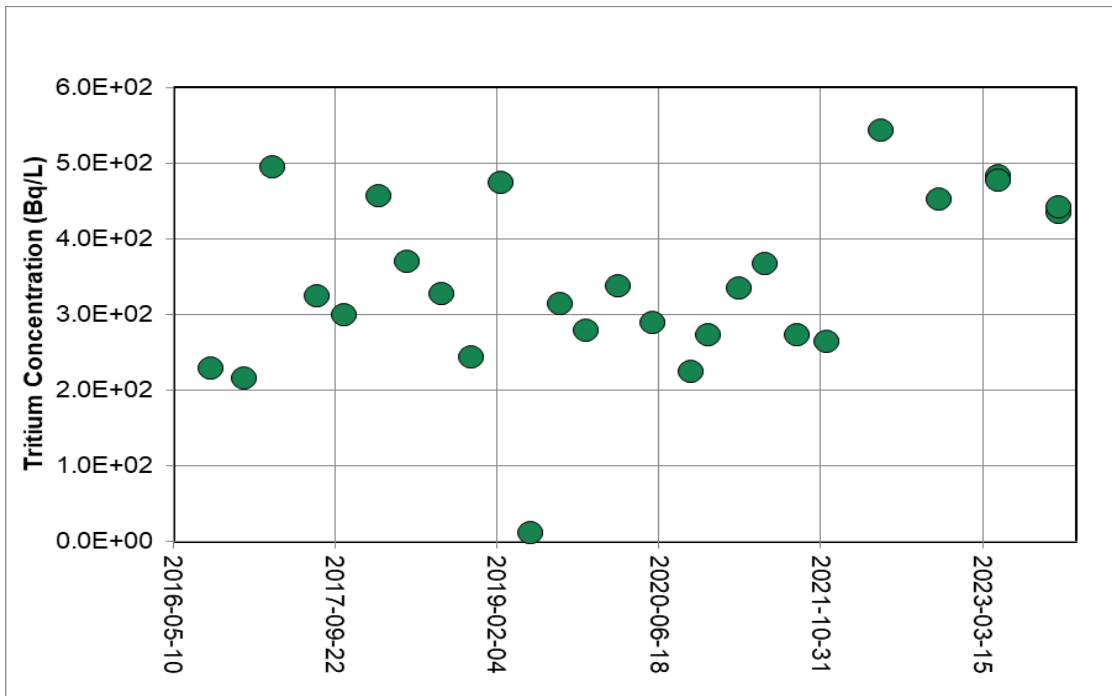
Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 27 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 7: SS6 Tritium Data



Graph 8: WSH269 Tritium Data

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 28 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

3.1.3 Trenches, Tile Holes, ICs and Quadricells

The area containing the trenches, tiles holes, ICs and Quadricells is in the central portion of the WWMF. In this area, tritium concentrations in groundwater and subsurface drainage are influenced by the ingress of groundwater into and egress of water out of waste structures, primarily from the tile holes and Trenches in Stages 1 and 3 (Ecometrix, 2022b).

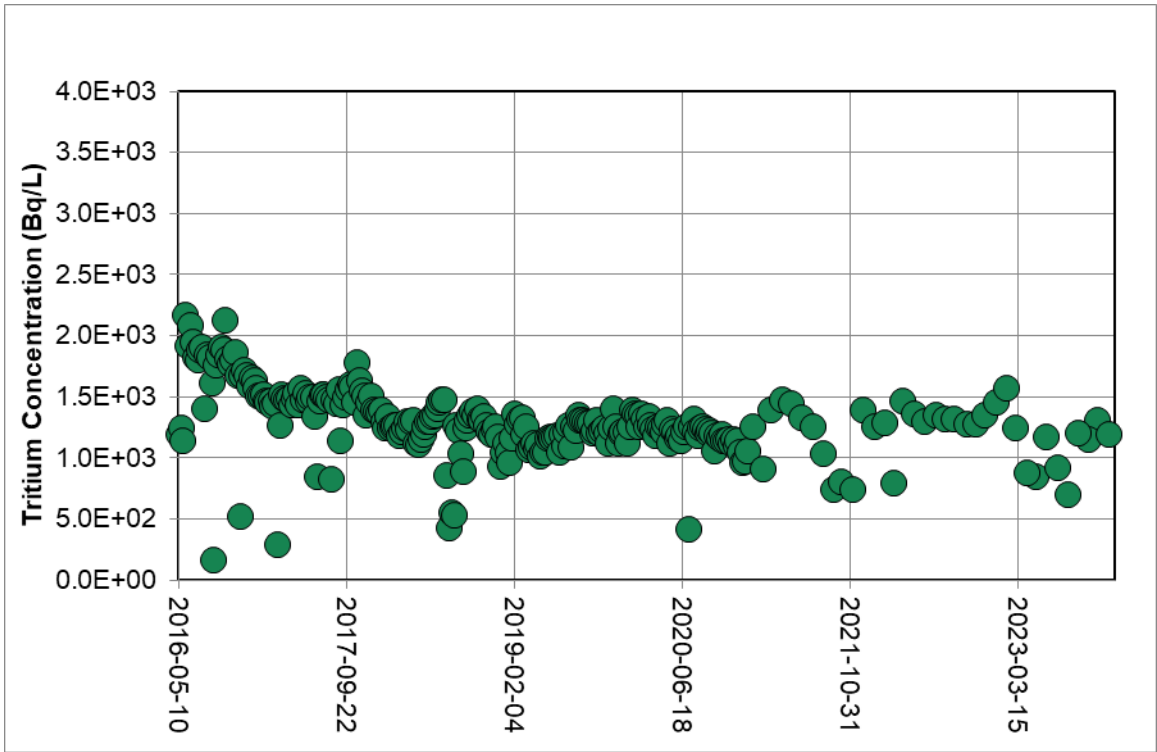
The subsurface drainage in the central part of the WWMF is collected from around the:

- Stage 1 tile holes (TH101 to TH180) and Trenches (TRH3 to TRH6), and sampled at SS1;
- remaining tile holes and Trenches (TRH7 to TRH10), and sampled at SS2; and
- Stage 3 and 3E Trenches, and sampled at SS3.

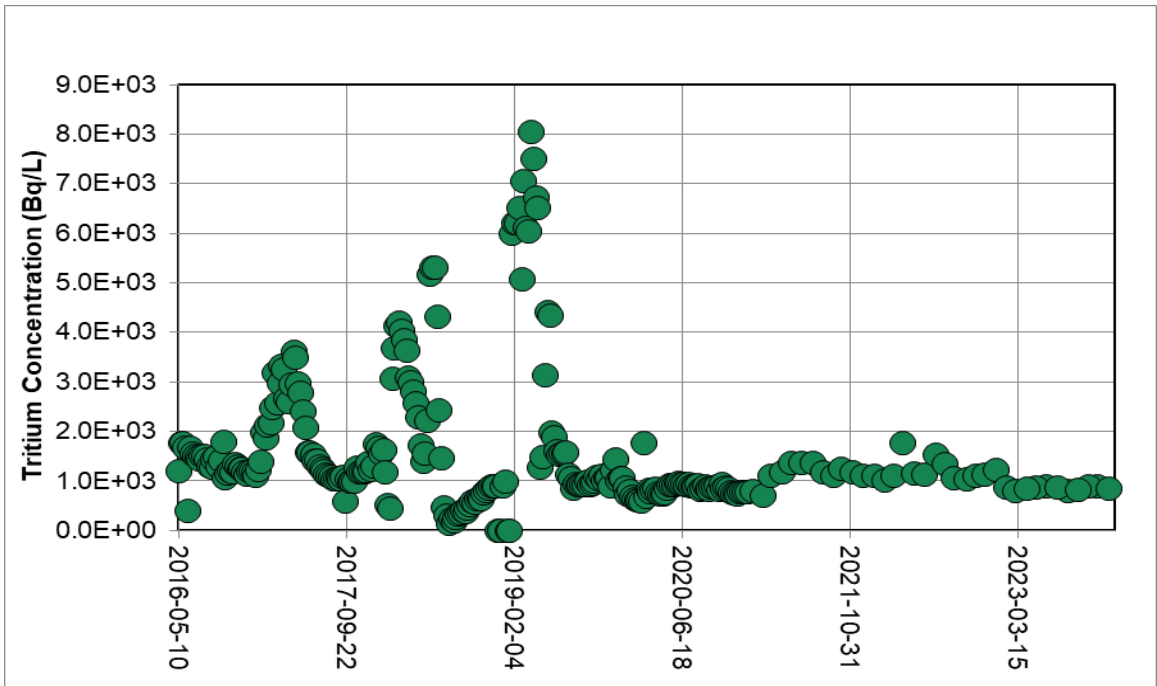
Tritium concentrations in groundwater and subsurface drainage in this area in 2023 are summarized in Appendix A, Tables A3-a and A3-b, respectively. Maximum tritium concentrations in 2023 are shown spatially in Figure 9.

Tritium concentrations in subsurface drainage since 2012 are shown in Graph 9 for SS1, Graph 10 for SS2 and Graph 11 for SS3. Tritium concentrations have fluctuated temporally but have decreased overall. Maximum tritium concentrations measured at SS1, SS2, and SS3 in 2023 were 1,570 Bq/L, 1,220 Bq/L and 3,200 Bq/L respectively. Meanwhile, the annual average tritium concentrations measured at SS1, SS2, and SS3 in 2023 were 1,134.7 Bq/L, 879.9 Bq/L and 2,667.5 Bq/L, respectively (Graphs 9 to 11 and Table A-3b).

