Supporting Document 1-5

Surface Water Quantity Existing Conditions Report

Twin Creeks Environmental Centre Landfill Optimization Project Environmental Assessment

WM Canada

Watford, Ontario

May 2026

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Revision History

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Executive Summary

WSP Canada Inc. (WSP) was contracted by HDR Corporation on behalf of WM Canada (WM) to prepare this Draft Surface Water Quantity Existing Conditions Report for the Twin Creeks Environmental Centre (TCEC) Landfill Optimization Project Environmental Assessment (EA). The purpose of this report is to present the existing surface water quantity (hydrology) conditions of the TCEC site and surrounding area.

The TCEC is located at 5768 Nauvoo Rd. approximately 1 km north of the Village of Watford in the Township of Warwick, Ontario. The TCEC is bounded by agricultural area on all sides, with the closest residential area being in Watford in the south. The On-site Study Area for Surface Water Quantity focuses on the on-site ditches and Stormwater Ponds 1, 2, 3 and 4. The Off-Site Study Area for Surface Water Quantity includes the area within the vicinity of the TCEC extending approximately 1 km out from the On-Site Study Area along with the Kersey Drain to the east, Van Kessel Drain to the west, and municipal drainage tile at catch basin SS1. The municipal drainage tile ultimately flows to the Gilliland-Geerts Drain, beneath Nauvoo Road (County Road 79). The assessment of external areas will enable a more comprehensive characterization of existing conditions at a watershed scale to assist in the assessment of potential surface water quantity effects.

There are approximately 5 years of approved landfill airspace capacity remaining at the TCEC (i.e., capacity will be reached in approximately 2031). The proposed optimization would provide additional airspace of approximately 14.3 million cubic metres (m^3), which could extend the site life by approximately 12 years (from 2031 to 2043) and may be achieved through alternative landfill configurations or alternative methods within the existing 301-hectare TCEC site area. No changes are proposed to the size of the TCEC site area, approved service area, or annual fill rate.

The investigations to characterize existing Surface Water Quantity included the following tasks:

- A desktop review of background data to understand the baseline conditions;
- A site reconnaissance to corroborate existing conditions;
- Confirmation of overland flow routes, drainage boundaries and outlet locations;
- Inventory of existing hydraulic structures (i.e., location, size, material);
- Measurements of typical stream channel geometry (i.e., bottom width, side slopes, depth); and
- Climate and stream flow monitoring (initiated in the fall of 2015) to collect:
  - Rainfall data and ambient temperature data;
  - Water temperature and water levels data; and

- Stream flow gauging measurements.

The site reconnaissance was conducted on September 28, 2022. Visual observation of the four stormwater management ponds and surrounding drainage features was completed to assess the current condition and performance.

Hydrologic modelling was completed in Visual OTTHYMO (6.2) to determine the peak return period flows at each outlet location, and to evaluate the function of the existing stormwater management ponds.

According to the existing conditions analysis, the ponds are functioning adequately and the SWM Pond 1 has the highest peak outflow of 0.704 m^3/s as per the hydrologic modeling for the 100-year design storm. SWM Pond 2, 3 and 4 show a peak outflow of 0.529 m^3/s, 0.671 m^3/s and 0.372 m^3/s respectively for the 100-year design storm. The peak outflow to Gilliland-Geerts Drain from the site was 4.68 m^3/s.

Further, it should be noted that the catchment areas of the TCEC site are to remain unchanged for the landfill optimization vertical expansion alternatives being considered. As such, drainage patterns within the site and off-site are expected to remain unchanged.

Other considerations:

During construction, there is a potential for short-term sediment wash-off from the site. To protect the downstream receiving system and other natural features, on-site sediment control measures are necessary during construction and should not be removed until the end of construction period when the site has been stabilized. Construction phasing must be scheduled to minimize the extent and period to which disturbed soils are exposed to weathering. To prevent erosion during construction at TCEC, WM uses intermediate cover materials, silt fences, and hydraulic seeding to stabilize soils and control runoff, with these measures continuing as new landfill cells are developed.

Acronyms, Units and Glossary

Acronyms

Acronym	Definition
CN	Curve Number
D&O	Design and Operations
EA	Environmental Assessment
EAA	*Environmental Assessment Act*
IDF	Intensity Duration Frequency
MECP	Ministry of Environment, Conservation and Parks
MNRF	Ministry of Natural Resources and Forestry
SCRCA	St. Clair Region Conservation Authority
SCS	United States Department of Agriculture Soil Conservation Survey
SWM	Stormwater Management
TCEC	Twin Creeks Environmental Centre
ToR	Terms of Reference
T_P	Time to Peak
WM	WM Canada

Units

Unit	Definition
ha	hectare
km	kilometre
m	metre
m^3	cubic metre

Glossary

Term	Definition
Approval	Permission granted by an authorized individual or organization for a project to proceed. This may be in the form of program approval, certificate of approval, or provisional certificate of approval.
Capacity (Disposal Volume)	The total volume of air space available for disposal of waste at a landfill site for a particular design (typically in m^3); includes both waste and daily cover materials but excludes the final cover.

Glossary

Term	Definition
Composting	The controlled microbial decomposition of organic matter, such as food and yard wastes, in the presence of oxygen, into finished compost (humus), a soil-like material. Humus can be used in vegetable and flower gardens, hedges, etc.
Composting facility	A facility designed to compost organic matter either in the presence of oxygen (aerobic) or absence of oxygen (anaerobic).
Environment	As defined by the *Environmental Assessment Act*, environment means: • air, land or water • plant and animal life, including human life • the social, economic and cultural conditions that influence the life of humans or a community • any building, structure, machine or other device or thing made by humans • any solid, liquid, gas, odour, heat, sound, vibration or radiation resulting directly or indirectly from human activities • any part or combination of the foregoing and the interrelationships between any two or more of them (ecosystem approach).
Environmental Assessment (EA)	A systematic planning process that is conducted in accordance with applicable laws or regulations aimed at assessing the effects of a proposed project on the environment.
Evaluation criteria	Evaluation criteria are considerations or factors taken into account in assessing the advantages and disadvantages of various alternatives being considered.
Greenhouse gas (GHG)	Any of the gases whose absorption of solar radiation is responsible for the greenhouse effect, including carbon dioxide, methane, ozone, and the fluorocarbons.
Indicators	Indicators are specific characteristics of the evaluation criteria that can be measured or determined in some way, as opposed to the actual criteria, which are fairly general.
Landfill gas (LFG)	The gases produced from the wastes disposed in a landfill; the main constituents are typically carbon dioxide and methane, with small amounts of other organic and odour-causing compounds.
Landfill site	An approved engineered site / facility used for the final disposal of waste. Landfills are waste disposal sites where waste is spread in layers, compacted to the smallest practical volume, and typically covered by soil.
Leachate	Liquid that drains from solid waste in a landfill and which contains dissolved, suspended and/or microbial contaminants from the breakdown of this waste.
Mitigation	Measures taken to reduce adverse impacts on the environment.
Project	Is defined in the *Environmental Assessment Act* as: one or more enterprises or activities or a proposal, plan or program in respect of an enterprise or activity.
Proponent	A person who: • carries out or proposes to carry out a project • is the owner or person having charge, management or control of a project
Receptor	The person, plant or wildlife species that may be affected due to exposure to a contaminant.
Terms of Reference (ToR)	A terms of reference is a document that sets out detailed requirements for the preparation of an Environmental Assessment.
Waste	Refuse from places of human or animal habitation; unwanted materials left over from a manufacturing process.

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1 Introduction

This report presents a description of the existing conditions for Surface Water Quantity for the WM Canada (WM) Twin Creeks Environmental Centre (TCEC) Landfill Optimization Project in support of the environmental assessment (EA). The purpose of the EA is to assess the potential effects of the proposed landfill optimization on the environment. The EA is being carried out in accordance with the requirements of the *Environmental Assessment Act* (*EAA*) and Terms of Reference (ToR), which was approved by the Ministry of Environment, Conservation and Parks (MECP) on December 13, 2022.

The approved ToR included a preliminary description of the existing conditions within the area surrounding the TCEC, with the commitment that a more detailed description of existing environmental conditions would be prepared as part of the EA. In accordance with the approved ToR, additional investigative studies were carried out as necessary to generate a more detailed description of the existing natural, cultural, socio-economic, and built environments for use in the assessment of the effects of the alternative methods for the TCEC Landfill Optimization Project during the EA.

WM, the owner and operator of the TCEC in Watford, Ontario, has initiated an EA seeking approval to optimize the landfill design and operation, maximizing the use of the constructed infrastructure and the significant investment made at the TCEC. There are approximately 5 years of approved landfill airspace capacity remaining at the TCEC (i.e., capacity will be reached in approximately 2031). The proposed optimization would provide additional airspace capacity of up to approximately 14.3 million m^3, which could extend the site life by about 12 years (from 2031 to 2043). No changes are proposed to the size of the current 301 ha TCEC site area, the approved service area, or the annual fill rate.

There is a need for the continued development of the TCEC as it is a significant component of the provincial waste management network and infrastructure, which is lacking in sufficient and secure long-term disposal capacity. Optimizing the future development of the TCEC allows for on-going sustainable business operations and continued provision of essential financial support for community services and programs.

This Surface Water Quantity Existing Conditions Report is one component of the EA. The EA Study Report will incorporate the information presented herein as appropriate, and this report will be included with the EA Study Report as a supporting document. Surface water quality existing conditions are addressed in a separate report.

This Surface Water Quantity report has been prepared in accordance with the workplan included as part of the approved ToR. The workplan outlines the tasks required to support the EA through the characterization of existing conditions and assessment of potential environmental effects of the Project on the Surface Water

Quantity environment, including the evaluation of the various alternative methods and the identification and assessment of a preferred alternative. This work plan outlines the scope of the Surface Water Quantity work, including protocols and/or standards to be adhered to while the work is undertaken.

The objective of this Surface Water Quantity Existing Conditions Report is to comprehensively characterize the existing hydrological conditions at the TCEC and surrounding area. Specifically, this report addresses the below objectives:

- A desktop review of background data to understand baseline conditions;
- Observations from site reconnaissance;
- Confirmations of overland flow routes, drainage boundaries, and outlet locations;
- Inventory of existing hydraulic structures;
- Typical stream channel geometry;
- Hydrologic modelling; and
- Climate and stream flow monitoring results.

2 TCEC and Study Areas

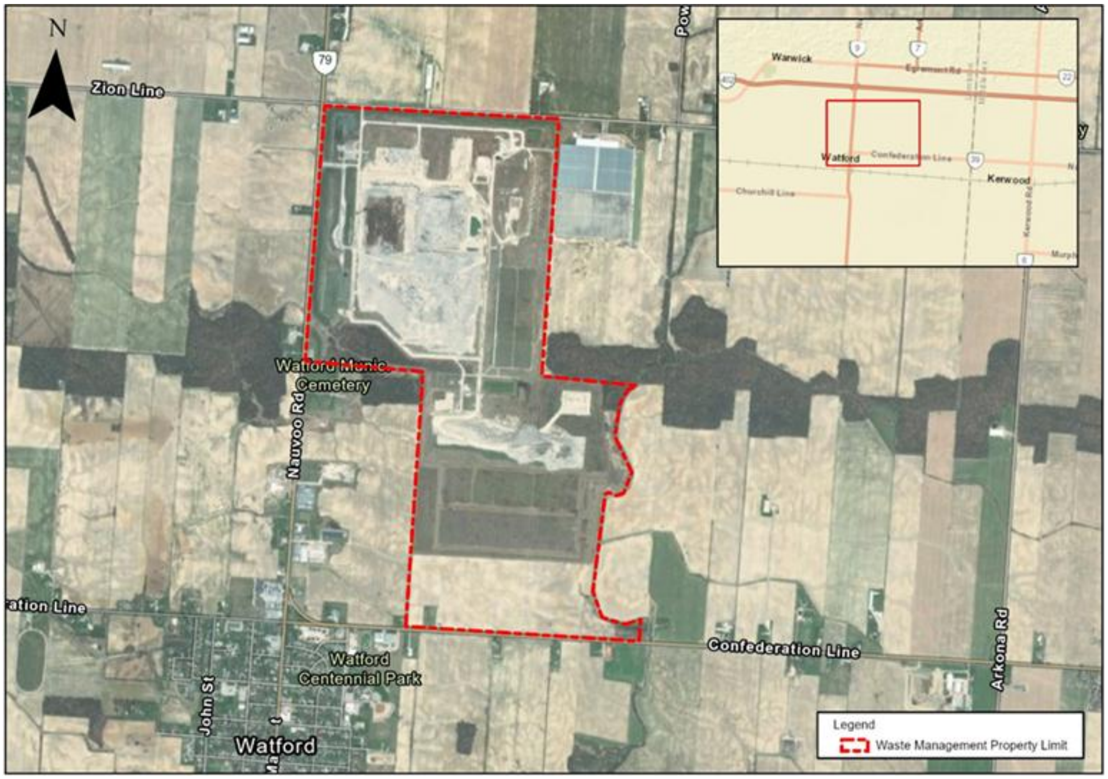
The TCEC is located at 5768 Nauvoo Rd. approximately 1 km north of the Village of Watford in the Township of Warwick, Ontario. The subject site is bounded by agricultural area on all sides, with the closest residential area being in Watford in the south. The topography of the area is flat with some rolling hills. The site lies at the surface water divide between Bear Creek Watershed to the west and the Brown Creek Watershed to the east. The location of the site is shown in **Figure 2-1**, with the On- and Off-site Study Areas shown in **Figure 2-2**.

The TCEC is a regional facility that provides safe and convenient disposal services for communities, businesses and industries serving the Province of Ontario. The landfill is approved to receive municipal, industrial, commercial, and institutional solid non-hazardous wastes generated, including non-hazardous contaminated soil.

The TCEC is engineered with environmental protection systems that meet or exceed regulatory requirements and are subject to highly regulated monitoring and reporting requirements. Systems include engineered liners and covers, leachate collection and removal, landfill gas collection and control, and on-site leachate disposal through phytoremediation.

Leachate that is generated in the waste is conveyed toward a perimeter leachate collection system. WM received approval to treat leachate through a phytoremediation system consisting of a 9.3 ha poplar system planted on the existing landfill cap in 2003. Surplus leachate is trucked off-site to approved wastewater treatment plants.

Figure 2-1. Site Location

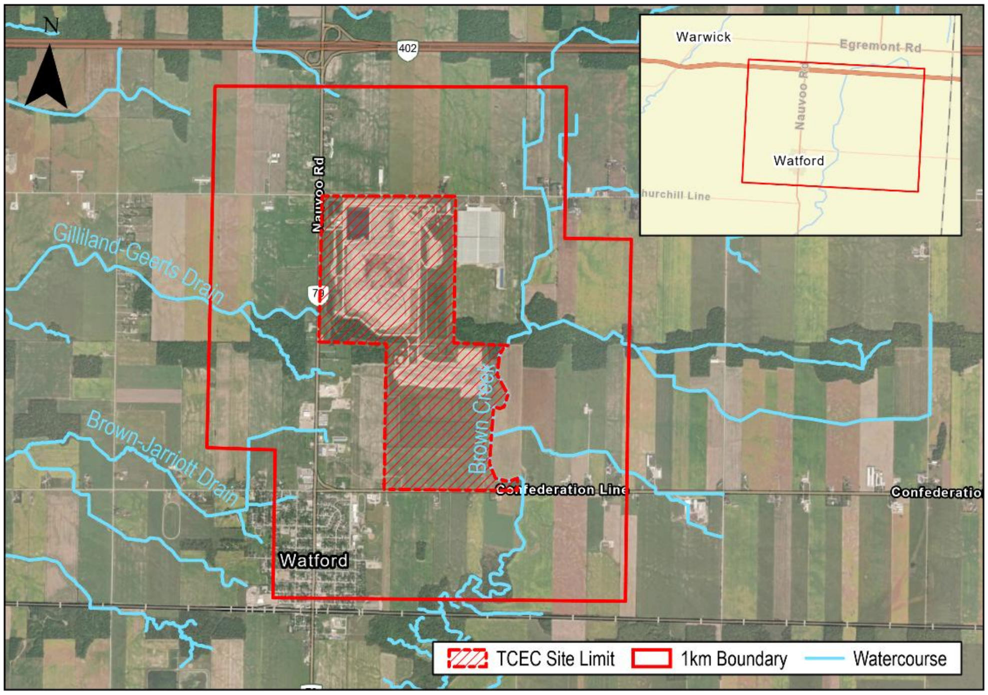


During the EA, existing conditions and potential effects will be considered in the context of two study areas: on-site and off-site. The general study areas proposed for the purposes of the EA are:

- On-site Study Area: the existing TCEC.
- Off-site Study Area: the lands within the vicinity of the TCEC extending approximately 1 km out from the On-site Study Area.

For the water quantity analysis, the focus is on the drainage conditions within the TCEC site limit, with an evaluation of overall drainage patterns and channel geometry in the offsite study area. **Figure 2-2** shows the On-site and Off-site Study Area boundaries.

Figure 2-2. On-Site and Off-Site Study Areas



3 Methods

This Surface Water Quantity Existing Conditions Report was developed based on the evaluation criteria, indicators, and data sources included in the approved ToR, which were developed in consultation with government agencies and other stakeholders. The evaluation criteria, rationale, indicators and data sources used for Surface Water Quantity as per the approved ToR are provided in **Table 3-1**.

The existing conditions analysis focused on the on-site ditches and Stormwater Ponds 1, 2, 3 and 4 and extended to the Off-Site Study Area within the vicinity of the TCEC, shown in **Figure 2-2**. Future analysis of proposed conditions will evaluate the identified indicators and compare with the analysis presented in this report.

Table 3-1. Evaluation Criteria, Indicators and Data Sources for Surface Water (Hydrology)

Evaluation Criteria	Rationale	Indicators	Data Sources
Natural Environment			
Surface Water Environment			
Surface Water Quantity	Construction of physical works may disrupt natural surface drainage patterns and may alter runoff and peak flows. The presence of the expanded landfill may also affect base flow to surface water.	• Change in runoff volumes and peak flows resulting from steeper and longer side slopes. • Changes to drainage areas on-site and off-site. • Predicted occurrence and degree of off-site effects to surface water flows.	• On-site stormwater management system design for expanded landfill. • Landfill design and operations data. • Hydrologic modelling. • Annual monitoring reports. • Published flow information and hydrology design standards from MECP, MNRF, Environment Canada and SCRCA. • Site reconnaissance. • Topographic surveys. • Air photos. • Drainage maps. • Watershed mapping areas including municipal water supply sources within the Off-site Study Area from SCRCA. • Typical stream channel geometry within the Off-site Study Area, to the extent accessible. • Water well survey within the off-site study area. • PTTW records. • Liaison with MECP, SCRCA, downstream riparian landowners along Gilliland-Geerts Drain between Nauvoo Road and Underpass Road, Township of Warwick.