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 9: SS1 Tritium Data

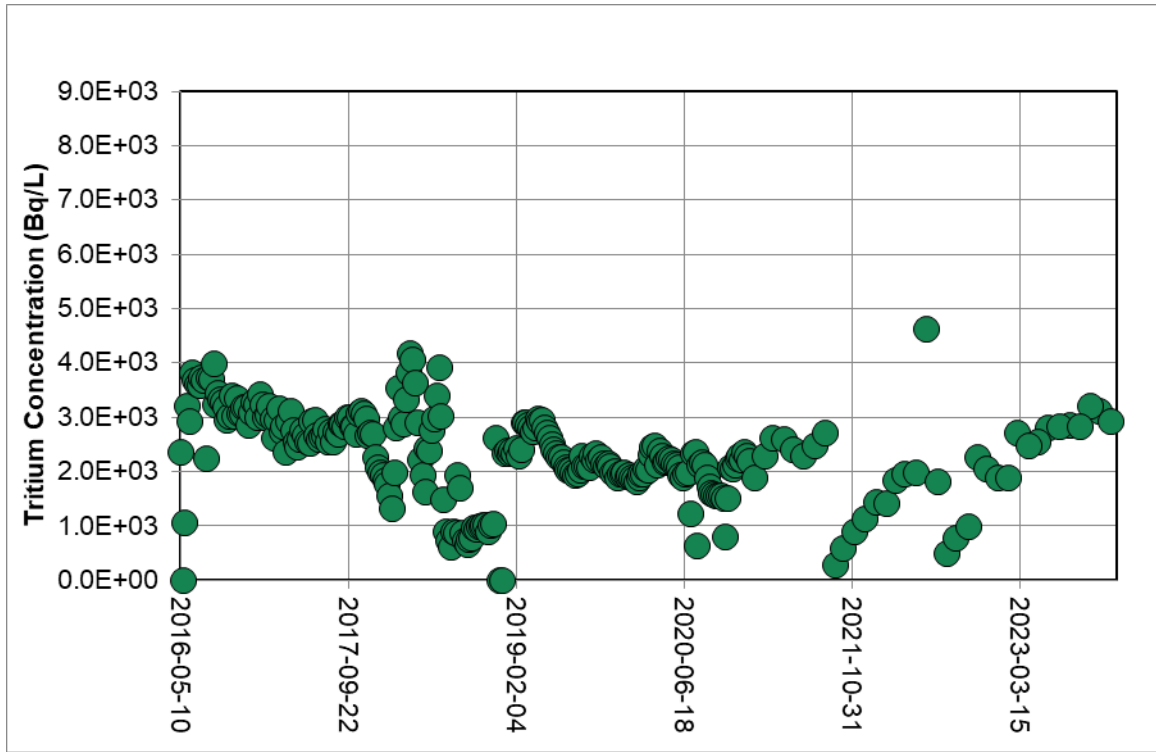


Graph 10: SS2 Tritium Data

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 30 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 11: SS3 Tritium Data

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 31 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

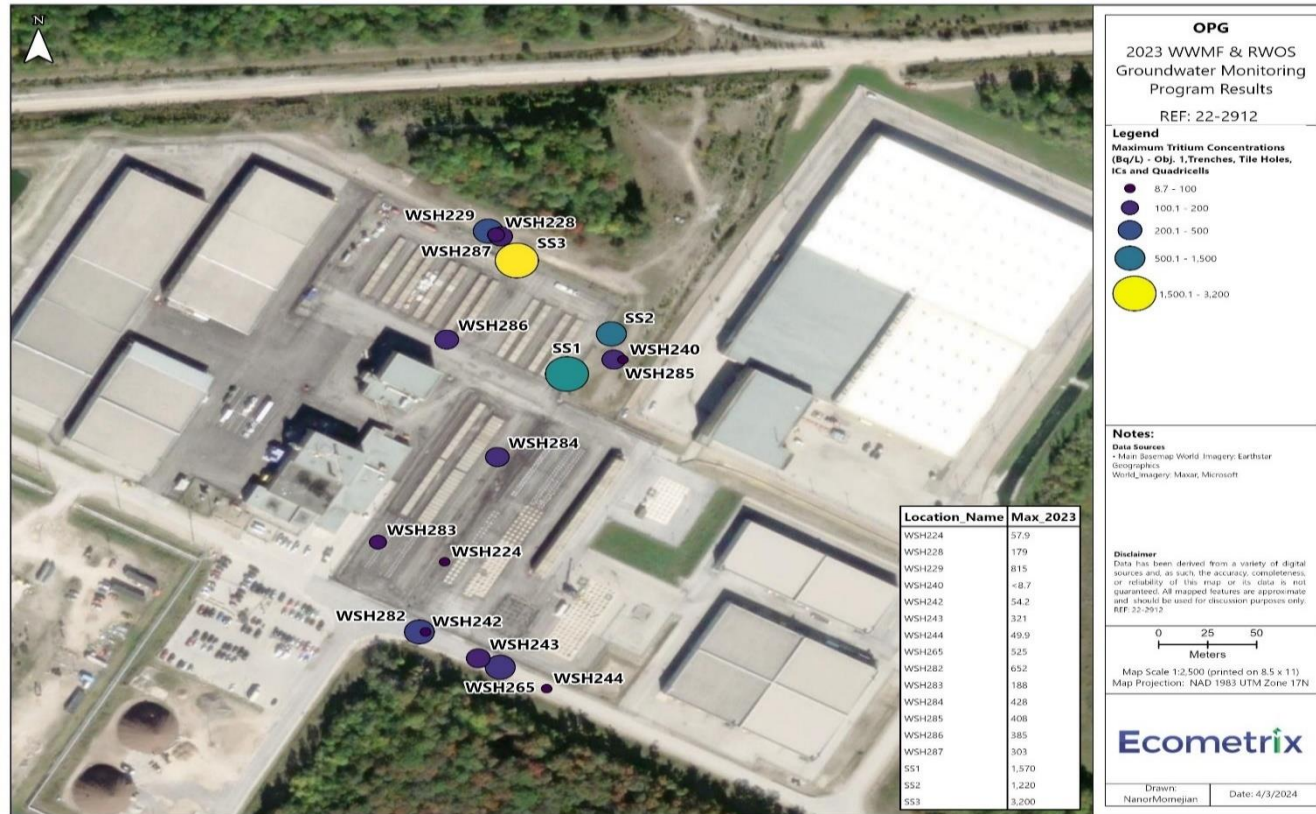


Figure 9: 2023 Maximum Tritium Concentrations – Objective 1 (A), Trenches Tile Holes, Inground Containers and Quadr cells

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 32 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

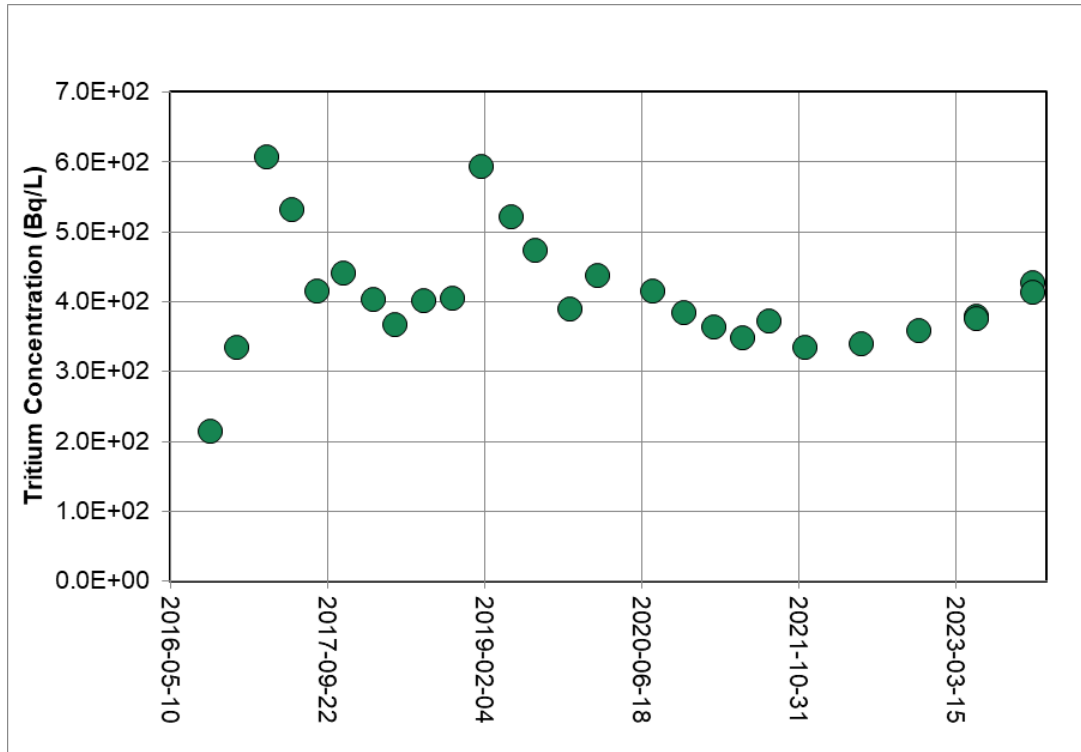
Over this central portion of the WWMF, groundwater is inferred to flow, generally from south of the ICs, tile holes and Quadricells to the north, in both HU1-3 and HU7 (Section 2.4). However, the groundwater flow directions are understood to be more complex in the southeastern portion of this area, where mounding of groundwater in the area around WSH224 has been noted (Jensen, 1996). There is also a groundwater divide in the HU1-3 south of the ICs, tile holes and Quadricells. The MSA is interpreted to be present beneath the majority of this area and is for the most part overlain by several metres of fill/till material (Ecometrix, 2022b). Groundwater flow in the MSA is interpreted to be to the east (Section 2.4).

Across this entire central portion of the site, tritium concentrations in HU1-3 are at or close to background conditions and indicate that routine operations contribute low levels of tritium to groundwater in this area. Wells monitoring tritium concentrations in HU1-3 include: WSH265, WSH282, WSH283, WSH284, WSH285, and WSH286. Monitoring well WSH287 is screened deeper in the till (HU3/5). Tritium concentrations in these wells are, for the most part, stable, as is shown for WSH284 in Graph 12. At well WSH282, maximum concentrations in February 2019 (807 Bq/L) and again in May 2022 (693 Bq/L), with concentrations decreasing to background levels between these times (Graph 13). Improving conditions are demonstrated by gradually decreasing tritium concentrations such as in WSH265 (Graph 14). East of the Stage 3 trenches, tritium concentrations are increasing very gradually in well WSH285 (Graph 15); however, tritium concentrations in that well are still within the range of concentrations observed in the wells south of the ICs, tile holes and Quadricells and the slow increase is considered related to routine operational conditions and not an inadvertent release.

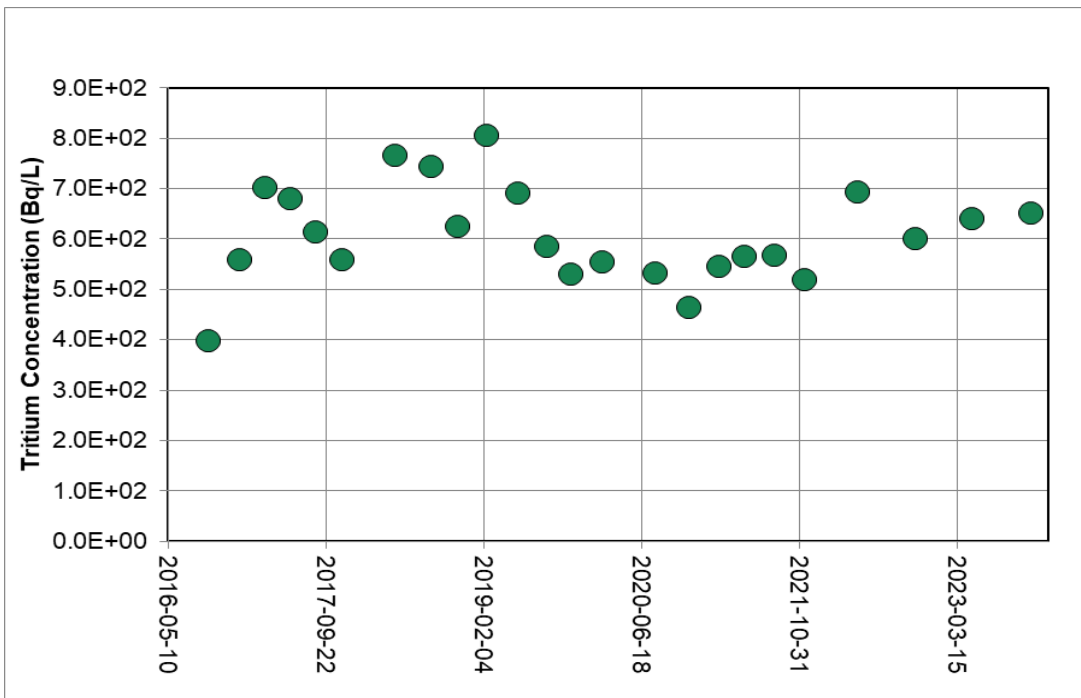
Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 33 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 12: WSH284 Tritium Data

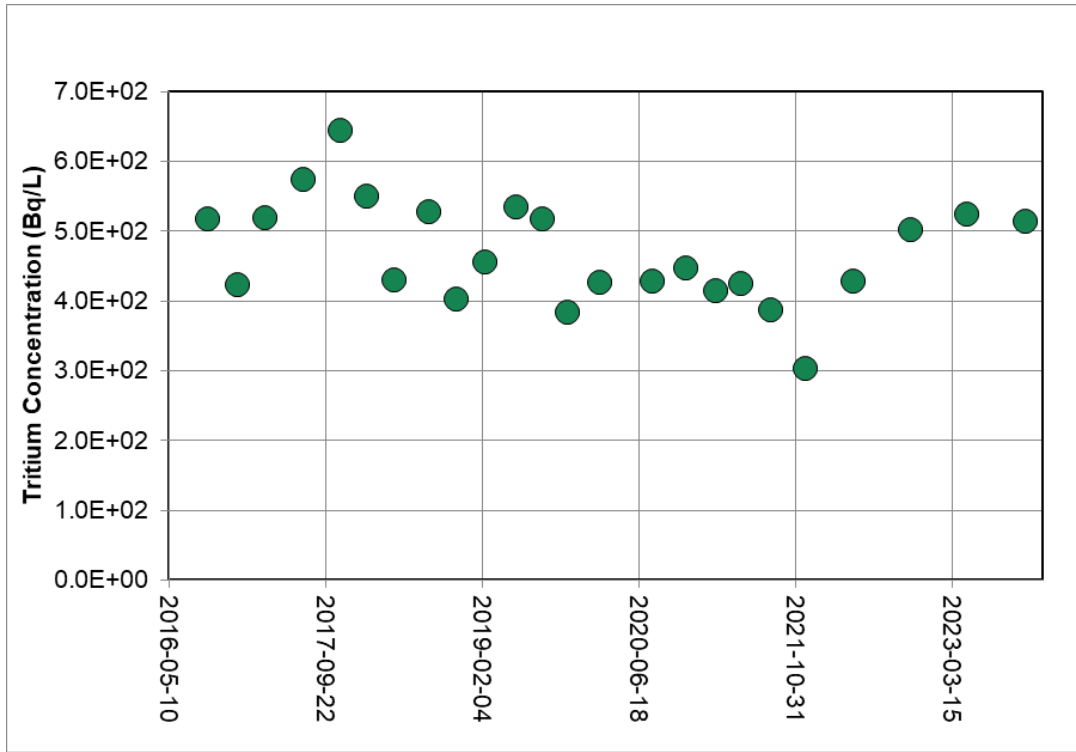


Graph 13: WSH282 Tritium Data

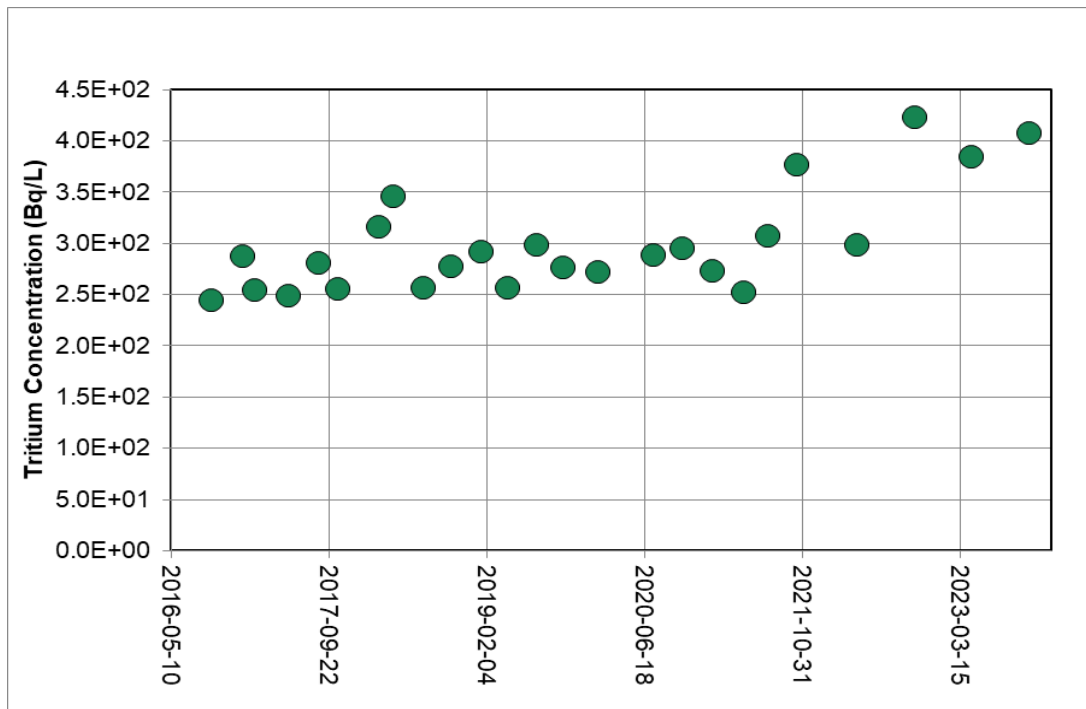
Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 34 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 14: WSH265 Tritium Data