3.1 Data Collection and Review

The following data sources were reviewed to establish the existing site conditions:

- Survey data from September 2022;
    - The survey recorded existing site topography which was used to define catchment areas and flow patterns.
    - The survey also identified the location and geometry of hydraulic structures.
- Site Reconnaissance on September 28, 2022;

  - Site reconnaissance was done to confirm the existing drainage patterns and assess the condition of the stormwater management features. Details are presented in **Section 3.2**.
- Design & Operations (D&O) Report 2008;
  - The D&O Report contains information on the stormwater management pond design, outlet structures, site background, and previously completed modelling.
- Aerial Imagery.
  - Aerial imagery was used to identify land use and offsite drainage patterns.

3.2 Field Studies

The WSP drainage team visited the site on September 28, 2022, to conduct a site reconnaissance and conduct a review of the existing conditions of the stormwater management facilities. Site reconnaissance was done to confirm the existing drainage patterns on the TCEC site and to assess the condition of the stormwater management features. Specifically, each of the four stormwater management ponds were observed and photographed, as well as the Nauvoo Road culvert site outlet.

3.3 Characterization of Existing Conditions

The existing conditions for Surface Water Quantity were characterized as follows:

1. Information collected from the sources identified in **Section 3.1** was reviewed and summarized;
2. Field studies were undertaken to confirm the existing drainage patterns and assess the condition of the stormwater management features (**Section 4.1**); and
3. Hydrologic modelling was conducted to determine existing condition peak flows and pond performance as a baseline condition with which future proposed condition hydrologic modelling can be compared. Furthermore, the 2-year design storm flows are considered as average flows leaving the site which have also been determined and are presented in **Table 4-4** and discussed within **Section 4.5.2.**

3.4 Mitigating Erosion Potential

To mitigate potential erosion during construction activities, WM implements a range of surface-level erosion and sediment control measures. One of the primary strategies currently in use at the TCEC site includes the application of intermediate cover materials, which help stabilize exposed soils. Additionally, silt fences are strategically installed to intercept and slow runoff, thereby reducing the risk of sediment transport off-site. These protective measures are standard practice for all active construction zones and will continue to be applied as new landfill cells are developed at higher elevations under the Landfill Optimization Project. In areas that are not actively being developed and are expected to remain undisturbed for extended periods, WM employs hydraulic seeding techniques to establish vegetative cover. This vegetation plays a critical role in long-term erosion control by anchoring the soil and minimizing surface runoff.

4 Description of Existing Conditions

This section discusses the stormwater management features that currently exist on the TCEC site, the locations where water leaves the site, offsite drainage conditions, an inventory of existing hydraulic structures, and a description of the hydrologic modelling performed as well as the results of the hydrologic analysis.

4.1 Stormwater Management Ponds

Stormwater at the TCEC site is managed through four SWM ponds. A series of ditches direct runoff to the ponds, and from the ponds to the outlets. Each pond has an outlet structure that is designed to control the pond outflow during a range of return period storm events. Each pond is described in detail in the sections below.

The observations from the site reconnaissance for the stormwater management facilities are also noted and documented below. Exhibits showing the existing catchment areas, the offsite drainage patterns, and the hydraulic structures are shown in **Appendix A**. A series of photographs from the site reconnaissance showing the SWM ponds are included in **Appendix B.**

4.1.1 Stormwater Pond 1

Stormwater Pond 1 is located centrally on the site, to the southeast of the TCEC landfill (**Appendix A - Exhibit 1**). The area draining to this pond is approximately 40.21 ha and the total footprint of the pond, shown in **Figure 4-1**, is approximately 0.8 ha/ 21,429 m³, which includes two forebays and a permanent pool of 3,651 m³. The pond provides water quality treatment for runoff from the site with a 75% TSS removal rate. The two inlets are swales which direct runoff from catchment G4B (10% imperviousness) into the forebays (swale geometry is shown in **Figure 4-2** and **Figure 4-3**).

The outlet control arrangement for this pond consists of two outlet control structures that provide staged discharge from the pond. Structure 1 includes a 1,500 mm diameter riser with a riser crest elevation of 238.7 m, two 150 mm diameter lower orifices at invert elevation 237.6 m, and two 150 mm diameter upper orifices at invert elevation 238.0 m. Discharge is conveyed through a 750 mm diameter outlet pipe, 25 m in length, with upstream and downstream invert elevations of 237.5 m and 237.4 m, respectively. A rectangular weir is also provided with a crest elevation of 238.3 m and a length of 1.2 m. Structure 2 includes a 1,500 mm diameter riser with a riser crest elevation of 238.7 m, two 200 mm diameter lower orifices at invert elevation

238.0 m, and no upper orifice or rectangular weir. Discharge from Structure 2 is also conveyed through a 750 mm diameter outlet pipe, 25 m in length, with upstream and downstream invert elevations of 237.5 m and 237.4 m, respectively. As such, this pond is regulated by a staged outlet control system rather than by outlet pipes alone. The pond normal water level is 237.6 m, and outflow from the pond is eventually directed towards Outlet G. The inlet and outlet structures were not accessible during the site visit for depth measurements. A silt fence separates the forebay and the permanent pool and was observed to be in good condition during the site visit.

Figure 4-1. Pond 1 Features

Figure 4-2. Pond 1 North Inlet Swale Geometry

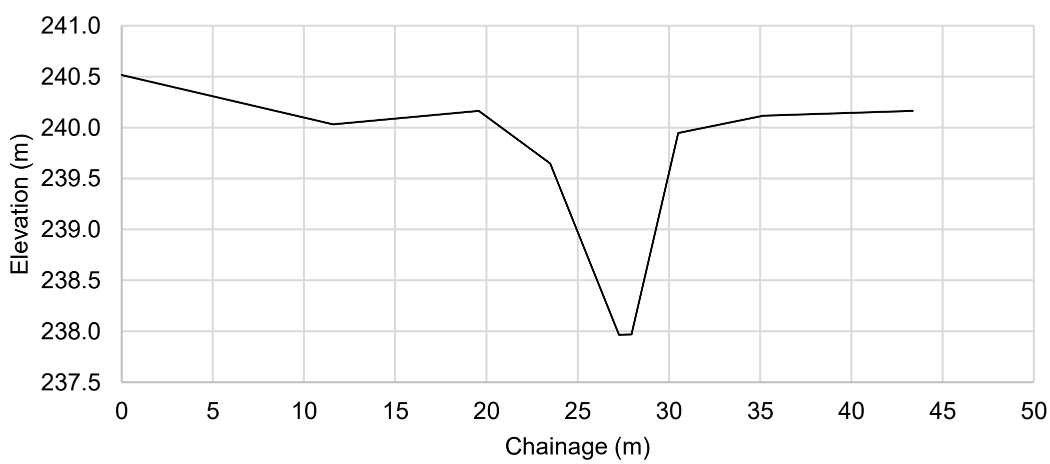
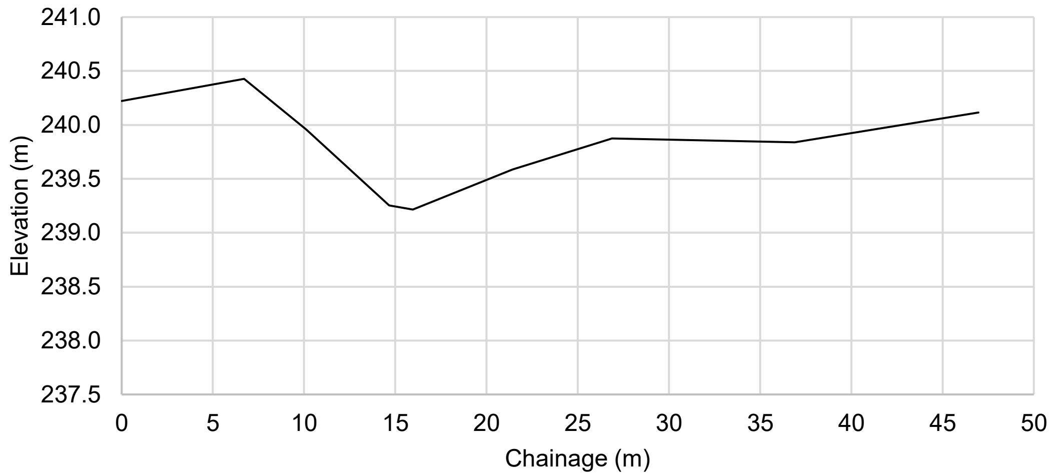


Figure 4-3. Pond 1 South Inlet Swale Geometry



4.1.2 Stormwater Pond 2

Stormwater Pond 2 is located on the west side of the site, southwest of the TCEC landfill. This pond is just east of Nauvoo Road (County Road 79) near the walking trail. The area draining to this pond is approximately 62.26 ha and the total footprint of the pond, shown in **Figure 4-4**, is approximately 2.0 ha/48,954 m³, which includes two forebays and a permanent pool of 10,856 m³. The pond provides water quality treatment for runoff from the site with a 75% TSS removal rate. The main inlet structure is a reinforced concrete box culvert with a span of 3 m and a rise of 1.2 m. There is an additional inlet and small forebay on the north side of the pond that receives surface runoff through swales. Runoff is received from catchments G4A, G3A, and G1B that have a total imperviousness of approximately 27%.

The outlet control arrangement for this pond consists of two outlet control structures that regulate pond discharge under a range of storm events. Structure 1 includes an 1,800 mm diameter riser with a riser crest elevation of 233.2 m, two 200 mm diameter lower orifices at invert elevation 232.3 m, and two 200 mm diameter upper orifices at invert elevation 232.6 m. Discharge is conveyed through a 1,050 mm diameter outlet pipe, 55 m in length, with upstream and downstream invert elevations of 231.7 m and 231.5 m, respectively. A rectangular weir is also provided with a crest elevation of 232.9 m and a length of 1.2 m. Structure 2 includes a 2,400 mm diameter riser with a riser crest elevation of 233.4 m, two 200 mm diameter lower orifices at invert elevation 232.3 m, and one 200 mm diameter upper orifice at invert elevation 232.8 m. Discharge from Structure 2 is conveyed through a 1,200 mm diameter outlet pipe, 55 m in length, with upstream and downstream invert elevations of 231.7 m and 231.5 m, respectively. No rectangular weir is provided for Structure 2. As such, this pond is regulated by a staged outlet control system rather than by outlet pipes alone and is discharged through a pair of outlet pipes toward Outlet G.

Furthermore, the depth of water that was observed at the inlet structure was approximately 76 cm and at the outlet structures was approximately 60 cm and 50 cm for the 1.05 m and 1.2 m diameter pipe culvert respectively. Additionally, there was an overflow channel that was lined with riprap and river stone with big boulders around it. The SWM pond main cell was observed to be full, slightly higher than the permanent pool elevation, and the overflow channel was conveying flows towards the walking trail. This is because on September 19 and 21 there were recent rainstorms just prior to the site reconnaissance on September 22, 2022. The pond normal water level is 232.3 m.

Figure 4-4. Pond 2 Features

4.1.3 Stormwater Pond 3

Stormwater Pond 3 is located in the northwest corner of the site just behind the office building. The area draining to this pond is approximately 31.84 ha and the total footprint of the pond, shown in **Figure 4-5**, is approximately 1.1 ha/24,996 m^3, which includes a forebay and a permanent pool of 4,843 m^3. The pond provides water quality treatment for runoff from the site with a 75% TSS removal rate. The inlet structure is a reinforced concrete box culvert which is 3 m wide and 1.2 m high and the water depth was observed to be approximately 27 cm. Runoff is received from catchment AB that has approximately 10% imperviousness.

The outlet control arrangement for this pond consists of three outlet control structures that provide staged discharge from the pond to the downstream drainage system. Structure 1 includes a 1,200 mm diameter riser with a riser crest elevation of 237.2 m, two 200 mm diameter lower orifices at invert elevation 236.6 m, and two 200 mm diameter upper orifices at invert elevation 236.9 m. Discharge is conveyed through a 450 mm diameter outlet pipe, 90 m in length, with upstream and downstream invert elevations of 236.1 m and 235.8 m, respectively. No rectangular weir is provided for this structure. Structure 2 includes a 1,200 mm diameter riser with a riser crest elevation of 237.20 m, two 100 mm diameter lower orifices at invert elevation 236.6 m, and two 200 mm diameter upper orifices at invert elevation 236.9 m. Discharge is conveyed through a 600 mm diameter outlet pipe, 50 m in length, with upstream and downstream invert elevations of 236.1 m and 235.8 m, respectively. Structure 3 includes a 1,200 mm diameter riser with a riser crest elevation of 237.3 m, three 200 mm diameter lower orifices at invert elevation 236.8 m, and no upper orifice or rectangular weir. Discharge from Structure 3 is conveyed through a 600 mm diameter outlet pipe, 50 m in length, with upstream and downstream invert elevations of 236.1 m and 235.8 m, respectively. This pond is regulated by a staged outlet control system which is provided through multiple riser and orifice structures. As discussed above, pond has three outlet culverts that run under the berm and outlet to the ditch that runs along Nauvoo Road (County Road 79). Two pipe culverts (600 mm in diameter) outlet towards the south (Outlet B) whereas one pipe culvert (450 mm in diameter) outlets towards the north (Outlet A) into the roadside ditch. The pond normal water level is 236.6 m.

Figure 4-5. Pond 3 Features

4.1.4 Stormwater Pond 4

Stormwater Pond 4 is located in the northeast corner of the site just south of Zion Line. The area draining to this pond is approximately 15.77 ha and the total footprint of the pond, shown in **Figure 4-6**, is approximately 0.4 ha/8,328 m³, which includes the forebay and the permanent pool of 1,812 m³. The pond provides water quality treatment for runoff from the site with a 75% TSS removal rate. The inlet structure is a 1.05 m pipe culvert. Runoff is received from catchment C1B (11% imperviousness), and outflow is directed toward outlet C.

The outlet control arrangement for this pond consists of a single outlet control structure incorporating staged discharge controls within the riser system. The structure includes an 1,800 mm diameter riser with a riser crest elevation of 241.3 m, two 200 mm diameter lower orifices at invert elevation 240.4 m, and two 200 mm diameter upper orifices at invert elevation 240.7 m. Discharge is conveyed through a 1,050 mm diameter outlet pipe, approximately 355 m in length, with upstream and downstream invert elevations of 239.8 m and 239.6 m, respectively. A rectangular weir is also provided with a crest elevation of 241.0 m and a length of 1.2 m. As such, the pond discharge is regulated through an orifice-controlled riser structure with higher-level overflow control, rather than through a simple pipe outlet alone. The water depth was observed to be 4 cm and 11 cm at the inlet and outlet structure respectively. The pond normal water level is 240.4 m.

Figure 4-6. Pond 4 Features

4.2 Site Outlets

Locations where flow leaves the TCEC were confirmed during the site reconnaissance. Refer to **Appendix A – Exhibit 1** for the site plan showing the outlet locations. A total of 10 outlet locations were identified and have been described in the following sections.

4.2.1 Outlet A

This outlet is located at the northwest corner of the site at the intersection of Nauvoo Road (County Road 79) and Zion Line. The flow crosses Zion Line through a 400 mm CSP culvert. Flow to this outlet includes the small undeveloped area adjacent to the roadway (Catchment A) and a portion of the controlled flow from Pond 3 (Catchment AB). The downstream receiver of flows from Outlet A is the Auld-Redmond Drain.

4.2.2 Outlet B

This outlet is located approximately 270 m south of the intersection of Nauvoo Road and Zion Line. The flow crosses Nauvoo Road through a 900 mm concrete culvert. Flow to this outlet includes uncontrolled runoff from the area around the landfill entrance (Catchment B) and a portion of the controlled flow from Pond 3 (Catchment AB). The immediate downstream receiver of flows from Outlet B at Nauvoo Road is the Bryson-Fleming Drainage Works Drain which confluences with Gilliland-Geerts Drain near Underpass Road.

4.2.3 Outlet C

This outlet is located approximately 380 m east of the intersection of Nauvoo Road and Zion Line. The flow crosses Zion Line through an 800 mm CSP culvert. Flow to this outlet includes uncontrolled runoff from the perimeter berm (Catchment C1A) and controlled flow from Pond 4 (Catchment C1B). The downstream receiver of flows from Outlet C is the Auld-Redmond Drain.

4.2.4 Outlet D

This outlet is located approximately 440 m south of the intersection of Nauvoo Road and Zion Line. The flow crosses Nauvoo Road through an 825 mm concrete culvert after part of the flow passes through a 375 mm Big 'O' culvert through the perimeter berm. Flow to this outlet is primarily from grassed areas on either side of the perimeter berm (Catchment D). The immediate downstream receiver of flows from Outlet D at Nauvoo Road is the Bryson-Fleming Drainage Works Drain which confluences with Gilliland-Geerts Drain near Underpass Road.

4.2.5 Outlet E

This outlet is located approximately 650 m south of the intersection of Nauvoo Road and Zion Line. The flow crosses Nauvoo Road through an 825 mm CSP culvert after part of the flow passes through a 375 mm Big 'O' culvert through the perimeter berm. Like Outlet D, flow to this outlet is primarily from grassed areas on either side of the perimeter berm (Catchment E). The immediate downstream receiver of flows from Outlet E at Nauvoo Road is the Bryson-Fleming Drainage Works Drain which then confluences with Gilliland-Geerts Drain near Underpass Road.