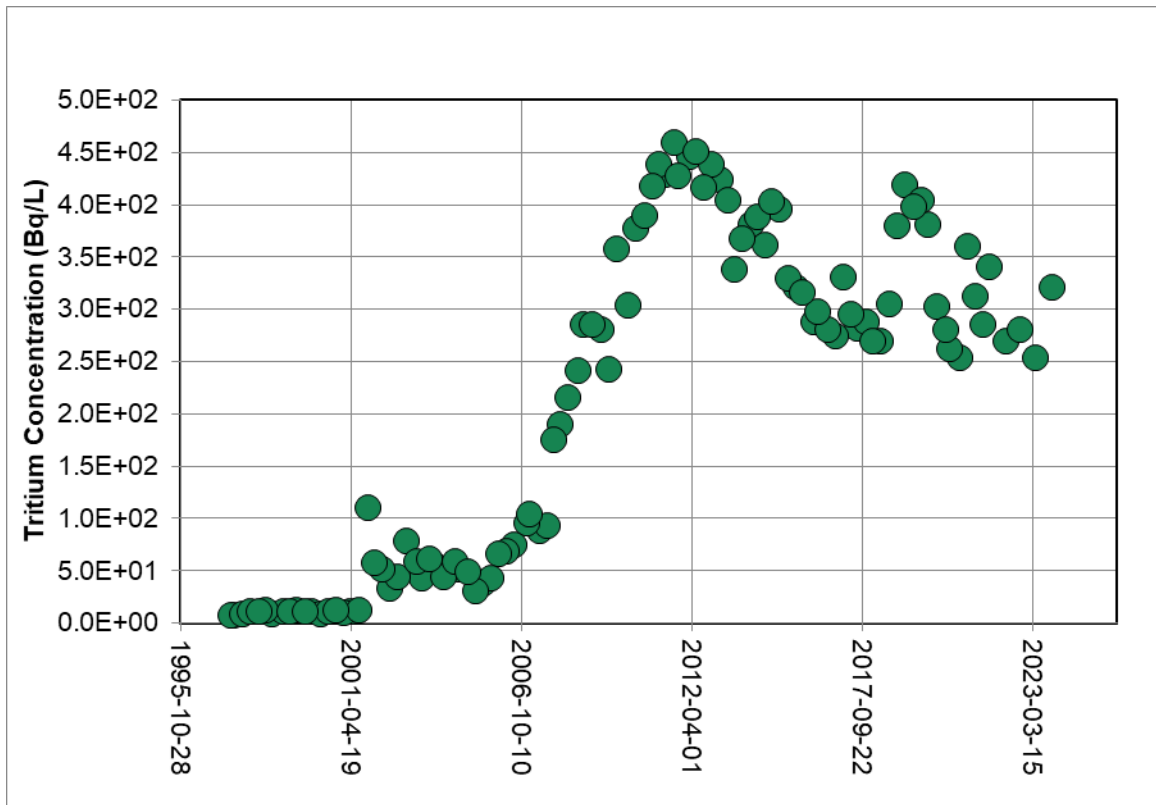


Graph 15: WSH285 Tritium Data

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 35 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

In deeper groundwater, tritium concentrations in the central part of the site are discussed for wells to the south, close to the Stage 1 trenches, tile holes, ICs, and Quadricells separately from conditions to the north, within the Stage 3 and 3E trenches. South of the ICs, tile holes and Quadricells and nested with wells in HU1-3 are deep till and bedrock monitoring wells, being WSH242 (HU7), WSH243 (HU7) and WSH244 (HU7). Tritium concentrations in bedrock at WSH244 are stable and below background levels. In well WSH243, tritium concentrations have been decreasing since 2013, with a maximum concentration of 321 Bq/L in 2023. Tritium levels in this well have decreased from an overall maximum value in September 2011 (460 Bq/L; Graph 16).



Graph 16: WSH243 Tritium Data

North of the Stage 3E trenches, tritium concentrations in the MSA and bedrock hydrostratigraphic units are monitored at locations WSH229 (HU4) and WSH228 (H7). East of the Stage 3 trenches, the MSA is monitored at location WSH240 (HU4). Tritium concentrations in WSH229 have been increasing over time, with concentrations fluctuating around 1,000 Bq/L since 2021 (Graph 17). Because tritium concentrations in shallow groundwater in the overlying till (monitored at WSH287) are at background values, it is considered possible that tritium concentrations in the MSA at WSH229 reflect tritium migration from beneath the LLSBs #1 to #10, consistent with the inferred groundwater flow direction in

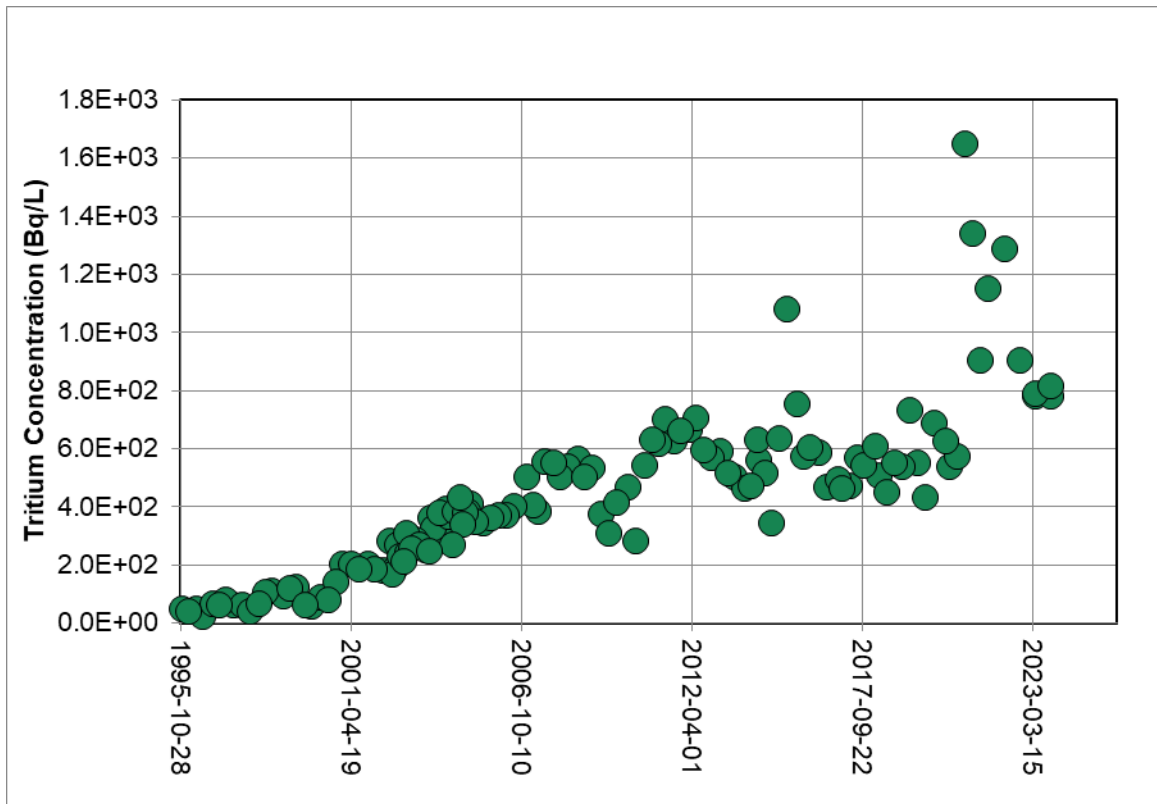
OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 36 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

the MSA to the east (Section 2.4). Further to the east in well WSH240 (HU4), tritium concentrations remain at background levels (Graph 18).

Tritium concentrations in the bedrock well in this area, at WSH228, show a different temporal behaviour, as shown in Graph 19. Concentrations in this well reached a maximum value of 518 Bq/L in 1999 and have been decreasing since that time. Maximum concentrations in WSH228 in 2023 were 179 Bq/L. The earlier source of tritium concentrations in this location is unknown and may have been related to the trenches. The persistence of low concentrations of tritium in groundwater in this well may indicate influence from the interconnectedness of the upper bedrock with the MSA.

Groundwater quality in this area will continue to be monitored.