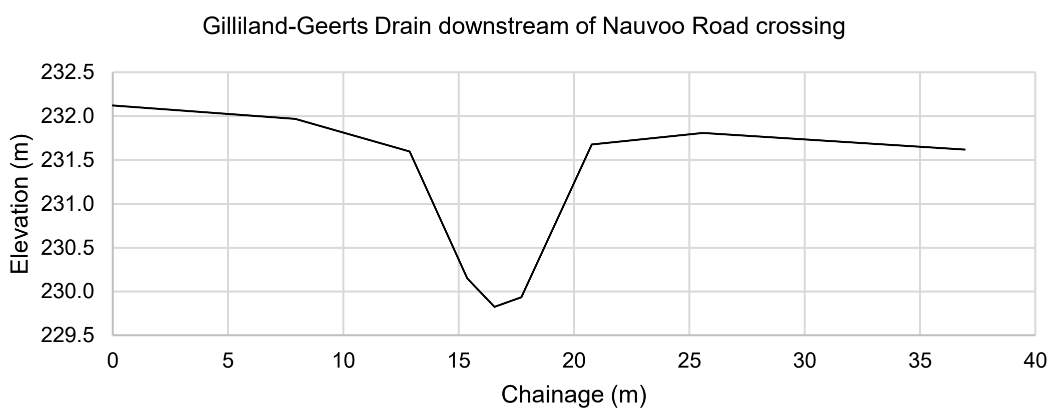
4.2.6 Outlet F

This outlet is located approximately 720 m south of the intersection of Nauvoo Road and Zion Line. The flow passes through a 525 mm Big 'O' culvert through the perimeter berm and joins the south-flowing ditch of Nauvoo Road. Similar to Outlets D and E, flow to this outlet is primarily from grassed areas on either side of the perimeter berm (Catchment F). The immediate downstream receiver of flows from Outlet F at Nauvoo Road is the Bryson-Fleming Drainage Works Drain which then confluences with Gilliland-Geerts Drain near Underpass Road.

4.2.7 Outlet G

This outlet is located approximately 1090 m south of the intersection of Nauvoo Road and Zion Line. The flow crosses Nauvoo Road through a 3.7 m x 2.8 m box culvert. This is the largest outlet on the site and conveys the highest flows. Catchments G1A and G2A are largely undeveloped and flow uncontrolled to the outlet. Catchments G1B, G3A, and G4A are controlled by Pond 2. Catchment G4B is controlled by Pond 1, with the outflow conveyed by roadside ditch and the Van Kessel Drain to the outlet. Downstream of Outlet G the flow remains within a defined flow channel (Gilliland-Geerts drain) which is a tributary to Bear Creek. The Gilliland-Geerts drain has a channel geometry as shown in **Figure 4-7**, with a bottom width of 2.3 m and a top width of 7.9 m.

Figure 4-7. Gilliland-Geerts Drain Channel Geometry (left to right looking downstream)

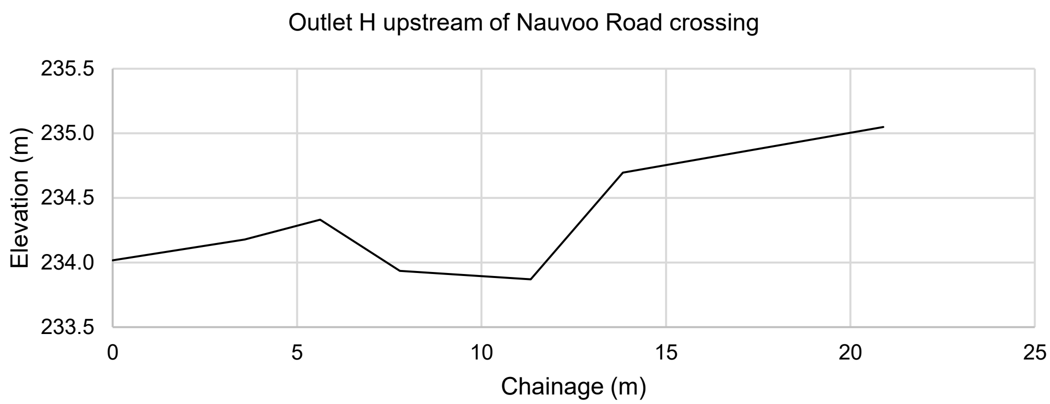


4.2.8 Outlet H

This outlet is located near the excess soil stockpile on the south half of the site and leaves the site to the west under the walking path through a 750 mm CSP. Flow to this outlet is from part of the excess soil stockpile and a small section of the poplar plantation (Catchment H). Downstream of Outlet H the flow crosses Nauvoo Road through a 2.0 m x 1.5 m culvert and connects with the flow from Outlet G further downstream. The downstream receivers of flows from Outlet H are the Vankessel

Drain and the Gilliland-Geerts Drain. The channel geometry upstream of the culvert crossing is as shown in **Figure 4-8**, with a bottom width of 3.5 m and a top width of 8.2 m.

Figure 4-8. Channel Geometry Downstream of Outlet H at the Nauvoo Road Crossing (left to right looking downstream)



4.2.9 Outlet I

This outlet is located near the southwest corner of the site. Flows from Catchment I leave the site at multiple locations through small culverts under the walking path. The immediate downstream receiver of flows from Catchment I are the Brown-Jarriott Drain Extension and the flows join further downstream to form a tributary to Bear Creek and the Gilliland-Geerts Drain.

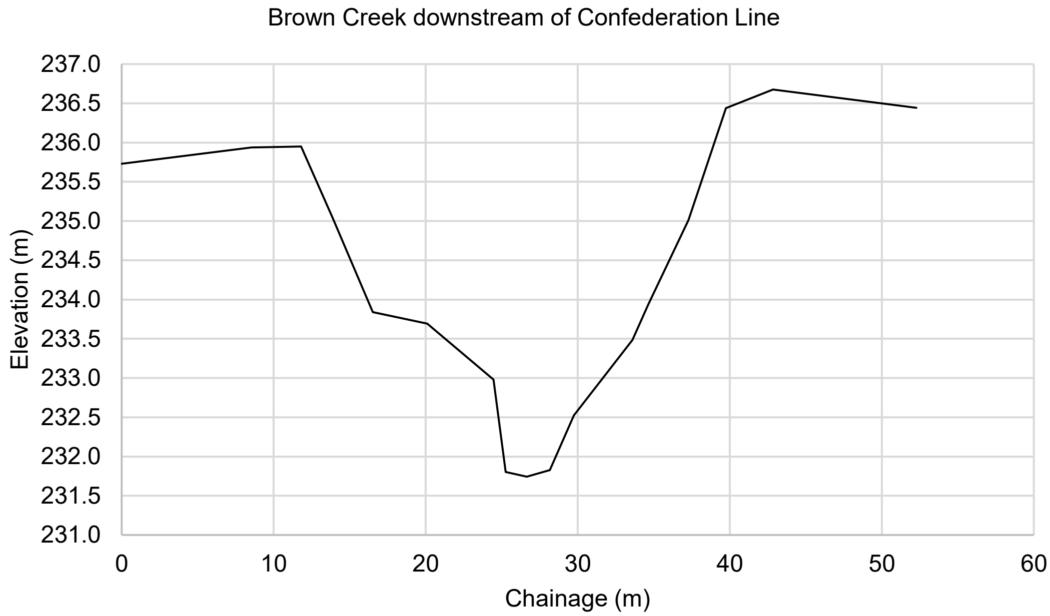
4.2.10 Outlet J

Catchment J drains a small area of perimeter berm in the northeast corner of the site. Uncontrolled flows are directed east along the Zion Line roadside ditch towards Brown Creek.

4.2.11 Remaining site area

The remaining site area that does not drain to the above outlets drains uncontrolled toward Brown Creek. This area is primarily undeveloped and contains multiple small drainage channels that discharge directly into Brown Creek. Brown Creek channel geometry was surveyed downstream of the Confederation Line crossing and is shown in **Figure 4-9.**

Figure 4-9. Brown Creek Channel Geometry (left to right looking downstream)



4.3 Off-Site Drainage Conditions

This section describes the offsite drainage conditions and the surrounding watersheds.

4.3.1 Drainage Boundaries and Overland Flow Routes

The TCEC site lies on the border between the Bear Creek and the Brown Creek watersheds. Exhibit 2 (**Appendix A**) shows the watershed boundaries and the watercourses that flow through the surrounding area. The Gilliland-Geerts Drain as well as the Brown-Jarriott Drain both flow west from the site toward Bear Creek, with the location where they meet in Bear Creek shown in Exhibit 2. Flow also leaves the site at the north boundary along a minor channel that captures flow from Outlet C and directs it northwest under Nauvoo Rd and west toward Bear Creek. These watersheds all eventually drain to the Sydenham River and then to the St. Clair River.

On the southwest side of the site, Brown Creek passes right along the site boundary. Runoff from adjacent agricultural fields within the off-site study area drains west toward Brown Creek and joins runoff from the on-site study area. The Brown Creek watershed begins north of the study area and has a well-defined channel well upstream of the Highway 402 crossing. There is no flow monitoring in Brown Creek (as per SCRCA), however significant flows are expected due to the size of the installed drainage infrastructure along Brown Creek at road crossings.

4.3.2 Gilliland-Geerts Drain

The Gilliland-Geerts drain is of particular interest, as it is the primary outfall for the site. All drainage from Catchment Area G, as discussed in **Section 4.2** above, flows into the Gilliland-Geerts Drain. The flow meanders through farmland and wooded area before passing beneath Underpass Road. The culvert that crosses Nauvoo Road is a reinforced concrete box culvert which has a 3.8 m span and 1.55 m rise. A picture of the crossing is presented in **Appendix B**.

A survey of riparian property owners along the Gilliland Geerts Drain was conducted by RWDI in July/August 2023 as a condition of the Permit to Take Water (System No. 4682-BLJRY) dated November 8, 2021. Furthermore, the survey indicated that there is no water taking that would be regulated by the *Ontario Water Resources Act* from the Gilliland-Geerts Drain. Therefore, an assessment of potential impacts on riparian water users was not required to be completed. The survey and methodology are included in **Appendix F**.

4.4 Inventory of Existing Hydraulic Structures

Three types of hydraulic structures exist within the study area: culverts, pond inlets, and pond outlets. These structures convey water under on-site and off-site roads, as well as direct flow in to and out of the on-site stormwater management ponds. The available information regarding existing culvert IDs, location, size, and material has been tabulated and is included in **Appendix C**. A summary of stormwater management pond outlet structures on the TCEC site has also been included in **Appendix C**. An exhibit showing structure IDs to identify their locations is included in **Appendix A**.

4.5 Hydrologic Modelling

Hydrologic modelling for the TCEC site was conducted to evaluate the existing peak flows leaving the site and the existing pond function. The results presented here can be used to compare with future conditions modelling so that impacts of proposed works can be mitigated.

Existing conditions catchment areas for the site were calculated based on the proposed catchment areas described in the Development and Operations Plans – Warwick Landfill Expansion (March 2008) and updated based on 2022 ground surface information as part of the site survey (**Exhibit 1**).

Four existing stormwater management ponds are located on the site (**Section 4.1**). These ponds are designed to store runoff from developed areas of the site, providing quantity and quality control. There are several uncontrolled areas within the site boundary which drain primarily undeveloped regions of the site.

The existing drainage areas are shown on Exhibit 1 in **Appendix A**.

4.5.1 Methodology

Hydrologic modelling was completed in Visual OTTHYMO (6.2). Existing conditions were modelled based on the drainage areas delineated in the Development and Operations Plans – Warwick Landfill Expansion (March 2008), with areas updated based on current topography and land use.

Furthermore, the hydrologic modelling parameters presented in **Table 4-2** were developed using a combination of background design information and updated existing conditions data. Existing catchment areas were based on the drainage areas described in the Development and Operations Plans – Warwick Landfill Expansion (March 2008) and were refined using 2022 survey information and current site topography and land use. Catchment slopes were derived from the updated surveyed ground surface and catchment delineation, while percent imperviousness and runoff characteristics were assigned based on current site land use and developed conditions observed on-site. Survey information was also used to confirm drainage patterns and the location including geometry of hydraulic structures.

The rainfall intensity information for the site was obtained from the Environment Canada Sarnia weather station Intensity-Duration-Frequency (IDF) data.

$$i = \left[\frac{A}{(Td)^B}\right]$$

Where:

- A, B = regression constants for each return period
- I = rainfall intensity (mm/hour)
- Td = storm duration (hours)

IDF parameters are summarized in **Table 4-1**.

Table 4-1. IDF Regression Constants

Return Period	A	B
2	22.5	0.713
5	29.7	0.726
10	34.4	0.732
25	40.4	0.737
50	44.9	0.740
100	49.3	0.743

The 4-hour Chicago design storm was used to evaluate peak flows at each outlet. The Chicago event distributions are widely accepted as a synthetic distribution for use in southern Ontario. The 4-hour Chicago design storm was created based on the above rainfall information. The 3-hour Chicago storm was also run, however the 4-hour results were found to be more conservative (i.e., higher peak flows and higher storage volumes). As such, the 4-hour Chicago storm results were chosen to be presented within this report. The results from both the 100-year 3-hour Chicago and the 100-year 4-hour Chicago are included in **Appendix D**.

4.5.2 Results

Modelling parameters for each drainage area were calculated and are shown in **Table 4-2**. Time to peak (i.e., the time it takes for the whole drainage area to contribute to runoff) was calculated as the average of the SCS Upland and CN methods.

The SCS Upland method calculates the flow velocity based on catchment slope and ground type and finds the time of concentration as the catchment length divided by the flow velocity.

The SCS CN method calculates the flow velocity based on curve number, flow length, and effective slope.

Table 4-2. Catchment Modelling Parameters

Catchment ID	Drainage Area (ha)	Runoff Coefficient	Curve Number	Imperviousness (%)	Slope (%)	Initial Abstraction Pervious (mm)	Initial Abstraction Impervious (mm)	Time to Peak (hr)
A	0.94	0.44	84	14	0.60	3.88	n/a	0.12
AB	31.84	0.42	85	10	0.80	3.47	n/a	0.93
B	6.99	0.51	81	28	1.00	5.90	2.00	n/a
C1A	6.77	0.42	83	14	0.40	4.12	n/a	0.50
C1B	15.77	0.42	84	11	0.90	3.94	n/a	0.42
D	2.10	0.38	82	6	0.50	4.32	n/a	0.14
E	1.31	0.38	82	7	0.70	4.30	n/a	0.08
F	1.89	0.37	83	4	0.50	4.09	n/a	0.22
G1A	12.45	0.39	82	9	0.30	3.07	n/a	1.03
G1B	32.91	0.41	84	10	0.50	2.71	n/a	0.60
G2A	19.40	0.35	81	2	0.40	2.96	n/a	0.66
G3A	18.71	0.39	83	5	0.70	2.75	n/a	2.44
G4A	10.64	0.41	83	12	0.50	2.86	n/a	1.12
G4B	40.21	0.42	84	10	0.30	2.71	n/a	1.20
H	8.60	0.37	82	1	1.80	4.16	n/a	0.31
I	22.13	0.37	82	1	0.40	4.16	n/a	1.07
J	1.93	0.38	82	3	0.60	4.12	n/a	0.29

Existing condition peak flows for the 4-hour Chicago design storm are shown in **Table 4-3**. Visual OTTHYMO model output is included in **Appendix D**.

Table 4-3. Existing Conditions Peak Flows

Outlet ID	Ultimate Flow Receiver	2-year	5-year	10-year	25-year	50-year	100-year
A	Auld-Redmond Drain	0.07	0.10	0.14	0.18	0.22	0.26
B	Gilliland-Geerts Drain	0.42	0.57	0.68	0.81	0.91	1.01
C	Auld-Redmond Drain	0.15	0.25	0.32	0.43	0.52	0.64
D	Gilliland-Geerts Drain	0.08	0.13	0.17	0.23	0.28	0.33
E	Gilliland-Geerts Drain	0.07	0.12	0.16	0.21	0.26	0.30
F	Gilliland-Geerts Drain	0.05	0.09	0.12	0.16	0.20	0.23
G	Gilliland-Geerts Drain	0.41	0.70	0.90	1.18	1.39	1.63
H	Gilliland-Geerts Drain	0.17	0.30	0.40	0.54	0.65	0.77
I	Brown-Jarriott Drain Extension and Gilliland-Geerts Drain	0.21	0.35	0.45	0.58	0.69	0.81
J	Brown Creek	0.04	0.08	0.10	0.13	0.16	0.19

The total flows leaving to Auld-Redmond Drain, Brown Creek, Brown-Jarriott Drain Extension and Gilliland-Geerts Drain are shown in **Table 4-4.**

Table 4-4. Peak Flows Leaving To Ultimate Receivers

Ultimate Flow Receiver	2-year	5-year	10-year	25-year	50-year	100-year
Auld-Redmond Drain	0.22	0.35	0.46	0.61	0.74	0.90
Brown-Jarriott Drain Extension	0.11	0.18	0.23	0.29	0.35	0.41
Gilliland-Geerts Drain	1.31	2.09	2.66	3.42	4.04	4.68
Brown Creek	0.04	0.08	0.10	0.13	0.16	0.19

The 2-year design storm peak flows are considered as the average flows leaving the site to the ultimate receivers which range from 0.04 m^3/s to 1.31 m^3/s.

Pond function was also evaluated in Visual OTTHYMO. **Table 4-5** shows the peak inflow, peak outflow, and maximum storage used in each SWM pond during the 100-year event.

Table 4-5. SWM Pond Function During 100-year Event

Pond ID	Peak Inflow (m^3/s)	Peak Outflow (m^3/s)	Maximum Storage Used (ha·m)
1	1.490	0.704	0.943
2	2.460	0.529	1.625
3	1.451	0.671	0.732
4	1.247	0.372	0.347

5 Summary of Existing Conditions

This report has discussed the existing conditions for surface water quantity at the TCEC site and within the Off-Site Study Area. Seventeen catchment areas were delineated based on the updated survey information from September 2022 and were modelled in Visual OTTHYMO to show pond function and peak flows as summarised in **Table 5-1**.

Table 5-1. Summary of Existing Conditions

<table>
<tr><th>Outlet ID</th><th>Catchment ID</th><th>Drainage Area (ha)</th><th>100-year Peak Flow</th></tr>
<tr><td rowspan="2">A</td><td>A</td><td>0.94</td><td rowspan="2">0.26</td></tr>
<tr><td rowspan="2">AB</td><td rowspan="2">31.84</td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">1.01</td></tr>
<tr><td>B</td><td>6.99</td></tr>
<tr><td rowspan="2">C</td><td>C1A</td><td>6.77</td><td rowspan="2">0.64</td></tr>
<tr><td>C1B</td><td>15.77</td></tr>
<tr><td>D</td><td>D</td><td>2.10</td><td>0.33</td></tr>
<tr><td>E</td><td>E</td><td>1.31</td><td>0.30</td></tr>
<tr><td>F</td><td>F</td><td>1.89</td><td>0.23</td></tr>
<tr><td rowspan="6">G</td><td>G1A</td><td>12.45</td><td rowspan="6">1.63</td></tr>
<tr><td>G1B</td><td>32.91</td></tr>
<tr><td>G2A</td><td>19.40</td></tr>
<tr><td>G3A</td><td>18.71</td></tr>
<tr><td>G4A</td><td>10.64</td></tr>
<tr><td>G4B</td><td>40.21</td></tr>
<tr><td>H</td><td>H</td><td>8.60</td><td>0.77</td></tr>
</table>

Outlet ID	Catchment ID	Drainage Area (ha)	100-year Peak Flow
I	I	22.13	0.81
J	J	1.93	0.19

Site reconnaissance was completed on September 28, 2022, with observations made on the current state of SWM infrastructure. The four SWM ponds and 10 outlet locations were identified and discussed.