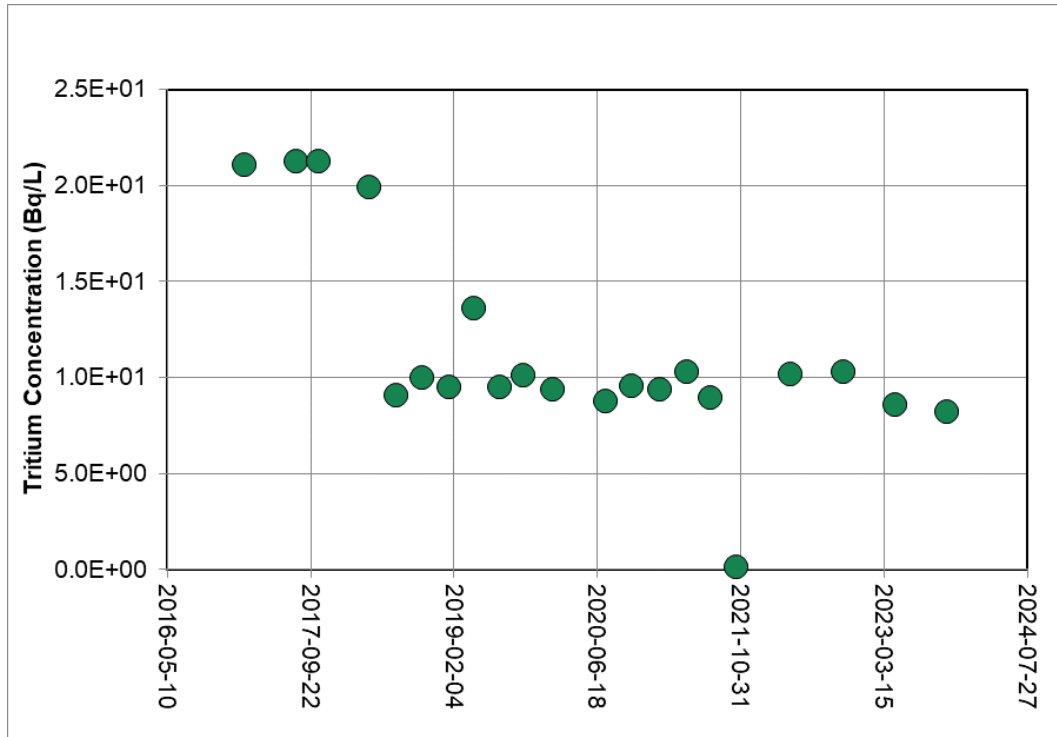


Graph 17: WSH229 Tritium Data

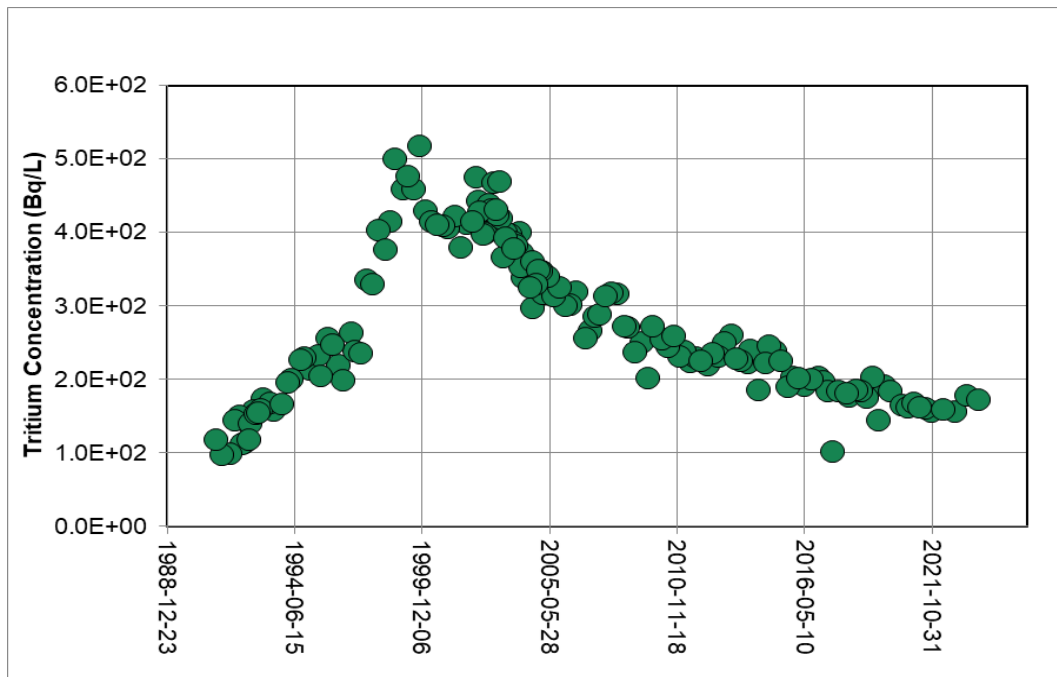
Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 37 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 18: WSH240 Tritium Data



Graph 19: WSH228 Tritium Data

Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 38 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

3.2 Objective 1 (B) Results – RWOS1

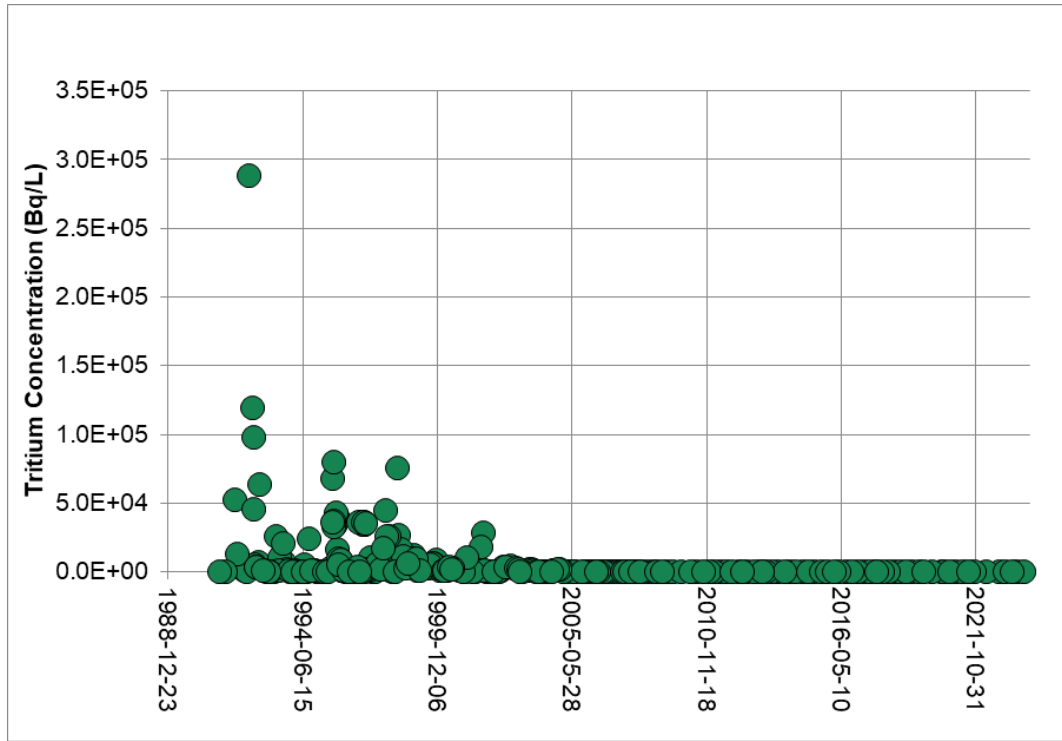
In developing the GWPMP for RWOS1, tritium concentrations in groundwater beneath the RWOS1 were determined to be comparable to those measured in precipitation (wet deposition) and no localized tritium sources were identified (Ecometrix, 2022b). The potential for the influence of SSCs on groundwater at RWOS1 is considered low; new wastes have not been received at RWOS1 since the 1970s and some wastes were relocated in the 1990s and 2000s.

The frequency of sampling of groundwater monitoring wells in the RWOS1 wells is semi-annual. Maximum tritium concentrations in groundwater beneath the RWOS1 are shown in Figure 10.

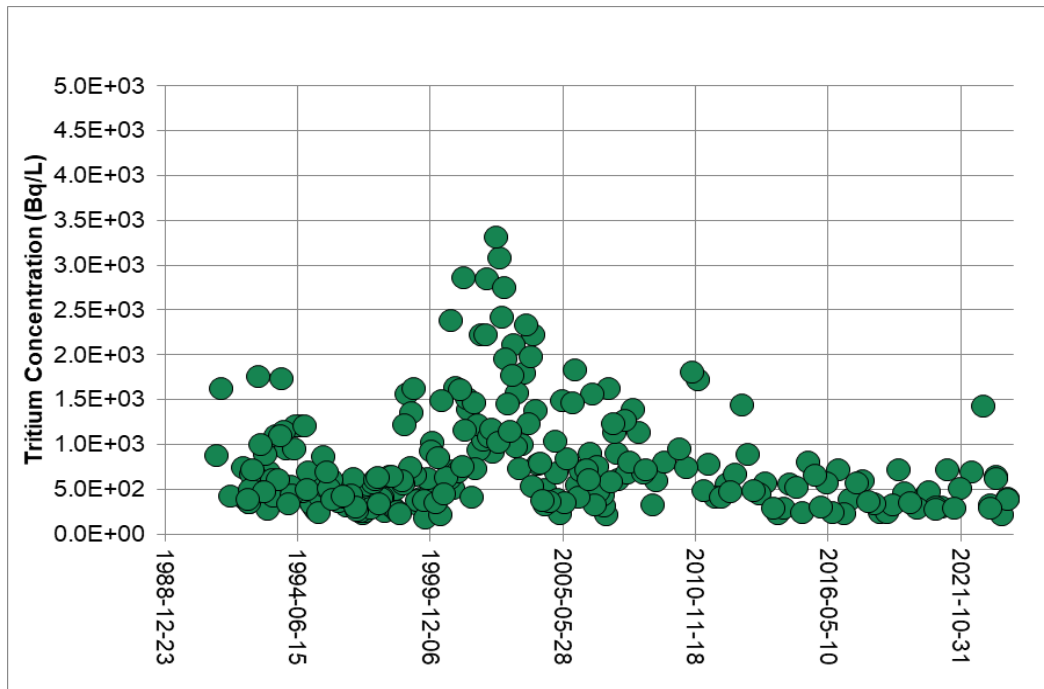
Tritium concentrations in 2023 were within the historical range for all wells within the RWOS1. Fluctuations in tritium concentrations in RWOS1 wells are observed, as is shown for wells WSH122 and WSH123 over the last ten years in Graph 20 and Graph 21; however, the concentrations observed over time were stable. Fluctuations in tritium concentrations reflect fluctuations in tritium concentrations in precipitation (Ecometrix, 2022b).

As was concluded in the GWPMP, there is no evidence of the influence of the SSCs on groundwater tritium concentrations at RWOS1. Groundwater will continue to be monitored in this area.

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 20: WSH122 Tritium Data



Graph 21: WSH123 Tritium Data

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 40 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 10: 2023 Maximum Tritium Concentrations – Objective 1 (B), RWOS1

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 41 of 63

Title:	2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS
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3.3 Objective 1 (C) Results – Background Tritium

Objective 1 (C) was included as part of the GWPMP to monitor tritium concentrations some distance from, the inferred upgradient or cross-gradient groundwater flow direction, from structures, systems, and components (SSCs). Tritium concentrations in wells meeting these criteria provide the means of identifying changes in background concentrations related to air emissions around the WWMF, to be considered in interpreting data downgradient of SSCs.

Background concentrations of tritium in groundwater for the WWMF are measured in groundwater monitoring wells located in the southwest portion of the site, in two wells clusters:

- WSH277(HU1-3), WSH276 (HU5) and WSH275 (HU7); and
- WSH279 (HU4) and WSH278 (HU7).

Background tritium concentrations are additionally monitored in WSH301, on OPG lands north of the WWMF.