According to the existing conditions analysis, the ponds are functioning adequately and the SWM Pond 1 has the highest peak outflow of 0.704 m^3/s as per the hydrologic modeling for the 100-year design storm. SWM Pond 2, 3, and 4 show a peak outflow of 0.529 m^3/s, 0.671 m^3/s, and 0.372 m^3/s respectively for the 100-year design storm. The peak outflow to Gilliland-Geerts Drain from the site was 4.68 m^3/s for the 100-year design storm.

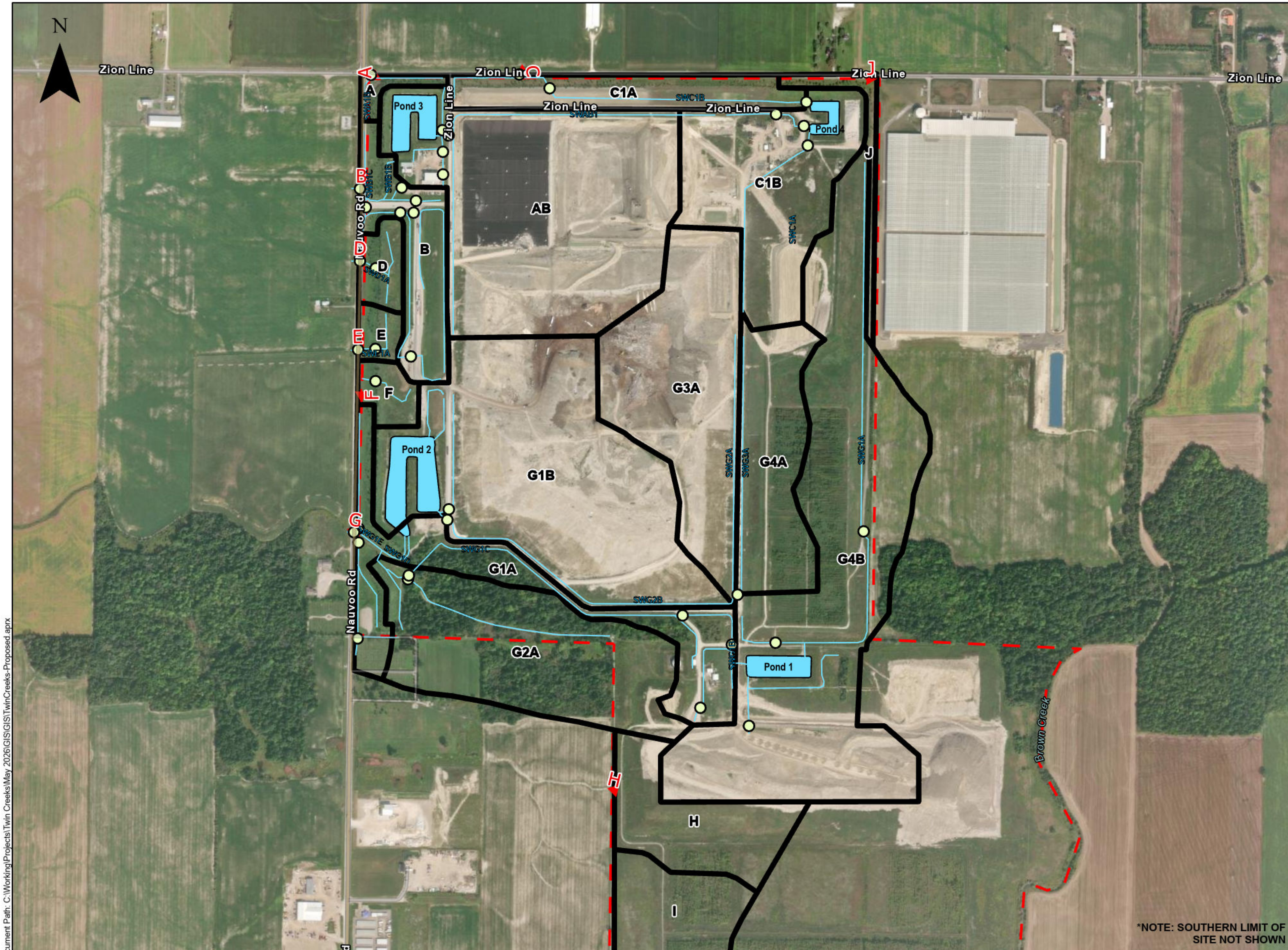
Further, it should be noted that the catchment areas of the TCEC site are to remain unchanged for the landfill optimization alternatives being considered. As such, drainage patterns within the site and off-site are expected to remain unchanged.

Other Considerations

During construction, there is a potential for short-term sediment wash-off from the site. To protect the downstream receiving system and other natural features, on-site sediment control measures are necessary during construction and should not be removed until the end of construction period when the site has been stabilized. Construction phasing must be scheduled to minimize the extent and period to which disturbed soils are exposed to weathering. To prevent erosion during construction at TCEC, WM uses intermediate cover materials, silt fences, and hydraulic seeding to stabilize soils and control runoff, with these measures continuing as new landfill cells are developed.

A

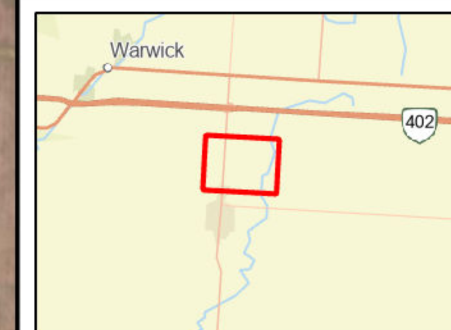
Exhibits



CLIENT
WASTE MANAGEMENT OF CANADA CORP.

PROJECT
TWIN CREEKS LANDFILL OPTIMIZATION

TITLE
EXHIBIT 1
CATCHMENT AREAS
EXISTING CONDITIONS



LEGEND
- Outlet
- SWM Ponds
- Waste Management Property Limit
- Existing Catchments
- Existing Ditches
- Culverts

0 0.07 0.15 km

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May 2026	
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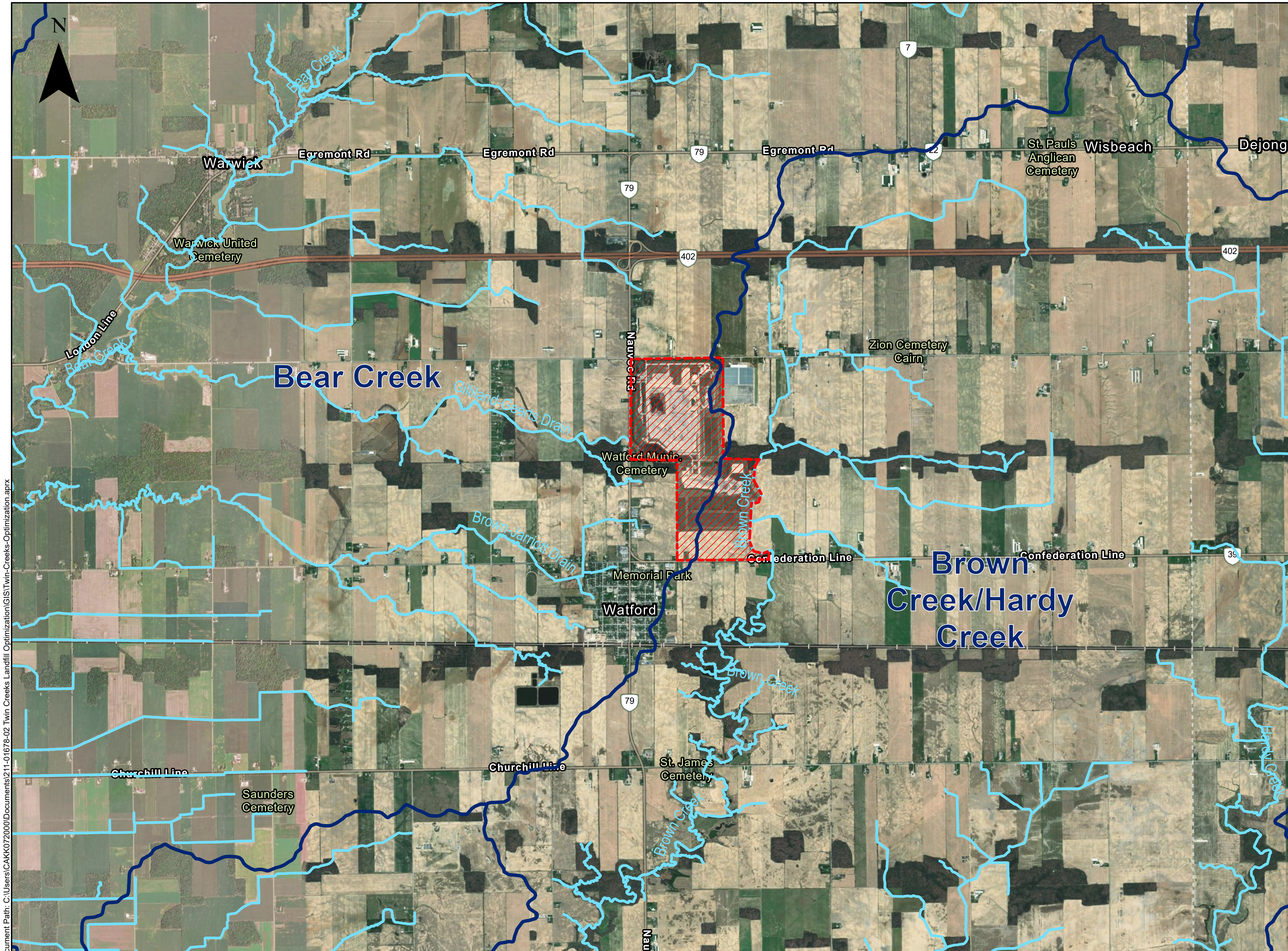
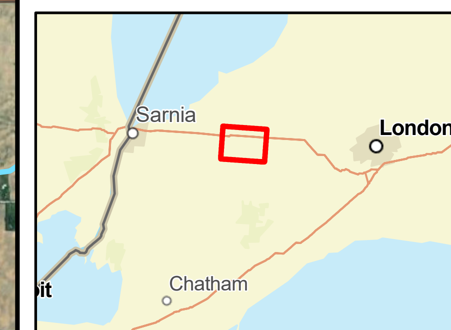


CLIENT
WM CANADA

PROJECT
TWIN CREEKS LANDFILL OPTIMIZATION

TITLE
EXHIBIT 2
WATERSHED MAP



LEGEND

- WM Canada Property Limit
- Watercourse
- Watershed Boundaries

0 0.5 1 km

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Document Path: C:\Users\CAKK072000\Documents\211-01678-02 Twin Creeks Landfill Optimization\GIS\Twin-Creeks-Optimization.aprx

CLIENT

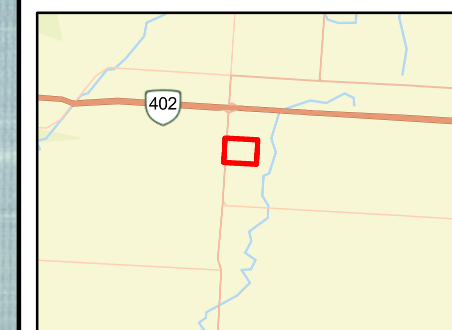
WM CANADA

PROJECT

TWIN CREEKS LANDFILL OPTIMIZATION

TITLE

EXHIBIT 3
HYDRAULIC STRUCTURES 1



LEGEND

- WM Canada Property Limit
- Culvert
- Pond Inlet
- Pond Outlet
- 5m Contours
- SWM Ponds
- Watercourse

0 0.04 0.08 km

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June 2024	
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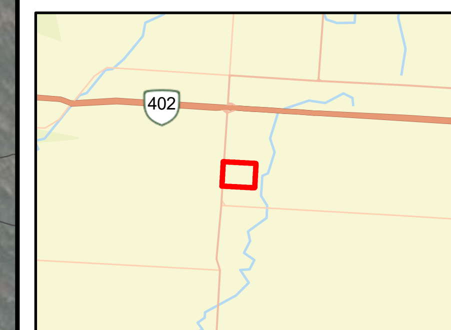
CLIENT
WM CANADA

PROJECT
TWIN CREEKS LANDFILL OPTIMIZATION

TITLE
EXHIBIT 4
HYDRAULIC STRUCTURES 2



LEGEND
- WM Canada Property Limit
- Culvert
- Pond Inlet
- Pond Outlet
- 5m Contours
- SWM Ponds
- Watercourse

0 0.04 0.08 km

DRAWN BY KK	CHECKED BY EK
June 2024	
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WM

CLIENT

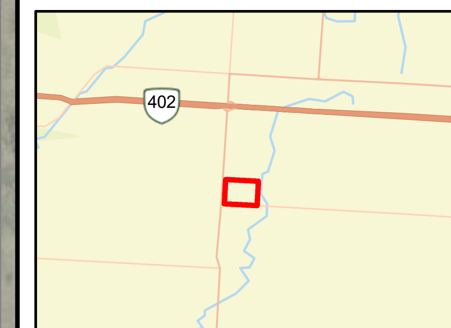
WM CANADA

PROJECT

TWIN CREEKS LANDFILL OPTIMIZATION

TITLE

EXHIBIT 5
HYDRAULIC STRUCTURES 3



LEGEND

- WM Canada Property Limit
- Culvert
- Pond Inlet
- Pond Outlet
- 5m Contours
- SWM Ponds
- Watercourse

0 0.04 0.08 km

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Document Path: C:\Users\CAKK072000\Documents\211-01678-02 Twin Creeks Landfill Optimization\GIS\Twin-Creeks-Optimization.aprx

B

Site Reconnaissance Photos

SWM Pond 1

SWM Pond 1 located at the southeast corner of the site. This image is overlooking the main cell of the pond towards east.

Looking west towards the RNG facility near SWM Pond 1.

Inflows entering the forebay of the SWM Pond 1 from the South Cell of the site near Street E.

Inflows entering the forebay of the SWM Pond 1 from the South Cell of the site near Street ‘E’ overlooking the forebay that is separated from the main cell by a berm.

SWM Pond 2

SWM Pond 2 located in the southwest corner of the site. Image looking northwest shows inflows into the pond from the reinforced concrete box culvert near Street ‘C’.

Image looking west shows inflows into the pond from the reinforced concrete box culvert near Street 'C'.

Image looking north shows the forebay and the berm that divides the forebay and the main cell of the SWM pond.

Image looking east shows the forebay and Street ‘C’ in distance.

Image looking north showing the forebay.

SWM Pond 3

SWM Pond 3 located in the southwest corner of the site. Image looking south towards the maintenance building shows inflows into the pond.

Image looking southwest shows the SWM pond forebay in foreground.

Image looking east shows the inlet structure of the SWM pond with Street ‘C’ in distance.

Image looking west shows the expansion area of the site and the reinforced concrete box culvert that acts as an inlet structure for the SWM Pond 3.

SWM Pond 4

SWM Pond 4 located in the northeast corner of the site. Image looking southwest towards the site with the forebay shown in foreground.

Image looking south shows the forebay in foreground and the main cell in distance.

Image looking north shows the main cell of the SWM pond with Zion Line in distance.

Nauvoo Road Culvert

Nauvoo Road culvert looking east (upstream) towards the site.

Nauvoo Road culvert looking west (downstream) outlets into the Gilliland Geerts Drain.