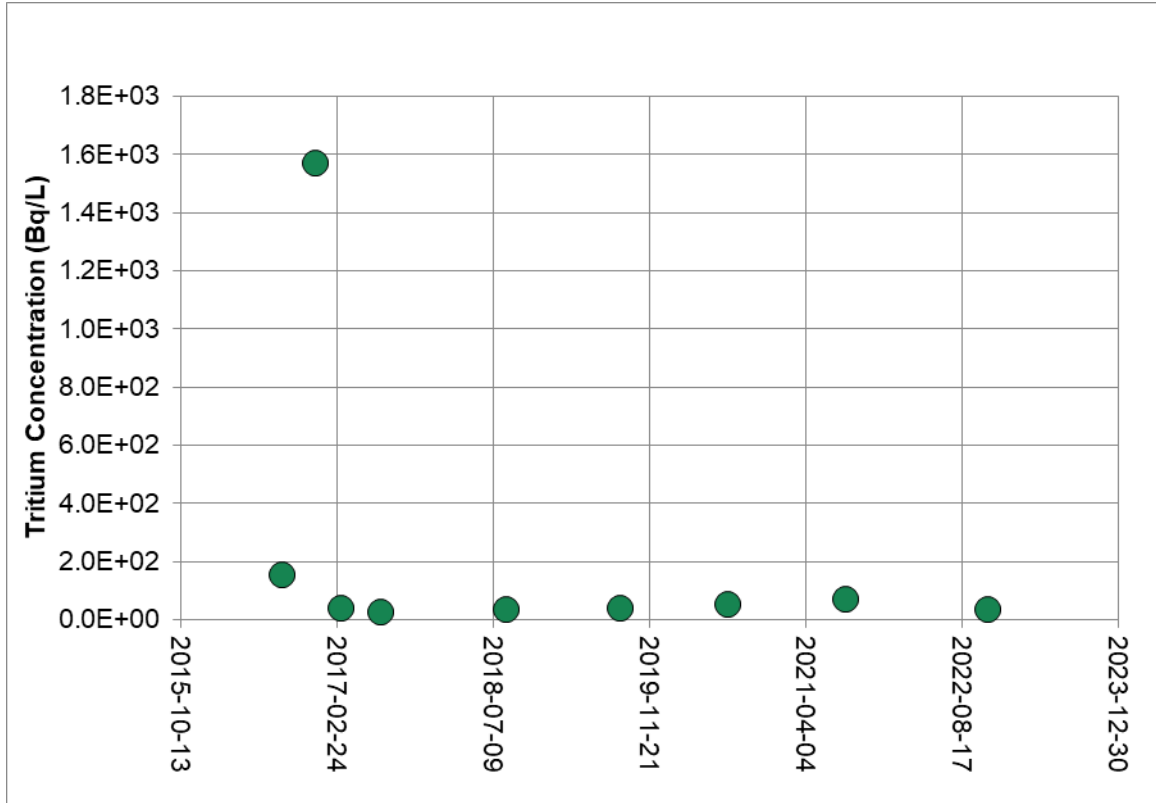
Tritium concentrations in background wells are provided in Appendix A, Table A-5. Maximum tritium concentrations in background monitoring wells are shown in Figure 11. Tritium concentrations in the background wells are stable over time, indicating that they are not being influenced by SSCs. The temporal behaviour of tritium in monitoring wells WSH278 is shown as an example of background tritium concentrations over time in Graph 22. Tritium concentrations in groundwater are fluctuating since 2017 both in the upper fill/till (WSH277) and the MSA (WSH279); (Appendix A, Table A-5) and are at or below detection in the unweathered till (WSH276) and bedrock (WSH278, WSH275 and WSH301); (Table A-5).

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 42 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Graph 22: WSH278 Tritium Data

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 43 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 11: 2023 Maximum Tritium Concentrations – Objective 1 (C), Background Monitoring Wells

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 44 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

3.4 Objective 2 Results – Annual Snapshot of Hydraulic Head Measurements

The groundwater flow directions inferred for HUs beneath the WWMF and the RWOS1 from hydraulic head data collected in 2023 are consistent with historical interpretations.

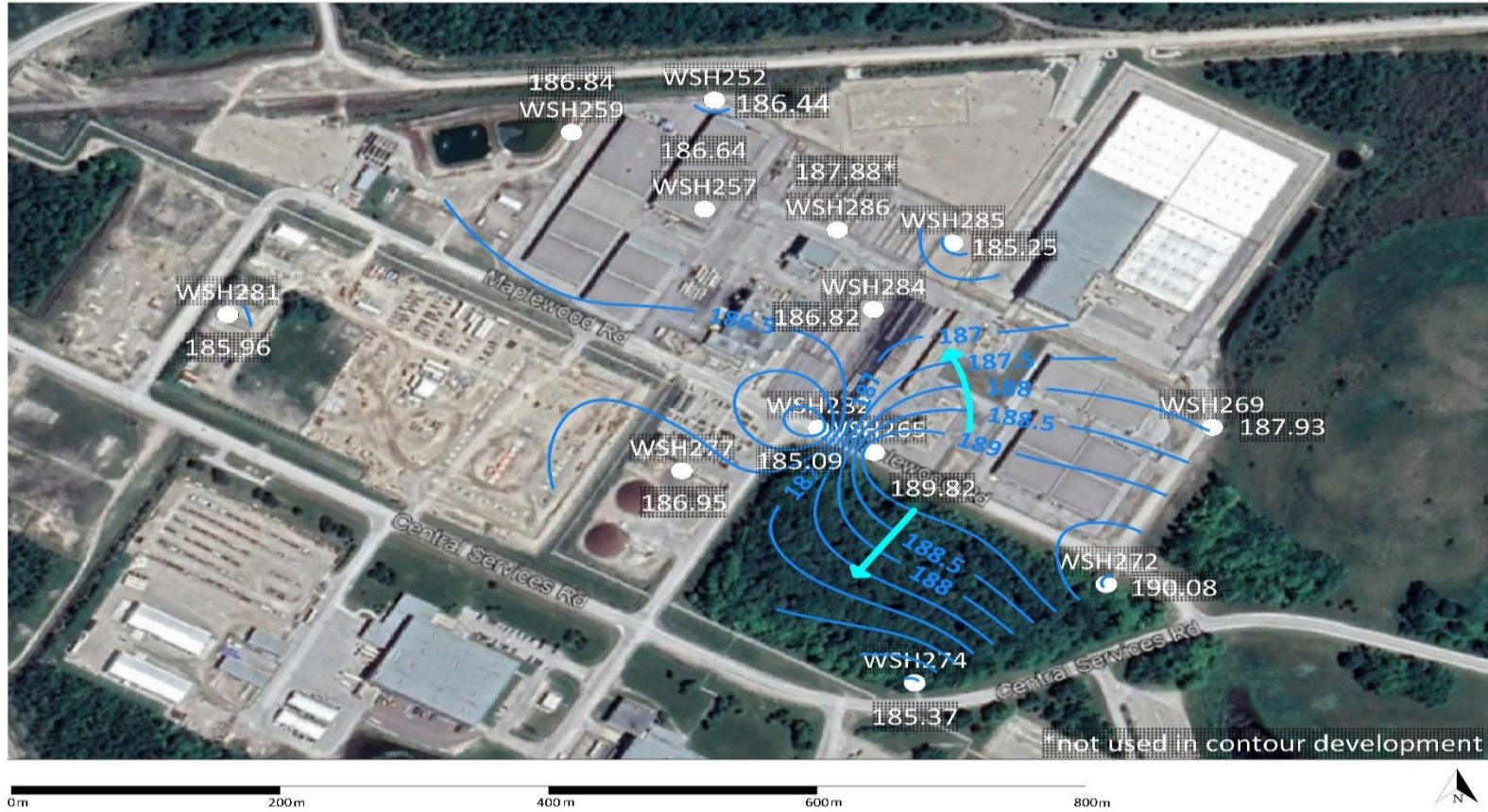
Inferred groundwater flow directions in HU1-3 are shown in Figure 12. The flow directions are complex in this hydrostratigraphic unit, which is considered to reflect influences from the subsurface drainage infrastructure and the heterogeneous nature of the till/fill material. Groundwater in HU1-3 is inferred to discharge to the SRD and other drainage ditches on the WWMF (e.g., perimeter ditches in the laydown area), which ultimately discharge to Lake Huron (Ecometrix, 2022b).

Groundwater flow in MSA is directed towards the east (Figure 13). Groundwater in the MSA also flows downward into the bedrock. Once in the bedrock, groundwater is inferred, from regional-scale water levels, to flow to Lake Huron (Ecometrix, 2022b). In the bedrock aquifer, groundwater is inferred to flow north towards Lake Huron, as shown in Figure 14.

Contours for the water table at RWOS1 are presented in Figure 15. Groundwater flow beneath the RWOS1 is inferred to flow away from WSH124 locally moving east and southwest. Ultimately, groundwater from beneath the RWOS1 is inferred, based on regional groundwater elevations in bedrock, to flow to the south towards Lake Huron (Ecometrix, 2022b).

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 45 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