C

Inventory of Hydraulic Structures

Project: Twin Creeks Landfill Optimization	No.: 211-01678-02	
By: KK	Date: 2023-03-23	Page:
Checked: EK	Checked: 2023-03-23	1

Subject: **Existing SWMF Outlet Structures**

	Orifices				Outlet Pipe		Rectangular Weir	
Pond #	O1		O2		Diameter (mm)	Length (m)	Elevation (m)	Length (m)
	Diameter (mm)	Elevation (m)	Diameter (mm)	Elevation (m)				
1	150 (x2)	237.6	150 (x2)	238	750	25	238.3	1.2
	200 (x2)	238	N/A	N/A	750	25	N/A	N/A
2	200 (x2)	232.3	200 (x2)	232.6	1050	55	232.9	1.2
	200 (x2)	232.3	200	232.8	1200	55	N/A	N/A
3	200 (x2)	236.6	200 (x2)	236.9	450	90	N/A	N/A
	100 (x2)	236.6	200 (x2)	236.9	600	50	N/A	N/A
	200 (x3)	236.8	N/A	N/A	600	50	N/A	N/A
4	200 (x2)	240.4	200 (x2)	240.7	1050	335	241	1.2

Project:	Twin Creeks Landfill Optimization	No.:	211-01678-02	
By:	KK	Date:	2023-03-23	Page:
Checked:	EK	Checked:	2023-03-23	1

Subject: **Existing Hydraulic Structures**

ID	Size (mm)	Approximate Length (m)	Material
OC001	400	14	CSP
OC002	900	30	CONC
OC003	600	43	CSP
OC004	800	14	CSP
OC005	3700X2800	24	CONC BOX
OC006	800	24	CSP
OC007	825	23	CONC
OS1-1	750	38	CONC
OS1-2	750	38	CONC
OS2-1	1050	27	CONC
OS2-2	1200	28	CONC
OS3-1	450	79	CONC
OS3-2	600	57	CONC
OS3-3	600	57	CONC
OS4-1	1050	38	CONC
SC001	300	6	HDPE
SC002	400	15	CSP
SC003	500	25	CSP
SC004	3000x1200	23	CONC BOX
SC005	1000	46	HDPE
SC006	900	27	CSP
SC007	500	60	CSP
SC008	900	24	CSP
SC009	1000	18	CSP
SC010	1150x820	24	CSPA
SC011	300	9	CSP
SC012	1000	30	CSP
SC013	500	11	CSP
SC014		16	
SC015	2050X1200	34	CONC BOX
SC016	1200X900	24	CONC BOX
SC017	2600X1200	32	CONC BOX
SC018	525	53	HDPE
SC019	375	61	HDPE
SC020		19	
SC021	750	12	HDPE
SC022	750	6	CSP
SC023	400	6	CSP
SC024	300	6	CSP
SC025		19	
SC026	900	25	CSP
SC027	500	5	CSP
SC028	400	5	CSP

D

Hydrologic Modelling Output

Existing Conditions

100-year 4-hour Chicago

```
==========================================================================================================

       V    V   I   SSSSS  U   U    A    L             (v 6.2.2015)
       V    V   I   SS     U   U   A A   L
        V  V    I    SS    U   U  AAAAA  L
        V  V    I     SS   U   U  A   A  L
         VV     I   SSSSS  UUUUU  A   A  LLLLL

        OOO   TTTTT  TTTTT  H   H  Y   Y  M   M   OOO    TM
       O   O    T      T    H   H   Y Y   MM MM  O   O
       O   O    T      T    H   H    Y    M   M  O   O
        OOO     T      T    H   H    Y    M   M   OOO
Developed and Distributed by Smart City Water Inc
```



```
                   *****  D E T A I L E D   O U T P U T *****


  Input   filename: C:\Program Files (x86)\Visual OTTHYMO 6.2\VO2\voin.dat
  Output  filename: C:\Users\CAKK072000\AppData\Local\Civica\VH5\1fc8c6ba-c089-4a7c-9924-7f19dee13d05\88e08943-
81bc-4969-8605-dc58f0779140\s
  Summary filename: C:\Users\CAKK072000\AppData\Local\Civica\VH5\1fc8c6ba-c089-4a7c-9924-7f19dee13d05\88e08943-
81bc-4969-8605-dc58f0779140\s


DATE: 07-16-2025                           TIME: 07:31:12

USER:



COMMENTS: ____________________________________________________________


----------------------------------------------------------------------------------------------------------
  ************************************************
  ** SIMULATION : 100-year-4hr-Chicago          **
  ************************************************

--------------------
| CHICAGO STORM    |    IDF curve parameters: A=1032.793
| Ptotal= 70.38 mm |                          B=   0.000
--------------------                          C=   0.743
                        used in:   INTENSITY =  A / (t + B)^C

                        Duration of storm  =  4.00 hrs
                        Storm time step    = 10.00 min
                        Time to peak ratio =  0.33

                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.00    5.06 |  1.00   26.53 |  2.00   10.53 |  3.00    5.93
                 0.17    5.69 |  1.17  186.64 |  2.17    9.23 |  3.17    5.57
                 0.33    6.55 |  1.33   33.08 |  2.33    8.25 |  3.33    5.25
                 0.50    7.79 |  1.50   20.27 |  2.50    7.49 |  3.50    4.97
                 0.67    9.78 |  1.67   15.20 |  2.67    6.87 |  3.67    4.72
                 0.83   13.66 |  1.83   12.37 |  2.83    6.36 |  3.83    4.51


------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0011)|   Area    (ha)=  12.45   Curve Number   (CN)= 82.0
```

```
|ID= 1 DT= 5.0 min |   Ia      (mm)=   3.10   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   1.03

        NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                             ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
               0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
               0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
               0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
               0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
               0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
               0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
               0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
               0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
               0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
               0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
               1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

    Unit Hyd Qpeak  (cms)=   0.462

    PEAK FLOW       (cms)=   0.479 (i)
    TIME TO PEAK    (hrs)=   2.500
    RUNOFF VOLUME    (mm)=  36.792
    TOTAL RAINFALL   (mm)=  70.382
    RUNOFF COEFFICIENT   =   0.523

    (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0012)|   Area    (ha)=  32.91   Curve Number   (CN)= 84.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   2.70   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.60

        NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                             ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
               0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
               0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
               0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
               0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
               0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
               0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
               0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
               0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
               0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
               0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
               1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

    Unit Hyd Qpeak  (cms)=   2.095

    PEAK FLOW       (cms)=   2.050 (i)
    TIME TO PEAK    (hrs)=   2.000
    RUNOFF VOLUME    (mm)=  39.467
    TOTAL RAINFALL   (mm)=  70.382
    RUNOFF COEFFICIENT   =   0.561

    (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.
```

```
--------------------------------------------------------------------------------
--------------------
| CALIB              |
| NASHYD   (  0031)|   Area     (ha)=  18.71   Curve Number   (CN)= 83.0
|ID= 1 DT= 5.0 min |   Ia       (mm)=   2.70   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   2.44
```

NOTE: RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.

---- TRANSFORMED HYETOGRAPH ----

TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr
0.083	5.06	1.083	26.53	2.083	10.53	3.08	5.93
0.167	5.06	1.167	26.53	2.167	10.53	3.17	5.93
0.250	5.69	1.250	186.64	2.250	9.23	3.25	5.57
0.333	5.69	1.333	186.64	2.333	9.23	3.33	5.57
0.417	6.55	1.417	33.08	2.417	8.25	3.42	5.25
0.500	6.55	1.500	33.08	2.500	8.25	3.50	5.25
0.583	7.79	1.583	20.27	2.583	7.49	3.58	4.97
0.667	7.79	1.667	20.27	2.667	7.49	3.67	4.97
0.750	9.78	1.750	15.20	2.750	6.87	3.75	4.72
0.833	9.78	1.833	15.20	2.833	6.87	3.83	4.72
0.917	13.66	1.917	12.37	2.917	6.36	3.92	4.51
1.000	13.66	2.000	12.37	3.000	6.36	4.00	4.51

```
Unit Hyd Qpeak  (cms)=   0.293

PEAK FLOW       (cms)=   0.395 (i)
TIME TO PEAK    (hrs)=   4.333
RUNOFF VOLUME    (mm)=  38.267
TOTAL RAINFALL   (mm)=  70.382
RUNOFF COEFFICIENT   =   0.544

(i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.
```

```
--------------------------------------------------------------------------------
--------------------
| CALIB              |
| NASHYD   (  0041)|   Area     (ha)=  10.64   Curve Number   (CN)= 83.0
|ID= 1 DT= 5.0 min |   Ia       (mm)=   2.90   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   1.12
```

NOTE: RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.

---- TRANSFORMED HYETOGRAPH ----

TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr
0.083	5.06	1.083	26.53	2.083	10.53	3.08	5.93
0.167	5.06	1.167	26.53	2.167	10.53	3.17	5.93
0.250	5.69	1.250	186.64	2.250	9.23	3.25	5.57
0.333	5.69	1.333	186.64	2.333	9.23	3.33	5.57
0.417	6.55	1.417	33.08	2.417	8.25	3.42	5.25
0.500	6.55	1.500	33.08	2.500	8.25	3.50	5.25
0.583	7.79	1.583	20.27	2.583	7.49	3.58	4.97
0.667	7.79	1.667	20.27	2.667	7.49	3.67	4.97
0.750	9.78	1.750	15.20	2.750	6.87	3.75	4.72
0.833	9.78	1.833	15.20	2.833	6.87	3.83	4.72
0.917	13.66	1.917	12.37	2.917	6.36	3.92	4.51
1.000	13.66	2.000	12.37	3.000	6.36	4.00	4.51

```
Unit Hyd Qpeak  (cms)=   0.363

PEAK FLOW       (cms)=   0.400 (i)
TIME TO PEAK    (hrs)=   2.667
RUNOFF VOLUME    (mm)=  38.105
TOTAL RAINFALL   (mm)=  70.382
```

```
     RUNOFF COEFFICIENT   =   0.541

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0051)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0012):    32.91   2.050     2.00    39.47
      + ID2= 2 (  0031):    18.71   0.395     4.33    38.27
        ====================================================
        ID = 3 (  0051):    51.62   2.157     2.00    39.03

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0051)|
|   3 +  2 =  1    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 3 (  0051):    51.62   2.157     2.00    39.03
      + ID2= 2 (  0041):    10.64   0.400     2.67    38.10
        ====================================================
        ID = 1 (  0051):    62.26   2.460     2.08    38.87

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------
--------------------
| RESERVOIR(  0002)|     OVERFLOW IS OFF
| IN= 2---> OUT= 1 |
| DT=  5.0 min     |     OUTFLOW    STORAGE   |  OUTFLOW    STORAGE
--------------------      (cms)     (ha.m.)   |   (cms)     (ha.m.)
                          0.0000     0.0000   |   1.3450      2.1963
                          0.0302     0.2196   |   2.0056      2.4160
                          0.1060     0.4393   |   2.9861      2.6356
                          0.1484     0.6589   |   5.1073      3.0749
                          0.1976     0.8785   |   6.4750      3.5141
                          0.2620     1.0982   |   6.9124      3.9534
                          0.3256     1.3178   |   7.3312      4.3927
                          0.4719     1.5374   |   7.7329      4.8319
                          0.6161     1.7571   |   8.1186      5.2712
                          0.8070     1.9767   |   0.0000      0.0000

                               AREA     QPEAK     TPEAK       R.V.
                               (ha)     (cms)     (hrs)       (mm)
   INFLOW : ID= 2 (  0051)     62.260      2.460      2.08      38.87
   OUTFLOW: ID= 1 (  0002)     62.260      0.529      5.25      38.84

                  PEAK   FLOW   REDUCTION [Qout/Qin](%)= 21.50
                  TIME SHIFT OF PEAK FLOW         (min)=190.00
                  MAXIMUM  STORAGE   USED       (ha.m.)=  1.6245

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0021)|  Area    (ha)=  19.40   Curve Number   (CN)= 81.0
|ID= 1 DT= 5.0 min |  Ia      (mm)=   3.00   # of Linear Res.(N)= 3.00
--------------------  U.H. Tp(hrs)=   0.66

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
```

```
              0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
              0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
              0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
              0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
              0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
              0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
              0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
              0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
              0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
              0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
              1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   1.123

     PEAK FLOW       (cms)=   1.007 (i)
     TIME TO PEAK    (hrs)=   2.083
     RUNOFF VOLUME    (mm)=  35.760
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.508

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
| CALIB             |
| NASHYD   (  0042)|   Area    (ha)=  40.21   Curve Number   (CN)= 84.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   2.70   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   1.20

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
               TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
              0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
              0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
              0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
              0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
              0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
              0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
              0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
              0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
              0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
              0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
              0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
              1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   1.280

     PEAK FLOW       (cms)=   1.490 (i)
     TIME TO PEAK    (hrs)=   2.750
     RUNOFF VOLUME    (mm)=  39.468
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.561

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
| RESERVOIR(  0001)|     OVERFLOW IS OFF
| IN= 2---> OUT= 1 |
| DT=  5.0 min     |     OUTFLOW    STORAGE   |  OUTFLOW    STORAGE
--------------------      (cms)     (ha.m.)   |   (cms)     (ha.m.)
                          0.0000     0.0000   |   0.7119      0.9480
                          0.0123     0.0780   |   1.9253      1.1420
                          0.0329     0.1570   |   2.5634      1.3440
                          0.0407     0.2380   |   2.7870      1.5530
```

```
                    0.0476     0.3210   |   2.9936      1.7700
                    0.0805     0.4060   |   3.1872      1.9930
                    0.1414     0.4920   |   3.3696      2.2250
                    0.1808     0.5790   |   3.6262      2.5860
                    0.2708     0.6690   |   3.7476      2.7730
                    0.4375     0.7600   |   0.0000      0.0000

                         AREA     QPEAK     TPEAK       R.V.
                         (ha)     (cms)     (hrs)       (mm)
   INFLOW : ID= 2 (  0042)     40.210      1.490      2.75      39.47
   OUTFLOW: ID= 1 (  0001)     40.210      0.704      4.67      39.43

                 PEAK   FLOW   REDUCTION [Qout/Qin](%)= 47.22
                 TIME SHIFT OF PEAK FLOW         (min)=115.00
                 MAXIMUM  STORAGE   USED       (ha.m.)=  0.9427

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0052)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    40.21   0.704     4.67    39.43
      + ID2= 2 (  0011):    12.45   0.479     2.50    36.79
        ===================================================
        ID = 3 (  0052):    52.66   0.914     4.25    38.81

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0052)|
|   3 +  2 =  1    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 3 (  0052):    52.66   0.914     4.25    38.81
      + ID2= 2 (  0002):    62.26   0.529     5.25    38.84
        ===================================================
        ID = 1 (  0052):   114.92   1.398     4.50    38.83

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0052)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0052):   114.92   1.398     4.50    38.83
      + ID2= 2 (  0021):    19.40   1.007     2.08    35.76
        ===================================================
        ID = 3 (  0052):   134.32   1.627     4.17    38.38

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0017)|   Area    (ha)=  31.84   Curve Number   (CN)= 85.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   3.50   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.93

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
               0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
               0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
```

```
              0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
              0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
              0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
              0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
              0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
              0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
              0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
              0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
              1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   1.308

     PEAK FLOW       (cms)=   1.451 (i)
     TIME TO PEAK    (hrs)=   2.417
     RUNOFF VOLUME    (mm)=  40.044
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.569

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
| RESERVOIR(  0020)|     OVERFLOW IS OFF
| IN= 2---> OUT= 1 |
| DT=  5.0 min     |     OUTFLOW    STORAGE   |  OUTFLOW    STORAGE
--------------------      (cms)     (ha.m.)   |   (cms)     (ha.m.)
                          0.0000     0.0000   |   1.7783      1.1263
                          0.0245     0.1030   |   1.8455      1.2511
                          0.0690     0.2080   |   1.9113      1.3782
                          0.1181     0.3152   |   1.9743      1.5076
                          0.2257     0.4245   |   2.0363      1.6394
                          0.3402     0.5360   |   2.1548      1.9101
                          0.4374     0.6496   |   2.2669      2.1903
                          0.7664     0.7654   |   2.3755      2.4803
                          1.3220     0.8835   |   2.4795      2.7803
                          1.6822     1.0038   |   2.5047      2.8569

                                AREA     QPEAK     TPEAK       R.V.
                                (ha)     (cms)     (hrs)       (mm)
   INFLOW : ID= 2 (  0017)     31.840      1.451      2.42      40.04
   OUTFLOW: ID= 1 (  0020)     31.840      0.671      4.08      40.01

                  PEAK   FLOW   REDUCTION [Qout/Qin](%)= 46.23
                  TIME SHIFT OF PEAK FLOW         (min)=100.00
                  MAXIMUM  STORAGE   USED       (ha.m.)=  0.7319

-------------------------------------------------------------------------------
--------------------
| DIVERTHYD(  0023)|
| IN= 1   # OUT= 5 |
--------------------
     Outflow / Inflow  Relationships

      Flow 1 + Flow 2 + Flow 3 + Flow 4 + Flow 5 = Total
      (cms)    (cms)    (cms)    (cms)    (cms)    (cms)
       0.00     0.00     0.00     0.00     0.00     0.00
       0.02     0.01     0.00     0.00     0.00     0.02
       0.05     0.02     0.00     0.00     0.00     0.07
       0.07     0.02     0.02     0.00     0.00     0.12
       0.11     0.04     0.08     0.00     0.00     0.23
       0.16     0.07     0.11     0.00     0.00     0.34
       0.20     0.10     0.14     0.00     0.00     0.44
       0.27     0.34     0.16     0.00     0.00     0.77
       0.29     0.64     0.39     0.00     0.00     1.32
       0.30     0.70     0.68     0.00     0.00     1.68
       0.31     0.73     0.73     0.00     0.00     1.78
       0.32     0.76     0.76     0.00     0.00     1.85
       0.33     0.79     0.79     0.00     0.00     1.91
```

```
      0.34     0.81     0.81     0.00     0.00     1.97
      0.35     0.84     0.84     0.00     0.00     2.04
      0.36     0.87     0.87     0.00     0.00     2.10
      0.38     0.91     0.91     0.00     0.00     2.21
      0.40     0.96     0.96     0.00     0.00     2.32
      0.42     1.01     1.01     0.00     0.00     2.43
      0.43     1.04     1.04     0.00     0.00     2.50

                          AREA     QPEAK     TPEAK    R.V.
                          (ha)     (cms)     (hrs)    (mm)
    TOTAL HYD.(ID= 1):   31.84      0.67      4.08   40.01
    ====================================================
    ID= 2  (   3)    :  15.95      0.25      4.08   40.01
    ID= 3  (   3)    :   8.86      0.27      4.08   40.01
    ID= 4  (   3)    :   7.04      0.15      4.08   40.01
    ID= 5  (   3)    :   0.00      0.00      0.00    0.00
    ID= 6  (   3)    :   0.00      0.00      0.00    0.00
--------------------------------------------------------------------------------
--------------------
| ROUTEPIPE(  0028)|     PIPE Number     =   1.00
| IN= 2---> OUT= 1 |     Diameter    (mm)=1650.00
| DT=  5.0 min     |     Length       (m)= 500.00
--------------------     Slope      (m/m)=  0.005
                         Manning n       =  0.013

     <----------------- TRAVEL TIME TABLE -------------------->
       DEPTH      VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
        (m)      (cu.m.)      (cms)        (m/s)        min
       0.09     .216E+02       0.0          0.80        10.40
       0.17     .600E+02       0.1          1.25         6.67
       0.26     .108E+03       0.3          1.61         5.18
       0.35     .164E+03       0.6          1.91         4.36
       0.43     .225E+03       1.0          2.18         3.83
       0.52     .290E+03       1.4          2.41         3.46
       0.61     .358E+03       1.9          2.61         3.19
       0.69     .428E+03       2.4          2.79         2.99
       0.78     .499E+03       2.9          2.95         2.83
       0.87     .570E+03       3.5          3.08         2.70
       0.96     .642E+03       4.1          3.20         2.61
       1.04     .712E+03       4.7          3.29         2.53
       1.13     .780E+03       5.2          3.36         2.48
       1.22     .844E+03       5.8          3.41         2.44
       1.30     .905E+03       6.2          3.44         2.43
       1.39     .961E+03       6.6          3.43         2.43
       1.48     .101E+04       6.9          3.40         2.45
       1.56     .105E+04       6.9          3.31         2.52
       1.65     .107E+04       6.5          3.02         2.76
                                    <---- hydrograph ---->   <-pipe / channel->
                              AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                              (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
  INFLOW : ID= 2 (  0023)     8.86     0.27    4.08  40.01      0.22      1.44
  OUTFLOW: ID= 1 (  0028)     8.86     0.27    4.17  40.01      0.22      1.43



--------------------------------------------------------------------------------
--------------------
| ROUTEPIPE(  0030)|     PIPE Number     =   1.00
| IN= 2---> OUT= 1 |     Diameter    (mm)=1650.00
| DT=  5.0 min     |     Length       (m)= 500.00
--------------------     Slope      (m/m)=  0.005
                         Manning n       =  0.013

     <----------------- TRAVEL TIME TABLE -------------------->
       DEPTH      VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
        (m)      (cu.m.)      (cms)        (m/s)        min
       0.09     .216E+02       0.0          0.80        10.40
       0.17     .600E+02       0.1          1.25         6.67
```

```
      0.26     .108E+03       0.3          1.61         5.18
      0.35     .164E+03       0.6          1.91         4.36
      0.43     .225E+03       1.0          2.18         3.83
      0.52     .290E+03       1.4          2.41         3.46
      0.61     .358E+03       1.9          2.61         3.19
      0.69     .428E+03       2.4          2.79         2.99
      0.78     .499E+03       2.9          2.95         2.83
      0.87     .570E+03       3.5          3.08         2.70
      0.96     .642E+03       4.1          3.20         2.61
      1.04     .712E+03       4.7          3.29         2.53
      1.13     .780E+03       5.2          3.36         2.48
      1.22     .844E+03       5.8          3.41         2.44
      1.30     .905E+03       6.2          3.44         2.43
      1.39     .961E+03       6.6          3.43         2.43
      1.48     .101E+04       6.9          3.40         2.45
      1.56     .105E+04       6.9          3.31         2.52
      1.65     .107E+04       6.5          3.02         2.76
                                   <---- hydrograph ---->   <-pipe / channel->
                              AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                              (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
  INFLOW : ID= 2 (  0023)     7.04     0.15    4.08  40.01      0.17      1.25
  OUTFLOW: ID= 1 (  0030)     7.04     0.15    4.17  40.01      0.17      1.25



--------------------------------------------------------------------------------
--------------------
| CALIB              |
| STANDHYD (  0019)|   Area    (ha)=   6.99
|ID= 1 DT= 5.0 min |   Total Imp(%)=  28.00   Dir. Conn.(%)=  28.00
--------------------
                              IMPERVIOUS    PERVIOUS (i)
     Surface Area     (ha)=       1.96         5.03
     Dep. Storage     (mm)=       2.00         5.00
     Average Slope     (%)=       2.00         1.00
     Length            (m)=     215.87       712.00
     Mannings n          =      0.013        0.250

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                               ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
               0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
               0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
               0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
               0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
               0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
               0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
               0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
               0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
               0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
               0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
               1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Max.Eff.Inten.(mm/hr)=     186.64        25.57
               over (min)         5.00        90.00
     Storage Coeff.  (min)=       2.57 (ii)   86.92 (ii)
     Unit Hyd. Tpeak (min)=       5.00        90.00
     Unit Hyd. peak  (cms)=       0.29         0.01
                                                           *TOTALS*
     PEAK FLOW       (cms)=       1.00         0.15          1.006 (iii)
     TIME TO PEAK    (hrs)=       1.33         2.75           1.33
     RUNOFF VOLUME    (mm)=      68.38        35.29          44.55
     TOTAL RAINFALL   (mm)=      70.38        70.38          70.38
     RUNOFF COEFFICIENT   =       0.97         0.50           0.63
```

```
***** WARNING: STORAGE COEFF. IS SMALLER THAN TIME STEP!

       (i) CN PROCEDURE SELECTED FOR PERVIOUS LOSSES:
            CN*  =  82.0    Ia = Dep. Storage  (Above)
      (ii) TIME STEP (DT) SHOULD BE SMALLER OR EQUAL
           THAN THE STORAGE COEFFICIENT.
     (iii) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0029)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0019):     6.99   1.006     1.33    44.55
      + ID2= 2 (  0028):     8.86   0.265     4.17    40.01
        ====================================================
        ID = 3 (  0029):    15.85   1.006     1.33    42.01

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0029)|
|   3 +  2 =  1    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 3 (  0029):    15.85   1.006     1.33    42.01
      + ID2= 2 (  0030):     7.04   0.152     4.17    40.01
        ====================================================
        ID = 1 (  0029):    22.88   1.006     1.33    41.40

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------
--------------------
| ROUTEPIPE(  0032)|     PIPE Number     =   1.00
| IN= 2---> OUT= 1 |     Diameter    (mm)=1650.00
| DT=  5.0 min     |     Length       (m)= 500.00
--------------------     Slope      (m/m)=  0.005
                         Manning n       =  0.013

     <----------------- TRAVEL TIME TABLE -------------------->
       DEPTH      VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
        (m)      (cu.m.)      (cms)        (m/s)        min
       0.09     .216E+02       0.0          0.80        10.40
       0.17     .600E+02       0.1          1.25         6.67
       0.26     .108E+03       0.3          1.61         5.18
       0.35     .164E+03       0.6          1.91         4.36
       0.43     .225E+03       1.0          2.18         3.83
       0.52     .290E+03       1.4          2.41         3.46
       0.61     .358E+03       1.9          2.61         3.19
       0.69     .428E+03       2.4          2.79         2.99
       0.78     .499E+03       2.9          2.95         2.83
       0.87     .570E+03       3.5          3.08         2.70
       0.96     .642E+03       4.1          3.20         2.61
       1.04     .712E+03       4.7          3.29         2.53
       1.13     .780E+03       5.2          3.36         2.48
       1.22     .844E+03       5.8          3.41         2.44
       1.30     .905E+03       6.2          3.44         2.43
       1.39     .961E+03       6.6          3.43         2.43
       1.48     .101E+04       6.9          3.40         2.45
       1.56     .105E+04       6.9          3.31         2.52
       1.65     .107E+04       6.5          3.02         2.76
                                    <---- hydrograph ---->   <-pipe / channel->
                              AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                              (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
   INFLOW : ID= 2 (  0023)   15.95     0.25    4.08  40.01      0.22      1.41
   OUTFLOW: ID= 1 (  0032)   15.95     0.25    4.08  40.01      0.22      1.41
```

```
---------------------------------------------------------------------------------
--------------------
| CALIB              |
| NASHYD   (  0018)|   Area     (ha)=   0.94   Curve Number   (CN)= 84.0
|ID= 1 DT= 5.0 min |   Ia       (mm)=   3.90   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.12

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
                0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
                0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
                0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
                0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
                0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
                0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
                0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
                0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
                0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
                0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
                1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   0.299

     PEAK FLOW       (cms)=   0.178 (i)
     TIME TO PEAK    (hrs)=   1.333
     RUNOFF VOLUME    (mm)=  37.965
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.539

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

---------------------------------------------------------------------------------


--------------------
| ADD HYD  (  0033)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0018):     0.94   0.178     1.33    37.97
      + ID2= 2 (  0032):    15.95   0.252     4.08    40.01
        ===================================================
        ID = 3 (  0033):    16.89   0.261     4.00    39.90

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
---------------------------------------------------------------------------------
--------------------
| CALIB              |
| NASHYD   (  0034)|   Area     (ha)=   6.77   Curve Number   (CN)= 83.0
|ID= 1 DT= 5.0 min |   Ia       (mm)=   4.10   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.50

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
                0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
                0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
                0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
```

```
             0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
             0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
             0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
             0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
             0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
             0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
             0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
             1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   0.517

     PEAK FLOW       (cms)=   0.451 (i)
     TIME TO PEAK    (hrs)=   1.833
     RUNOFF VOLUME    (mm)=  37.133
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.528

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0035)|   Area    (ha)=  15.77   Curve Number   (CN)= 84.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   3.90   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.42

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
              TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
               hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
             0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
             0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
             0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
             0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
             0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
             0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
             0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
             0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
             0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
             0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
             0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
             1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   1.434

     PEAK FLOW       (cms)=   1.247 (i)
     TIME TO PEAK    (hrs)=   1.750
     RUNOFF VOLUME    (mm)=  38.475
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.547

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| RESERVOIR(  0036)|     OVERFLOW IS OFF
| IN= 2---> OUT= 1 |
| DT=  5.0 min     |     OUTFLOW    STORAGE   |  OUTFLOW    STORAGE
--------------------      (cms)     (ha.m.)   |   (cms)     (ha.m.)
                          0.0000     0.0000   |   0.9922      0.4686
                          0.0150     0.0403   |   1.3581      0.5239
                          0.0508     0.0819   |   1.4554      0.5809
                          0.0745     0.1250   |   1.5104      0.6396
                          0.1065     0.1696   |   1.5636      0.6999
                          0.1567     0.2156   |   1.6156      0.7620
                          0.1928     0.2631   |   1.6657      0.8257
```

```
                        0.2872     0.3021   |   1.7150      0.8913
                        0.4020     0.3627   |   1.7631      0.9586
                        0.5684     0.4149   |   1.8561      1.0987

                              AREA     QPEAK     TPEAK       R.V.
                              (ha)     (cms)     (hrs)       (mm)
   INFLOW : ID= 2 (  0035)     15.770      1.247      1.75      38.48
   OUTFLOW: ID= 1 (  0036)     15.770      0.372      2.83      38.43

                 PEAK   FLOW   REDUCTION [Qout/Qin](%)= 29.84
                 TIME SHIFT OF PEAK FLOW         (min)= 65.00
                 MAXIMUM  STORAGE   USED       (ha.m.)=  0.3471

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0037)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0034):      6.77   0.451     1.83    37.13
      + ID2= 2 (  0036):     15.77   0.372     2.83    38.43
        =====================================================
        ID = 3 (  0037):     22.54   0.643     2.25    38.04

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0045)|   Area    (ha)=   2.10   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.30   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.14

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
               0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
               0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
               0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
               0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
               0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
               0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
               0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
               0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
               0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
               0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
               1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   0.573

     PEAK FLOW       (cms)=   0.329 (i)
     TIME TO PEAK    (hrs)=   1.417
     RUNOFF VOLUME    (mm)=  35.572
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.505

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0046)|   Area    (ha)=   1.31   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.30   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.08
```

```
        NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                            ---- TRANSFORMED HYETOGRAPH ----
               TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
              0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
              0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
              0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
              0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
              0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
              0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
              0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
              0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
              0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
              0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
              0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
              1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

    Unit Hyd Qpeak  (cms)=   0.625

    PEAK FLOW       (cms)=   0.301 (i)
    TIME TO PEAK    (hrs)=   1.333
    RUNOFF VOLUME    (mm)=  33.811
    TOTAL RAINFALL   (mm)=  70.382
    RUNOFF COEFFICIENT   =   0.480

    (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0047)|   Area    (ha)=   1.89   Curve Number   (CN)= 83.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.10   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.22

        NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                            ---- TRANSFORMED HYETOGRAPH ----
               TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
              0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
              0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
              0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
              0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
              0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
              0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
              0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
              0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
              0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
              0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
              0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
              1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

    Unit Hyd Qpeak  (cms)=   0.328

    PEAK FLOW       (cms)=   0.230 (i)
    TIME TO PEAK    (hrs)=   1.500
    RUNOFF VOLUME    (mm)=  37.086
    TOTAL RAINFALL   (mm)=  70.382
    RUNOFF COEFFICIENT   =   0.527

    (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

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--------------------
| CALIB            |
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```
| NASHYD   (  0015)|   Area     (ha)=   8.60   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia       (mm)=   5.00   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.31

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
                0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
                0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
                0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
                0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
                0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
                0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
                0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
                0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
                0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
                0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
                1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   1.060

     PEAK FLOW       (cms)=   0.766 (i)
     TIME TO PEAK    (hrs)=   1.583
     RUNOFF VOLUME    (mm)=  35.276
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.501

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

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--------------------
| CALIB            |
| NASHYD   (  0016)|   Area     (ha)=  22.13   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia       (mm)=   4.20   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   1.07

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
                0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
                0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
                0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
                0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
                0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
                0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
                0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
                0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
                0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
                0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
                1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   0.790

     PEAK FLOW       (cms)=   0.805 (i)
     TIME TO PEAK    (hrs)=   2.583
     RUNOFF VOLUME    (mm)=  35.920
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.510

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.
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--------------------
| CALIB              |
| NASHYD   (  0048)|   Area    (ha)=   1.93   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.10   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.29

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                                       ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    5.06 | 1.083   26.53 | 2.083   10.53 |  3.08    5.93
                0.167    5.06 | 1.167   26.53 | 2.167   10.53 |  3.17    5.93
                0.250    5.69 | 1.250  186.64 | 2.250    9.23 |  3.25    5.57
                0.333    5.69 | 1.333  186.64 | 2.333    9.23 |  3.33    5.57
                0.417    6.55 | 1.417   33.08 | 2.417    8.25 |  3.42    5.25
                0.500    6.55 | 1.500   33.08 | 2.500    8.25 |  3.50    5.25
                0.583    7.79 | 1.583   20.27 | 2.583    7.49 |  3.58    4.97
                0.667    7.79 | 1.667   20.27 | 2.667    7.49 |  3.67    4.97
                0.750    9.78 | 1.750   15.20 | 2.750    6.87 |  3.75    4.72
                0.833    9.78 | 1.833   15.20 | 2.833    6.87 |  3.83    4.72
                0.917   13.66 | 1.917   12.37 | 2.917    6.36 |  3.92    4.51
                1.000   13.66 | 2.000   12.37 | 3.000    6.36 |  4.00    4.51

     Unit Hyd Qpeak  (cms)=   0.254

     PEAK FLOW       (cms)=   0.186 (i)
     TIME TO PEAK    (hrs)=   1.583
     RUNOFF VOLUME    (mm)=  35.983
     TOTAL RAINFALL   (mm)=  70.382
     RUNOFF COEFFICIENT   =   0.511

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

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Existing Conditions

100-year 3-hour Chicago

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=============================================================================================================

       V    V   I    SSSSS  U   U    A    L             (v 6.2.2015)
       V    V   I    SS     U   U   A A   L
        V  V    I     SS    U   U  AAAAA  L
        V  V    I      SS   U   U  A   A  L
         VV     I    SSSSS  UUUUU  A   A  LLLLL

        OOO   TTTTT  TTTTT  H   H  Y   Y  M   M   OOO    TM
       O   O    T      T    H   H   Y Y   MM MM  O   O
       O   O    T      T    H   H    Y    M   M  O   O
        OOO     T      T    H   H    Y    M   M   OOO
Developed and Distributed by Smart City Water Inc
```



```
                   *****  D E T A I L E D   O U T P U T *****


  Input   filename: C:\Program Files (x86)\Visual OTTHYMO 6.2\VO2\voin.dat
  Output  filename: C:\Users\CAKK072000\AppData\Local\Civica\VH5\1fc8c6ba-c089-4a7c-9924-7f19dee13d05\05ba6f71-
d5d4-44a6-b1bd-4cde131d36ba\s
  Summary filename: C:\Users\CAKK072000\AppData\Local\Civica\VH5\1fc8c6ba-c089-4a7c-9924-7f19dee13d05\05ba6f71-
d5d4-44a6-b1bd-4cde131d36ba\s


DATE: 07-16-2025                           TIME: 07:31:04

USER:



COMMENTS: ____________________________________________________________


-------------------------------------------------------------------------------------------------------------
  ************************************************
  ** SIMULATION : 100-year-3hr-Chicago          **
  ************************************************

--------------------
| CHICAGO STORM    |    IDF curve parameters: A=1032.793
| Ptotal= 65.35 mm |                          B=   0.000
--------------------                          C=   0.743
                        used in:   INTENSITY =  A / (t + B)^C

                        Duration of storm  =  3.00 hrs
                        Storm time step    = 10.00 min
                        Time to peak ratio =  0.33

                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                 0.00    6.55 |  0.83  186.64 |  1.67   10.53 |  2.50    6.36
                 0.17    7.79 |  1.00   33.08 |  1.83    9.23 |  2.67    5.93
                 0.33    9.78 |  1.17   20.27 |  2.00    8.25 |  2.83    5.57
                 0.50   13.66 |  1.33   15.20 |  2.17    7.49 |
                 0.67   26.53 |  1.50   12.37 |  2.33    6.87 |


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--------------------
| CALIB            |
| NASHYD   (  0011)|   Area    (ha)=  12.45   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   3.10   # of Linear Res.(N)= 3.00
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```
--------------------   U.H. Tp(hrs)=   1.03

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                                      ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
                0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
                0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
                0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
                0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
                0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
                0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
                0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
                0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   0.462

     PEAK FLOW       (cms)=   0.458 (i)
     TIME TO PEAK    (hrs)=   2.250
     RUNOFF VOLUME    (mm)=  32.837
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.502

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0012)|   Area    (ha)=  32.91   Curve Number   (CN)= 84.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   2.70   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.60

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                                      ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
                0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
                0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
                0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
                0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
                0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
                0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
                0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
                0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   2.095

     PEAK FLOW       (cms)=   1.959 (i)
     TIME TO PEAK    (hrs)=   1.667
     RUNOFF VOLUME    (mm)=  35.350
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.541

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0031)|   Area    (ha)=  18.71   Curve Number   (CN)= 83.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   2.70   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   2.44
```

```
        NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                             ---- TRANSFORMED HYETOGRAPH ----
               TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
              0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
              0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
              0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
              0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
              0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
              0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
              0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
              0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
              0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

    Unit Hyd Qpeak  (cms)=   0.293

    PEAK FLOW       (cms)=   0.370 (i)
    TIME TO PEAK    (hrs)=   3.833
    RUNOFF VOLUME    (mm)=  34.227
    TOTAL RAINFALL   (mm)=  65.350
    RUNOFF COEFFICIENT   =   0.524

    (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0041)|   Area    (ha)=  10.64   Curve Number   (CN)= 83.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   2.90   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   1.12

        NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                             ---- TRANSFORMED HYETOGRAPH ----
               TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
              0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
              0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
              0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
              0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
              0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
              0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
              0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
              0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
              0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

    Unit Hyd Qpeak  (cms)=   0.363

    PEAK FLOW       (cms)=   0.382 (i)
    TIME TO PEAK    (hrs)=   2.333
    RUNOFF VOLUME    (mm)=  34.068
    TOTAL RAINFALL   (mm)=  65.350
    RUNOFF COEFFICIENT   =   0.521

    (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0051)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0012):    32.91   1.959     1.67    35.35
      + ID2= 2 (  0031):    18.71   0.370     3.83    34.23
        ====================================================
```

```
        ID = 3 (  0051):    51.62   2.058     1.67    34.94

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0051)|
|   3 +  2 =  1    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 3 (  0051):    51.62   2.058     1.67    34.94
      + ID2= 2 (  0041):    10.64   0.382     2.33    34.07
        ===================================================
        ID = 1 (  0051):    62.26   2.350     1.75    34.79

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------
--------------------
| RESERVOIR(  0002)|     OVERFLOW IS OFF
| IN= 2---> OUT= 1 |
| DT=  5.0 min     |     OUTFLOW    STORAGE   |  OUTFLOW    STORAGE
--------------------      (cms)     (ha.m.)   |   (cms)     (ha.m.)
                          0.0000     0.0000   |   1.3450      2.1963
                          0.0302     0.2196   |   2.0056      2.4160
                          0.1060     0.4393   |   2.9861      2.6356
                          0.1484     0.6589   |   5.1073      3.0749
                          0.1976     0.8785   |   6.4750      3.5141
                          0.2620     1.0982   |   6.9124      3.9534
                          0.3256     1.3178   |   7.3312      4.3927
                          0.4719     1.5374   |   7.7329      4.8319
                          0.6161     1.7571   |   8.1186      5.2712
                          0.8070     1.9767   |   0.0000      0.0000

                                AREA     QPEAK     TPEAK       R.V.
                                (ha)     (cms)     (hrs)       (mm)
   INFLOW : ID= 2 (  0051)     62.260      2.350      1.75      34.79
   OUTFLOW: ID= 1 (  0002)     62.260      0.441      4.83      34.76

                   PEAK   FLOW   REDUCTION [Qout/Qin](%)= 18.76
                   TIME SHIFT OF PEAK FLOW         (min)=185.00
                   MAXIMUM  STORAGE   USED       (ha.m.)=  1.4909

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0021)|   Area    (ha)=  19.40   Curve Number   (CN)= 81.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   3.00   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.66

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                               ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
               0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
               0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
               0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
               0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
               0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
               0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
               0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
               0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   1.123

     PEAK FLOW       (cms)=   0.960 (i)
     TIME TO PEAK    (hrs)=   1.750
```

```
     RUNOFF VOLUME    (mm)=  31.882
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.488

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB             |
| NASHYD   (  0042)|   Area    (ha)=  40.21   Curve Number   (CN)= 84.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   2.70   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   1.20

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
                0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
                0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
                0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
                0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
                0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
                0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
                0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
                0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   1.280

     PEAK FLOW       (cms)=   1.428 (i)
     TIME TO PEAK    (hrs)=   2.417
     RUNOFF VOLUME    (mm)=  35.350
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.541

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| RESERVOIR(  0001)|     OVERFLOW IS OFF
| IN= 2---> OUT= 1 |
| DT=  5.0 min     |     OUTFLOW    STORAGE   |  OUTFLOW    STORAGE
--------------------      (cms)     (ha.m.)   |   (cms)     (ha.m.)
                          0.0000     0.0000   |   0.7119      0.9480
                          0.0123     0.0780   |   1.9253      1.1420
                          0.0329     0.1570   |   2.5634      1.3440
                          0.0407     0.2380   |   2.7870      1.5530
                          0.0476     0.3210   |   2.9936      1.7700
                          0.0805     0.4060   |   3.1872      1.9930
                          0.1414     0.4920   |   3.3696      2.2250
                          0.1808     0.5790   |   3.6262      2.5860
                          0.2708     0.6690   |   3.7476      2.7730
                          0.4375     0.7600   |   0.0000      0.0000

                                AREA     QPEAK     TPEAK       R.V.
                                (ha)     (cms)     (hrs)       (mm)
   INFLOW : ID= 2 (  0042)     40.210     1.428      2.42      35.35
   OUTFLOW: ID= 1 (  0001)     40.210     0.635      4.25      35.31

                  PEAK   FLOW   REDUCTION [Qout/Qin](%)= 44.51
                  TIME SHIFT OF PEAK FLOW         (min)=110.00
                  MAXIMUM  STORAGE   USED       (ha.m.)=  0.8958

--------------------------------------------------------------------------------

--------------------
```

```
| ADD HYD  (  0052)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0001):    40.21   0.635     4.25    35.31
      + ID2= 2 (  0011):    12.45   0.458     2.25    32.84
        ====================================================
        ID = 3 (  0052):    52.66   0.830     3.67    34.73

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0052)|
|   3 +  2 =  1    |         AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 3 (  0052):    52.66   0.830     3.67    34.73
      + ID2= 2 (  0002):    62.26   0.441     4.83    34.76
        ====================================================
        ID = 1 (  0052):   114.92   1.229     3.92    34.75

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0052)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------          (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0052):   114.92   1.229     3.92    34.75
      + ID2= 2 (  0021):    19.40   0.960     1.75    31.88
        ====================================================
        ID = 3 (  0052):   134.32   1.530     1.92    34.33

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0017)|   Area    (ha)=  31.84   Curve Number   (CN)= 85.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   3.50   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.93

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                               ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
               0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
               0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
               0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
               0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
               0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
               0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
               0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
               0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   1.308

     PEAK FLOW       (cms)=   1.387 (i)
     TIME TO PEAK    (hrs)=   2.083
     RUNOFF VOLUME    (mm)=  35.861
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.549

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

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--------------------
```

```
| RESERVOIR(  0020)|     OVERFLOW IS OFF
| IN= 2---> OUT= 1 |
| DT=  5.0 min     |     OUTFLOW    STORAGE   |  OUTFLOW    STORAGE
--------------------      (cms)     (ha.m.)   |   (cms)     (ha.m.)
                          0.0000     0.0000   |   1.7783     1.1263
                          0.0245     0.1030   |   1.8455     1.2511
                          0.0690     0.2080   |   1.9113     1.3782
                          0.1181     0.3152   |   1.9743     1.5076
                          0.2257     0.4245   |   2.0363     1.6394
                          0.3402     0.5360   |   2.1548     1.9101
                          0.4374     0.6496   |   2.2669     2.1903
                          0.7664     0.7654   |   2.3755     2.4803
                          1.3220     0.8835   |   2.4795     2.7803
                          1.6822     1.0038   |   2.5047     2.8569

                                AREA     QPEAK     TPEAK       R.V.
                                (ha)     (cms)     (hrs)       (mm)
   INFLOW : ID= 2 (  0017)     31.840     1.387      2.08      35.86
   OUTFLOW: ID= 1 (  0020)     31.840     0.606      3.67      35.83

                   PEAK   FLOW   REDUCTION [Qout/Qin](%)= 43.72
                   TIME SHIFT OF PEAK FLOW         (min)= 95.00
                   MAXIMUM  STORAGE   USED       (ha.m.)=  0.7092

--------------------------------------------------------------------------------
--------------------
| DIVERTHYD(  0023)|
| IN= 1   # OUT= 5 |
--------------------
     Outflow / Inflow  Relationships

      Flow 1 + Flow 2 + Flow 3 + Flow 4 + Flow 5 = Total
      (cms)    (cms)    (cms)    (cms)    (cms)    (cms)
       0.00     0.00     0.00     0.00     0.00     0.00
       0.02     0.01     0.00     0.00     0.00     0.02
       0.05     0.02     0.00     0.00     0.00     0.07
       0.07     0.02     0.02     0.00     0.00     0.12
       0.11     0.04     0.08     0.00     0.00     0.23
       0.16     0.07     0.11     0.00     0.00     0.34
       0.20     0.10     0.14     0.00     0.00     0.44
       0.27     0.34     0.16     0.00     0.00     0.77
       0.29     0.64     0.39     0.00     0.00     1.32
       0.30     0.70     0.68     0.00     0.00     1.68
       0.31     0.73     0.73     0.00     0.00     1.78
       0.32     0.76     0.76     0.00     0.00     1.85
       0.33     0.79     0.79     0.00     0.00     1.91
       0.34     0.81     0.81     0.00     0.00     1.97
       0.35     0.84     0.84     0.00     0.00     2.04
       0.36     0.87     0.87     0.00     0.00     2.10
       0.38     0.91     0.91     0.00     0.00     2.21
       0.40     0.96     0.96     0.00     0.00     2.32
       0.42     1.01     1.01     0.00     0.00     2.43
       0.43     1.04     1.04     0.00     0.00     2.50

                          AREA     QPEAK     TPEAK    R.V.
                          (ha)     (cms)     (hrs)    (mm)
     TOTAL HYD.(ID= 1):  31.84      0.61      3.67   35.83
     ==================================================
     ID= 2  (   3)    :  16.48      0.24      3.67   35.83
     ID= 3  (   3)    :   8.28      0.22      3.67   35.83
     ID= 4  (   3)    :   7.08      0.15      3.67   35.83
     ID= 5  (   3)    :   0.00      0.00      0.00    0.00
     ID= 6  (   3)    :   0.00      0.00      0.00    0.00
--------------------------------------------------------------------------------
--------------------
| ROUTEPIPE(  0028)|     PIPE Number     =   1.00
| IN= 2---> OUT= 1 |     Diameter    (mm)=1650.00
| DT=  5.0 min     |     Length       (m)= 500.00
```

```
--------------------     Slope      (m/m)=  0.005
                         Manning n       =  0.013

     <----------------- TRAVEL TIME TABLE -------------------->
       DEPTH      VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
        (m)      (cu.m.)      (cms)        (m/s)        min
       0.09     .216E+02       0.0          0.80        10.40
       0.17     .600E+02       0.1          1.25         6.67
       0.26     .108E+03       0.3          1.61         5.18
       0.35     .164E+03       0.6          1.91         4.36
       0.43     .225E+03       1.0          2.18         3.83
       0.52     .290E+03       1.4          2.41         3.46
       0.61     .358E+03       1.9          2.61         3.19
       0.69     .428E+03       2.4          2.79         2.99
       0.78     .499E+03       2.9          2.95         2.83
       0.87     .570E+03       3.5          3.08         2.70
       0.96     .642E+03       4.1          3.20         2.61
       1.04     .712E+03       4.7          3.29         2.53
       1.13     .780E+03       5.2          3.36         2.48
       1.22     .844E+03       5.8          3.41         2.44
       1.30     .905E+03       6.2          3.44         2.43
       1.39     .961E+03       6.6          3.43         2.43
       1.48     .101E+04       6.9          3.40         2.45
       1.56     .105E+04       6.9          3.31         2.52
       1.65     .107E+04       6.5          3.02         2.76
                                     <---- hydrograph ---->   <-pipe / channel->
                              AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                              (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
   INFLOW : ID= 2 (  0023)    8.28     0.22    3.67  35.83      0.20      1.36
   OUTFLOW: ID= 1 (  0028)    8.28     0.22    3.75  35.83      0.20      1.35



--------------------------------------------------------------------------------
--------------------
| ROUTEPIPE(  0030)|     PIPE Number     =   1.00
| IN= 2---> OUT= 1 |     Diameter    (mm)=1650.00
| DT=  5.0 min     |     Length       (m)= 500.00
--------------------     Slope      (m/m)=  0.005
                         Manning n       =  0.013

     <----------------- TRAVEL TIME TABLE -------------------->
       DEPTH      VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
        (m)      (cu.m.)      (cms)        (m/s)        min
       0.09     .216E+02       0.0          0.80        10.40
       0.17     .600E+02       0.1          1.25         6.67
       0.26     .108E+03       0.3          1.61         5.18
       0.35     .164E+03       0.6          1.91         4.36
       0.43     .225E+03       1.0          2.18         3.83
       0.52     .290E+03       1.4          2.41         3.46
       0.61     .358E+03       1.9          2.61         3.19
       0.69     .428E+03       2.4          2.79         2.99
       0.78     .499E+03       2.9          2.95         2.83
       0.87     .570E+03       3.5          3.08         2.70
       0.96     .642E+03       4.1          3.20         2.61
       1.04     .712E+03       4.7          3.29         2.53
       1.13     .780E+03       5.2          3.36         2.48
       1.22     .844E+03       5.8          3.41         2.44
       1.30     .905E+03       6.2          3.44         2.43
       1.39     .961E+03       6.6          3.43         2.43
       1.48     .101E+04       6.9          3.40         2.45
       1.56     .105E+04       6.9          3.31         2.52
       1.65     .107E+04       6.5          3.02         2.76
                                     <---- hydrograph ---->   <-pipe / channel->
                              AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                              (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
   INFLOW : ID= 2 (  0023)    7.08     0.15    3.67  35.83      0.17      1.24
   OUTFLOW: ID= 1 (  0030)    7.08     0.15    3.67  35.83      0.17      1.23
```