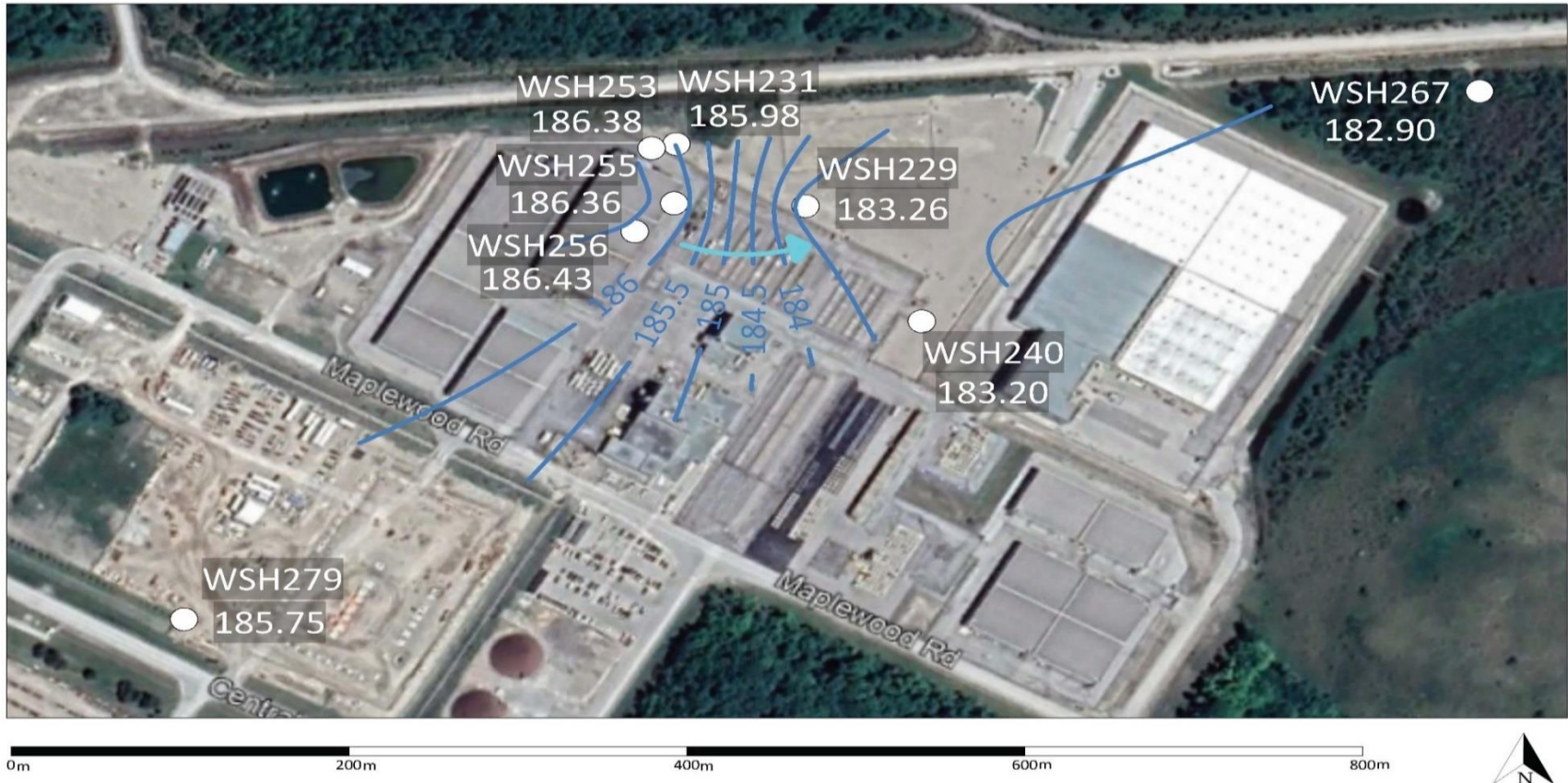


Note: Elevations and contours are reported in metres above sea level (masl)

Figure 12: 2023 Shallow (HU1-3) Groundwater Contours based on May 15th, 2023 measurements

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 46 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

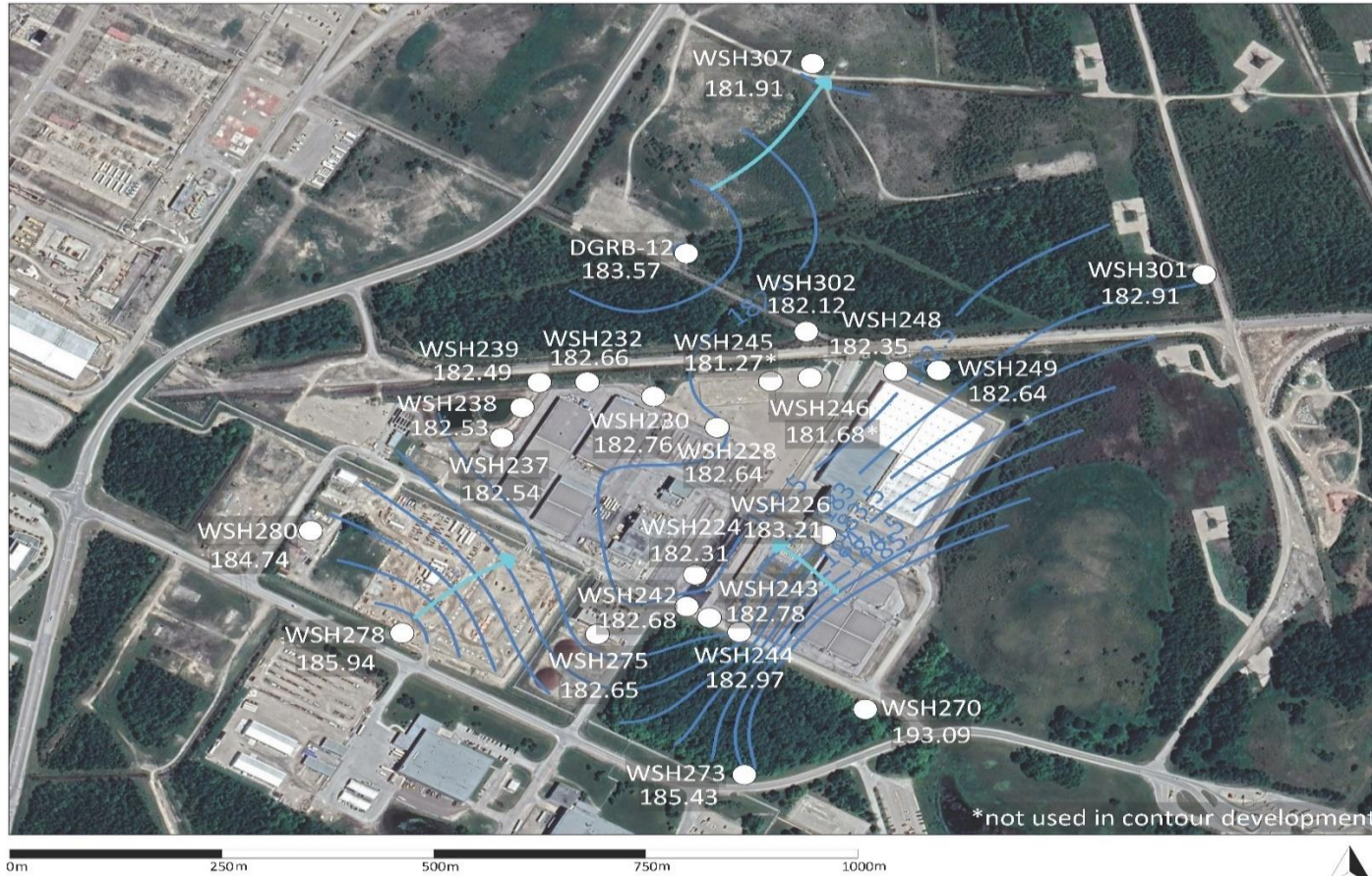


Note: Elevations and contours are reported in masl.

Figure 13: 2023 MSA (HU4) Groundwater Contours based on May 15th, 2023 measurements

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 47 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Note: Elevations and contours are reported in masl.

Figure 14: 2023 Bedrock (HU7) Groundwater Contours based on May 15th, 2023 measurements

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 48 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Note: Elevations and contours are reported in masl.
Figure 15: 2023 Native Sand (HU 2) Groundwater Contours at RWOS1 based on May 15th, 2023 measurements

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 49 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

3.5 Objective 3 Results – Downgradient Perimeter Groundwater Wells

Groundwater quality along the perimeter of the WWMF in the inferred downgradient direction of groundwater flow in the middle sand and bedrock hydrostratigraphic units, HU4 and HU7, respectively, is monitored to provide timely data to evaluate whether human and ecological receptors associated with the groundwater end uses are protected. Tritium concentrations in these wells are compared to numeric groundwater evaluation criteria to identify any potential for off-site groundwater end uses. Groundwater end uses are off-site potable water wells and the discharge of groundwater from beneath the site to Lake Huron.

Tritium concentrations in perimeter wells WSH245 (HU7), WSH249 (HU5), WSH263 (HU5), WSH267 (HU4), WSH307 (HU7), DGRB12A (HU5) and DGRB14 (HU5) are provided in Table A-6. Maximum tritium concentrations in background monitoring wells are shown in Figure 16. Monitoring wells WSH 307, DGRB12A and DGRB14 are located north of the WWMF site boundary on OPG lands.

Tritium concentrations in the perimeter wells are stable as shown in Graph 23 for WSH249, or decreasing as shown in Graph 24 for WSH263. The results for the perimeter wells remain substantively below groundwater evaluation criteria and confirm that the potential for adverse effects to water quality off-site beyond the WWMF site boundaries is low to negligible.

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 51 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS



Figure 16: 2023 Maximum Tritium Concentrations – Objective 3, Downgradient Perimeter Monitoring Wells

Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 52 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

4.0 2023 QUALITY ASSURANCE AND QUALITY CONTROL

The Quality Assurance and Quality Control for the groundwater monitoring program encompasses all activities in field sample collection, laboratory analysis and laboratory quality control. The objective is to provide confidence in the interpretation of the WWMF and RWOS1 groundwater monitoring data through a systematic and documented process.

4.1 Quality Assurance Program for Laboratories

In 2023, water samples were submitted to the Bruce Power Health Physics Lab, which performs laboratory activities according to a documented quality assurance program.

4.2 Quality Control Results

Field duplicates were collected at a prescribed frequency to measure sampling and analytical performance.

In 2023, 16 field duplicate samples of tritium in groundwater were collected. To understand sampling precision, two data quality objectives were defined in the GWPMP. The first objective is applied where concentrations of tritium being evaluated are greater than or equal to five times the detection limit and it is to achieve a relative percent difference (RPD) of 20% or less between the original and duplicate samples. The second objective is applied where the tritium concentrations being evaluated are less than five times the detection limit, and an absolute difference (AD) between the original and duplicate samples of less than two times the detection limit is to be achieved.

All sample and field duplicate pairs met the data quality objectives outlined above. The field technique and the laboratory's analytical methods employed were determined to be reproducible and reliable.

5.0 SUPPLEMENTARY STUDIES

There were no supplementary studies related to the groundwater monitoring program at WWMF or RWOS1 initiated in 2023.