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--------------------------------------------------------------------------------
--------------------
| CALIB            |
| STANDHYD (  0019)|   Area    (ha)=   6.99
|ID= 1 DT= 5.0 min |   Total Imp(%)=  28.00   Dir. Conn.(%)=  28.00
--------------------
                              IMPERVIOUS    PERVIOUS (i)
     Surface Area     (ha)=       1.96         5.03
     Dep. Storage     (mm)=       2.00         5.00
     Average Slope     (%)=       2.00         1.00
     Length            (m)=     215.87       712.00
     Mannings n          =      0.013        0.250

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                               ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
                0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
                0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
                0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
                0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
                0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
                0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
                0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
                0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Max.Eff.Inten.(mm/hr)=     186.64        24.61
                over (min)        5.00        90.00
     Storage Coeff.  (min)=       2.57 (ii)   88.22 (ii)
     Unit Hyd. Tpeak (min)=       5.00        90.00
     Unit Hyd. peak  (cms)=       0.29         0.01
                                                            *TOTALS*
     PEAK FLOW       (cms)=       1.00         0.14           1.004 (iii)
     TIME TO PEAK    (hrs)=       1.00         2.50            1.00
     RUNOFF VOLUME    (mm)=      63.35        31.37           40.32
     TOTAL RAINFALL   (mm)=      65.35        65.35           65.35
     RUNOFF COEFFICIENT   =       0.97         0.48            0.62

***** WARNING: STORAGE COEFF. IS SMALLER THAN TIME STEP!

       (i) CN PROCEDURE SELECTED FOR PERVIOUS LOSSES:
            CN*  =  82.0    Ia = Dep. Storage  (Above)
      (ii) TIME STEP (DT) SHOULD BE SMALLER OR EQUAL
           THAN THE STORAGE COEFFICIENT.
     (iii) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------


--------------------
| ADD HYD  (  0029)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0019):     6.99   1.004     1.00    40.32
      + ID2= 2 (  0028):     8.28   0.218     3.75    35.83
        ====================================================
        ID = 3 (  0029):    15.27   1.005     1.00    37.88

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------


--------------------
| ADD HYD  (  0029)|
```

```
|   3 +  2 =  1    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 3 (  0029):    15.27   1.005     1.00    37.88
      + ID2= 2 (  0030):     7.08   0.148     3.67    35.83
        ===================================================
        ID = 1 (  0029):    22.35   1.005     1.00    37.23

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------
--------------------
| ROUTEPIPE(  0032)|     PIPE Number     =   1.00
| IN= 2---> OUT= 1 |     Diameter    (mm)=1650.00
| DT=  5.0 min     |     Length       (m)= 500.00
--------------------     Slope      (m/m)=  0.005
                         Manning n       =  0.013

     <----------------- TRAVEL TIME TABLE -------------------->
       DEPTH      VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
        (m)      (cu.m.)      (cms)        (m/s)        min
       0.09     .216E+02       0.0          0.80       10.40
       0.17     .600E+02       0.1          1.25        6.67
       0.26     .108E+03       0.3          1.61        5.18
       0.35     .164E+03       0.6          1.91        4.36
       0.43     .225E+03       1.0          2.18        3.83
       0.52     .290E+03       1.4          2.41        3.46
       0.61     .358E+03       1.9          2.61        3.19
       0.69     .428E+03       2.4          2.79        2.99
       0.78     .499E+03       2.9          2.95        2.83
       0.87     .570E+03       3.5          3.08        2.70
       0.96     .642E+03       4.1          3.20        2.61
       1.04     .712E+03       4.7          3.29        2.53
       1.13     .780E+03       5.2          3.36        2.48
       1.22     .844E+03       5.8          3.41        2.44
       1.30     .905E+03       6.2          3.44        2.43
       1.39     .961E+03       6.6          3.43        2.43
       1.48     .101E+04       6.9          3.40        2.45
       1.56     .105E+04       6.9          3.31        2.52
       1.65     .107E+04       6.5          3.02        2.76
                                    <---- hydrograph ---->   <-pipe / channel->
                              AREA    QPEAK    TPEAK   R.V.   MAX DEPTH  MAX VEL
                              (ha)    (cms)    (hrs)   (mm)      (m)      (m/s)
   INFLOW : ID= 2 (  0023)   16.48     0.24     3.67  35.83      0.21      1.39
   OUTFLOW: ID= 1 (  0032)   16.48     0.24     3.75  35.83      0.21      1.38



--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0018)|   Area    (ha)=   0.94   Curve Number   (CN)= 84.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   3.90   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.12

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                                       ---- TRANSFORMED HYETOGRAPH ----
                TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                 hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
               0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
               0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
               0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
               0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
               0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
               0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
               0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
               0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
               0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57
```

```
     Unit Hyd Qpeak  (cms)=   0.299

     PEAK FLOW       (cms)=   0.169 (i)
     TIME TO PEAK    (hrs)=   1.000
     RUNOFF VOLUME    (mm)=  33.922
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.519

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0033)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)     (mm)
        ID1= 1 (  0018):      0.94   0.169     1.00    33.92
      + ID2= 2 (  0032):     16.48   0.238     3.75    35.83
        ====================================================
        ID = 3 (  0033):     17.42   0.238     3.75    35.72

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
-------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0034)|   Area    (ha)=   6.77   Curve Number   (CN)= 83.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.10   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.50

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
                0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
                0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
                0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
                0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
                0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
                0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
                0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
                0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   0.517

     PEAK FLOW       (cms)=   0.428 (i)
     TIME TO PEAK    (hrs)=   1.500
     RUNOFF VOLUME    (mm)=  33.117
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.507

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

-------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0035)|   Area    (ha)=  15.77   Curve Number   (CN)= 84.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   3.90   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.42

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
```

```
               hrs   mm/hr |   hrs   mm/hr |'  hrs   mm/hr |   hrs   mm/hr
             0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
             0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
             0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
             0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
             0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
             0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
             0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
             0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
             0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   1.434

     PEAK FLOW       (cms)=   1.186 (i)
     TIME TO PEAK    (hrs)=   1.417
     RUNOFF VOLUME    (mm)=  34.377
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.526

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| RESERVOIR(  0036)|     OVERFLOW IS OFF
| IN= 2---> OUT= 1 |
| DT=  5.0 min     |     OUTFLOW    STORAGE   |  OUTFLOW    STORAGE
--------------------      (cms)     (ha.m.)   |   (cms)     (ha.m.)
                          0.0000     0.0000   |   0.9922      0.4686
                          0.0150     0.0403   |   1.3581      0.5239
                          0.0508     0.0819   |   1.4554      0.5809
                          0.0745     0.1250   |   1.5104      0.6396
                          0.1065     0.1696   |   1.5636      0.6999
                          0.1567     0.2156   |   1.6156      0.7620
                          0.1928     0.2631   |   1.6657      0.8257
                          0.2872     0.3021   |   1.7150      0.8913
                          0.4020     0.3627   |   1.7631      0.9586
                          0.5684     0.4149   |   1.8561      1.0987