6.0 NOMENCLATURE OF SAMPLING LOCATIONS

Sampling Location Type	Identifier	Explanation of Nomenclature
Groundwater Monitoring Well ("Water Sampling Hole")	WSHXXX or DGRB-XX	XXX or XX represents a unique identifier

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 53 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

7.0 ACRONYMS AND UNITS

$\mu\text{Ci/kg}$	Micro curie per Kilogram
Bq/L	Becquerel per Litre
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
HU	Hydrostratigraphic Unit
LLSB	Low Level Storage Building
MW	Monitoring Well
OPG	Ontario Power Generation Inc.
QA/QC	Quality Assurance/Quality Control
RPD	Relative Percentage Difference
SAP	Sampling and Analysis Plan
SSC	Systems, Structures and Components
SGSB	Steam Generator Storage Building
RWCSB	Retube Waste Container Storage Building
WWMF	Western Waste Management Facility

8.0 REFERENCES

- Ecometrix, 2022a. Groundwater Protection and Monitoring Programs – CSA N288.7 Implementation at WWMF AND RWOS1. Report No. W-REP-07294-00002. October.
- Ecometrix, 2022b. Conceptual Site Model – CSA N288.7 Implementation at WWMF and RWOS1. Report No. W-REP-07294-00001. October.
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- Jensen and Heystee (Ontario Hydro), 1987. BNPD Radioactive Waste Operations Site 1 and 2 Survey of Local Geologic and Hydrogeologic Conditions. Report No. 87126.
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Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 54 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Appendix A: Tables A-1 to A-7

Table A-1a: 2023 Groundwater Results near LLSBs #1 to #10

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH230	Tritium	HU 7	Semi-Annual	--	696	--	748
WSH231	Tritium	HU4	Semi-Annual	--	8,660	--	9,320
WSH232	Tritium	HU7	Annual	--	11.5	--	--
WSH237	Tritium	HU7	Annual	--	9.43	--	--
WSH238	Tritium	HU7	Annual	--	<6.67	--	--
WSH239	Tritium	HU7	Annual	--	9.8	--	--
WSH252	Tritium	HU1-3	Annual	--	6,250	--	--
WSH253	Tritium	HU4	Semi-Annual	--	19,900	--	20,700
WSH255	Tritium	HU4	Semi-Annual	--	3,130	--	3,520
WSH256	Tritium	HU4	Annual	--	2,850	--	--
WSH257	Tritium	HU1-3	Annual	--	3,570	--	--
WSH259	Tritium	HU1-3	Annual	--	1,180	--	--
DGRB-12	Tritium	HU7	Annual	--	86.4	--	96.5

Note:

"--", Not required as per the WWMF GWMPMP

"N/A", Sample was not collected

Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 55 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table A-1b: 2023 Subsurface Drainage Results near LLSBs #1 to #10

Drainage ID	Analysis Parameter	Frequency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SS4B Subsurface	Tritium	Monthly	66,600	13,900	13,900	12,400	10,300	17,500	12,800	11,200	12,200	8,490	9,700	11,000

Administrative Limit: 98,000 Bq/L

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 56 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table A-2a: 2023 Groundwater Results near LLSBs #11 to #14, SGSB and RWCSB

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH226	Tritium	HU7	Semi-Annual	--	<7.23	--	<7.51
WSH269	Tritium	HU1-3	Semi-Annual	--	484	--	435
WSH270	Tritium	HU7	Annual	--	<8.1	--	--
WSH272	Tritium	HU1-3	Annual	--	297	--	--

Note:

"--", Not required as per the WWMF GWMPMP

Report

OPG Proprietary		
Document Number:	W-REP-07294-00005	Usage Classification:
		N/A
Sheet Number:	Revision Number:	Page:
N/A	R001	57 of 63

Title:
2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table A-2b: 2023 Subsurface Drainage near LLSBs #11 to #14, SGSB and RWCSB

Drainage ID	Analysis Parameter	Frequency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SS6 Subsurface	Tritium	Monthly	5,040	3,960	3,410	4,320	3,760	3,610	3,850	3,420	4,040	9,020	4,580	5,050

Administrative Limit: 98,000 Bq/L

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 58 of 63

Title:	2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS
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Table A-3a: 2023 Groundwater Results near Trenches, Tile Holes, ICs and Quadricells

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH224	Tritium	HU7	Annual	--	57.9	--	--
WSH228	Tritium	HU7	Semi-Annual	--	179	--	172
WSH229	Tritium	HU4	Semi-Annual	--	783	--	782
WSH240	Tritium	HU4	Semi-Annual	--	<8.62	--	<8.2
WSH242	Tritium	HU7	Semi-Annual	--	48.5	--	54.2
WSH243	Tritium	HU7	Semi-Annual	--	254	--	321
WSH244	Tritium	HU7	Annual	--	49.9	--	--
WSH265	Tritium	HU1-3	Semi-Annual	--	525	--	514
WSH282	Tritium	HU1-3	Semi-Annual	--	641	--	652
WSH283	Tritium	HU1-3	Semi-Annual	--	148	--	188
WSH284	Tritium	HU1-3	Semi-Annual	--	379	--	428
WSH285	Tritium	HU1-3	Semi-Annual	--	385	--	408
WSH286	Tritium	HU1-3	Semi-Annual	--	385	--	300
WSH287	Tritium	HU3/5	Semi-Annual	--	286	--	303

Note:

"--", Not required as per the WWMF GWMPM

Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 59 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table A-3b: 2023 Subsurface Drainage near near Trenches, Tile Holes, ICs and Quadricells

Drainage ID	Analysis Parameter	Frequency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SS1 Subsurface	Tritium	Monthly	1,450	1,570	1,240	879	843	1,170	918	696	1,200	1,150	1,310	1,190
SS2 Subsurface	Tritium	Monthly	1,220	870	787	846	862	889	854	786	828	893	884	840
SS3 Subsurface	Tritium	Monthly	1,880	1,870	2,710	2,470	2,540	2,800	2,830	2,840	2,830	3,200	3,110	2,930

Administrative Limit: 98,000 Bq/L

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: 1N/A	Revision Number: R001	Page: 60 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table A-4: 2023 Groundwater Results near RWOS1

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH122	Tritium	HU2	Semi-Annual	195	171	92.2	97.7
WSH123	Tritium	HU2	Semi-Annual	320	640	211	395
WSH124	Tritium	HU2	Semi-Annual	193	205	182	190
WSH125	Tritium	HU2	Semi-Annual	196	179	148	183
WSH126	Tritium	HU2	Semi-Annual	161	189	151	191

Note:

"--", Not required as per the WWMF GWMPM

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 61 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table A-5: 2023 Groundwater Results to Establish Background Concentrations at WWMF

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH275	Tritium	HU7	Annual	--	<7.61	--	--
WSH276	Tritium	HU5	Semi-Annual	--	29	--	16.6
WSH277	Tritium	HU1-3	Annual	--	451	--	301
WSH278	Tritium	HU7	Annual	--	13.6	--	--
WSH279	Tritium	HU4	Annual	--	191	--	263
WSH301	Tritium	HU7	Annual	--	<7.79	--	--

Note:

"--", Not required as per the WWMF GWPMP

Report

OPG Proprietary		
Document Number: W-REP-07294-00005		Usage Classification: N/A
Sheet Number: N/A	Revision Number: R001	Page: 62 of 63

Title:

2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table A-6: 2023 Groundwater Results in Downgradient Perimeter Wells at WWMF

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH245	Regular	HU7	Annual	--	<8.2	--	--
WSH249	Regular	HU7	Annual	--	<7.41	--	--
WSH263	Regular	HU5	Annual	--	52.6	--	--
WSH267	Regular	HU4	Annual	--	<8.17	--	--
WSH307	Regular	HU7	Annual	--	<7.74	--	--
DGRB-12A	Regular	HU5	Annual	--	<7.8	--	--
DGRB-14	Regular	HU5	Annual	--	44.2	--	--

Note:

"--", Not required as per the WWMF GWMPMP

Report

OPG Proprietary		
Document Number: W-REP-07294-00005	Usage Classification: N/A	
Sheet Number: N/A	Revision Number: R001	Page: 63 of 63

Title: 2023 WESTERN WASTE MANAGEMENT FACILITY GROUNDWATER PROGRAM RESULTS

Table A-7: Tritium Quality Control Results, Duplicate Samples and RPDs

Location	Sample Date	Sample Values (Bq/L)		RPD (%) ^a	Absolute Difference
		Duplicate	Primary		
WSH229	18-Apr-23	791	783	1.0	--
	18-Oct-23	815	782	4.1	--
WSH231	18-Apr-23	8,630	8,660	0.3	--
	18-Oct-23	9,390	9,320	0.7	--
WSH249	09-May-23	7.40	7.41	--	0.01
WSH252	19-May-23	6,390	6,250	2.2	--
WSH269	03-May-23	478	484	1.2	--
	03-Nov-23	442	435	1.6	--
WSH276	03-May-23	37.8	29	--	8.8
	03-Nov-23	22.5	16.6	--	5.9
WSH284	18-May-23	375	379	1.1	--
	16-Nov-23	414	428	3.3	--
WSH123	11-Jan-23	293	320	8.8	--
	17-Apr-23	617	640	3.7	--
	10-Oct-23	386	395	2.3	--
WSH126	20-Jul-23	151	191	23.4	--

Notes:

^a In the GWPMP (Ecometrix 2022a), two data quality objectives were defined for sampling precision. Where the tritium concentrations are more than 5 times the detection limit (DL), a Relative Percent Difference (RPD%) is calculated. Where the tritium concentrations are within 5*DL, an absolute difference is calculated between the sample and duplicate tritium concentrations and the absolute difference must be less than 2*DL. The detection limit for tritium varies by sample. Review of the historical information suggests that the lowest DL is generally approximately 8 Bq/L. Thus, samples with tritium values less than 40 Bq/L in 2023 were evaluated using the absolute difference criterion. All samples met the data quality objectives.