                                AREA     QPEAK     TPEAK       R.V.
                                (ha)     (cms)     (hrs)       (mm)
   INFLOW : ID= 2 (  0035)     15.770      1.186      1.42      34.38
   OUTFLOW: ID= 1 (  0036)     15.770      0.350      2.58      34.33

                   PEAK   FLOW   REDUCTION [Qout/Qin](%)= 29.51
                   TIME SHIFT OF PEAK FLOW         (min)= 70.00
                   MAXIMUM  STORAGE   USED       (ha.m.)=  0.3353

--------------------------------------------------------------------------------

--------------------
| ADD HYD  (  0037)|
|   1 +  2 =  3    |         AREA    QPEAK    TPEAK     R.V.
--------------------         (ha)    (cms)    (hrs)      (mm)
        ID1= 1 (  0034):     6.77   0.428     1.50    33.12
      + ID2= 2 (  0036):    15.77   0.350     2.58    34.33
        =====================================================
        ID = 3 (  0037):    22.54   0.601     2.00    33.97

     NOTE:  PEAK FLOWS DO NOT INCLUDE BASEFLOWS IF ANY.
--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0045)|   Area    (ha)=   2.10   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.30   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.14

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.
```

```
                                ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
                0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
                0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
                0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
                0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
                0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
                0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
                0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
                0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   0.573

     PEAK FLOW       (cms)=   0.313 (i)
     TIME TO PEAK    (hrs)=   1.083
     RUNOFF VOLUME    (mm)=  31.669
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.485

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0046)|   Area    (ha)=   1.31   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.30   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.08

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                                ---- TRANSFORMED HYETOGRAPH ----
                 TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
                  hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
                0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
                0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
                0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
                0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
                0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
                0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
                0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
                0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
                0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

     Unit Hyd Qpeak  (cms)=   0.625

     PEAK FLOW       (cms)=   0.288 (i)
     TIME TO PEAK    (hrs)=   1.000
     RUNOFF VOLUME    (mm)=  30.101
     TOTAL RAINFALL   (mm)=  65.350
     RUNOFF COEFFICIENT   =   0.461

     (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0047)|   Area    (ha)=   1.89   Curve Number   (CN)= 83.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.10   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.22

         NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                                ---- TRANSFORMED HYETOGRAPH ----
```

TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr
0.083	6.55	0.833	26.53	1.583	12.37	2.33	7.49
0.167	6.55	0.917	186.64	1.667	12.37	2.42	6.87
0.250	7.79	1.000	186.64	1.750	10.53	2.50	6.87
0.333	7.79	1.083	33.08	1.833	10.53	2.58	6.36
0.417	9.78	1.167	33.08	1.917	9.23	2.67	6.36
0.500	9.78	1.250	20.27	2.000	9.23	2.75	5.93
0.583	13.66	1.333	20.27	2.083	8.25	2.83	5.93
0.667	13.66	1.417	15.20	2.167	8.25	2.92	5.57
0.750	26.53	1.500	15.20	2.250	7.49	3.00	5.57

```
Unit Hyd Qpeak  (cms)=   0.328

PEAK FLOW       (cms)=   0.219 (i)
TIME TO PEAK    (hrs)=   1.167
RUNOFF VOLUME    (mm)=  33.075
TOTAL RAINFALL   (mm)=  65.350
RUNOFF COEFFICIENT   =   0.506

(i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.
```

```
--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0015)|   Area    (ha)=   8.60   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   5.00   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.31
```

NOTE: RAINFALL WAS TRANSFORMED TO 5.0 MIN. TIME STEP.

---- TRANSFORMED HYETOGRAPH ----

TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr
0.083	6.55	0.833	26.53	1.583	12.37	2.33	7.49
0.167	6.55	0.917	186.64	1.667	12.37	2.42	6.87
0.250	7.79	1.000	186.64	1.750	10.53	2.50	6.87
0.333	7.79	1.083	33.08	1.833	10.53	2.58	6.36
0.417	9.78	1.167	33.08	1.917	9.23	2.67	6.36
0.500	9.78	1.250	20.27	2.000	9.23	2.75	5.93
0.583	13.66	1.333	20.27	2.083	8.25	2.83	5.93
0.667	13.66	1.417	15.20	2.167	8.25	2.92	5.57
0.750	26.53	1.500	15.20	2.250	7.49	3.00	5.57

```
Unit Hyd Qpeak  (cms)=   1.060

PEAK FLOW       (cms)=   0.724 (i)
TIME TO PEAK    (hrs)=   1.250
RUNOFF VOLUME    (mm)=  31.358
TOTAL RAINFALL   (mm)=  65.350
RUNOFF COEFFICIENT   =   0.480

(i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.
```

```
--------------------------------------------------------------------------------
--------------------
| CALIB            |
| NASHYD   (  0016)|   Area    (ha)=  22.13   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.20   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   1.07
```

NOTE: RAINFALL WAS TRANSFORMED TO 5.0 MIN. TIME STEP.

---- TRANSFORMED HYETOGRAPH ----

TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr	TIME hrs	RAIN mm/hr

```
             0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
             0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
             0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
             0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
             0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
             0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
             0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
             0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
             0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

    Unit Hyd Qpeak  (cms)=   0.790

    PEAK FLOW       (cms)=   0.768 (i)
    TIME TO PEAK    (hrs)=   2.250
    RUNOFF VOLUME    (mm)=  31.985
    TOTAL RAINFALL   (mm)=  65.350
    RUNOFF COEFFICIENT   =   0.489

    (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

--------------------------------------------------------------------------------
--------------------
| CALIB             |
| NASHYD   (  0048)|   Area    (ha)=   1.93   Curve Number   (CN)= 82.0
|ID= 1 DT= 5.0 min |   Ia      (mm)=   4.10   # of Linear Res.(N)= 3.00
--------------------   U.H. Tp(hrs)=   0.29

        NOTE:  RAINFALL WAS TRANSFORMED TO   5.0 MIN. TIME STEP.


                              ---- TRANSFORMED HYETOGRAPH ----
              TIME    RAIN |  TIME    RAIN |'  TIME    RAIN |  TIME    RAIN
               hrs   mm/hr |   hrs   mm/hr |'   hrs   mm/hr |   hrs   mm/hr
             0.083    6.55 | 0.833   26.53 | 1.583   12.37 |  2.33    7.49
             0.167    6.55 | 0.917  186.64 | 1.667   12.37 |  2.42    6.87
             0.250    7.79 | 1.000  186.64 | 1.750   10.53 |  2.50    6.87
             0.333    7.79 | 1.083   33.08 | 1.833   10.53 |  2.58    6.36
             0.417    9.78 | 1.167   33.08 | 1.917    9.23 |  2.67    6.36
             0.500    9.78 | 1.250   20.27 | 2.000    9.23 |  2.75    5.93
             0.583   13.66 | 1.333   20.27 | 2.083    8.25 |  2.83    5.93
             0.667   13.66 | 1.417   15.20 | 2.167    8.25 |  2.92    5.57
             0.750   26.53 | 1.500   15.20 | 2.250    7.49 |  3.00    5.57

    Unit Hyd Qpeak  (cms)=   0.254

    PEAK FLOW       (cms)=   0.176 (i)
    TIME TO PEAK    (hrs)=   1.250
    RUNOFF VOLUME    (mm)=  32.048
    TOTAL RAINFALL   (mm)=  65.350
    RUNOFF COEFFICIENT   =   0.490

    (i) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

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Twin Creeks Environmental Centre: 2021 Fourth Quarter & Annual Monitoring Report Volume 1 of 5 – Compliance Monitoring

REPORT

WASTE MANAGEMENT OF CANADA CORPORATION

WATFORD, ONTARIO

TWIN CREEKS ENVIRONMENTAL CENTRE: 2021 FOURTH QUARTER & ANNUAL MONITORING REPORT VOLUME 1 OF 5 – COMPLIANCE MONITORING

RWDI #2101781-1000
March 1, 2022

SUBMITTED TO

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March 1, 2022

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Re: Waste Management of Canada Corporation
2021 Fourth Quarter and Annual Monitoring Report
Twin Creeks Environmental Centre, Warwick Township, County of Lambton, Ontario
Volumes 1 and 2 - Text, Figures, Tables, and Appendices

Dear Ms. McLachlan,

RWDI AIR Inc. (RWDI) is pleased to provide the 2021 Fourth Quarter and Annual Monitoring Report**, Volumes 1** and **2:** Compliance Monitoring and Operations Program, for the Twin Creeks Environmental Centre. **Volume 1** includes the text, figures, and tables. **Volume 2** includes the appendices, which contain the technical information and supporting documentation for the Compliance Monitoring and Operations Program and is provided in two (2) bound sections. **Volume 3** – Poplar System Monitoring Program, **Volume 4** – Ambient Air Quality Monitoring Program, and **Volume 5** – Noise Monitoring Program, are provided under separate covers

In November 2010, the Ministry of the Environment (MOE) issued the Technical Guidance Document entitled "*Monitoring and Reporting for Waste Disposal Sites, Groundwater and Surface Water*" (MOE, 2010). Appended to this report is a completed Monitoring and Screening Checklist from the above Technical Guidance Document, which provides certification of the Competent Environmental Practitioner (CEP). The Monitoring and Screening Checklist is provided in **Appendix S**.

Volumes 1 and 2 of the 2021 Fourth Quarter and Annual Monitoring Report have been prepared in consideration of Conditions 15.4 through 15.7 of amended Environmental Compliance Approval No. A032203, dated December 19, 2020 (Waste ECA), and provides a detailed interpretive analysis of the 2021 findings for the compliance monitoring at the Twin Creeks Environmental Centre and a summary of its operations in 2021.

We trust that this report satisfies your requirements. Please contact us if you have any questions.

Yours truly,

RWDI AIR Inc.

Khalid Hussein, P.Eng.
Project Manager

KAMH/kta

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1 INTRODUCTION

1.1 Purpose & Scope

The purpose of the 2021 Compliance Monitoring and Operations Program for Waste Management of Canada Corporation's (WM) Twin Creeks Environmental Centre (Site) is as follows.

- To report compliance with the terms and conditions of the relevant Environmental Compliance Approvals (ECAs) (waste, sewage, and air) and regulatory permits (PTTW) for the Site, the landfill gas flare systems, and stormwater management facilities for the reporting period of January 1 to December 31, 2021.
- To satisfy Conditions 5, 6, and 7 of the Environmental Assessment Act approval, dated January 15, 2007.
- To assess potential effects of the landfill on groundwater and surface water quality.
- To evaluate the monitoring program(s) on an annual basis and to recommend improvements as operations at the Site mature.
- To determine the need for the implementation of contingency measures.

Volumes 1 and 2 of the 2021 Fourth Quarter and Annual Monitoring Report (2021 Annual Report) satisfy the reporting requirements for both the fourth quarter (Q4) of 2021 (October 1 to December 31) and the 2021 compliance monitoring and operations calendar year monitoring period. Reporting involves a data collection component and a comprehensive analysis and interpretation component. The 2021 data were collected by WM and RWDI AIR Inc. (RWDI), while the data compiled for **Volumes 1 and 2** of the 2021 Annual Report were collated and analyzed by RWDI. The following presents a summary of the data collection responsibilities for the Compliance Monitoring Program in 2021.

Waste Management of Canada Corporation:

- Operations Logs (Dust and Litter)
- Leachate Volume Tracking
- Tonnage Tracking Information (Waste & Recyclables)
- Water Taking Information
- Complaint Logs
- Collection of Daily Liquid Levels from Expansion Site PDL Pumping Stations

RWDI AIR Inc.:

- Liquid Level Monitoring (Leachate and Groundwater)
- Groundwater Quality Monitoring
- Surface Water Quality Monitoring
- Contaminated Soil & ASR Quality Monitoring
- Leachate Quality Monitoring
- Monthly Collection of Liquid levels from Expansion Site SDL Pumping Stations
- Monthly Site Inspections
- Overall Data Collation and Reporting

Air quality, noise, total suspended particulate and Poplar System monitoring, and reporting were also completed by RWDI in 2021. The monitoring results, analysis, and interpretation for the Poplar System Monitoring Program are presented in **Volume 3** of the 2021 Annual Report. Approval to discontinue the monitoring of the Poplar Plantation was received on February 20, 2013, per Notice No. 1 of the Sewage ECA. Therefore, a relevant volume is not included in this Annual Report.

1.2 Site Regulatory Framework

The Site is owned and is operated by WM in conformance with the regulatory approvals noted below. Copies of the relevant ECAs and their amendments, as well as the PTTW, are provided in **Appendix A**.

- Amended Environmental Compliance Approval (ECA) No. A032203, dated December 19, 2020 (Waste ECA).
- Amended ECA for Industrial Sewage Works No. 2403-BE6LZ4, dated August 21, 2019 (Sewage ECA).
- ECA for Air No. 9488-AMPH4Y, dated July 6, 2017 (Air ECA).
- Amended Permit-To-Take-Water (PTTW) No. 4430-8PLMKV, dated January 17, 2012, for the removal of surface water from four (4) Sedimentation Ponds and the dewatering of the Secondary Drainage Layer (SDL) for the Expansion Site.
- PTTW No. 4682-BLJRYJ, dated November 8, 2021, for the removal of surface water from four (4) Sedimentation Ponds and the dewatering of the Secondary Drainage Layer (SDL) for the Expansion Site.
- MECP Letter entitled "Request for Modification to Surface Water Monitoring/Assessment Process at Twin Creeks Landfill", dated February 27, 2014 (2014 MECP Letter).

Throughout 2021, quarterly monitoring reports were submitted to relevant stakeholders in accordance with Condition 15.4 of the Waste ECA. **Volumes 1 and 2** of the 2021 Annual Report have been prepared in consideration of Conditions 15.4 through 15.7 of the Waste ECA and Condition 13(4) of the Sewage ECA. **Volumes 1 and 2** provide a detailed analysis of the 2021 findings for the compliance monitoring at the Site and its operation in 2021.

This 2021 Annual Report is also prepared in accordance with Conditions 5, 6, and 7 of the Notice of Approval to Proceed with the Undertaking, dated January 15, 2007, in regard to the Environmental Assessment Act (EAA) approval of the Warwick Landfill Expansion (renamed Twin Creeks Landfill and subsequently to Twin Creeks Environmental Centre).

1.3 Site Description & Background

The Site is a solid, non-hazardous waste landfill site that contains an old landfill (Existing Site) and an area approved for expansion (Expansion Site). The Site is located on Part of Lots 19 and 20, Concession 3, south of Egremont Road (SER), and part of Lots 20 to 22, Concession 4 SER, in the Township of Warwick, County of Lambton, Ontario. The Site occupies an area of 301 hectares (ha) with 101.8 ha permitted for landfilling. A Site Location Map is presented on **Figure 1**.

Landfill waste at the Site has two (2) distinct waste disposal areas: 1) the Existing Site; and 2) the Expansion Site. The Existing Site is divided into waste cells as presented on **Figure 2**. The progression of construction of the Expansion Site is summarized below and presented on **Figure 2**.

Expansion Site Cell	Date of First Waste Tonnage Deposited
Cell 1A Stage I	November 16, 2009
Cell 1A Stage II	September 21, 2010
Cell 1B Stage I	August 18, 2011
Cell 1B Stage II	June 20, 2012
Cell 2A	November 18, 2013
Cell 2B	September 25, 2014
Cell 2C	September 10, 2015
Cell 2D	August 19, 2016
Cell 2E	September 8, 2017
Cell 4A Stage 1	September 25, 2019
Cell 4A Stage 2	November 14, 2019
Cell 4B Stage 1	September 22, 2020
Cell 4B Stage 2	November 23, 2020
Cell 4C	August 10, 2021

During 2021, waste disposal occurred in Cell 4A, Cell 4B, and Cell 4C of the Expansion Site. Waste disposal in Cell 4C commenced on August 10, 2021, as the landfill liner system was approved to accept waste. Cell 6A pre-excavation activities related to the future construction of the Cell 6A landfill liner system of the Expansion Site were completed in 2021. Upon completion of the landfill liner system of Cell 6A, waste disposal is scheduled to also occur Cell 6A in 2022.

The South Cell (formerly South Fill Area) of the Existing Site consists of historical waste landfilled into trenches of various widths and depths excavated into the clayey soil. There are three (3) finger drains that transect through the trenches to provide gravity drainage toward the perimeter maintenance holes (MH16, MH17, and MH18) for leachate collection. The remainder of the waste footprint of the Existing Site also contains historical waste trenches but includes newer waste cells constructed with re-compacted clayey liners and, in some cells, waste underdrains.

Waste within the Expansion Site will extend to an average design depth of 15 m below existing grade. Leachate is managed with a liner system that directs leachate toward dedicated leachate pumping stations. The liner system consists of a primary drainage layer (PDL) below the waste to convey leachate, an underlying re-compacted clayey liner (primary liner), then a secondary drainage layer (SDL) for leak detection and contingency use, which is all underlain by a thick natural barrier of clayey soil. Design specifications are provided under Items 66 to 68 in Schedule A of the Waste ECA, namely, the report titled "*Development and Operations Plans – Warwick Landfill Expansion (Volumes 1 to 3)*", as prepared by Henderson Paddon & Associates and dated March 2008 (D&O Report).

Leachate generated at the Site can be managed either on-Site through irrigation for poplar trees to be treated by phytoremediation or by transport for off-Site treatment and disposal. The Poplar System was decommissioned in June 2014 as part of the construction activities to expand the footprint from the previous 3.3 ha to 9 ha. Leachate phytoremediation is approved for the expanded Poplar System located within the waste footprint of the Existing Site, as shown on **Figure 2**. In 2021, irrigation liquid was applied to the poplar trees intermittently from May 10 to September 30. It should be noted that the Poplar System pertains to a plot of poplar trees planted on the landfill cap of the Existing Site, whereas the Poplar Plantation refers to the plot of trees planted on native soil and is located south of the Existing Site. Details pertaining to the Poplar System Monitoring Program completed in 2021, including surface water monitoring in response to precipitation events of ≥ 10 millimetres (mm) in 24 hours, are provided in **Volume 3** of the 2021 Annual Report.

Surface water flow is ephemeral, with flow that typically occurs after snowmelt or prolonged periods of precipitation. Details on the surface water quality system are provided in **Section 2.4**. In summary, surface water is managed through a network of on-Site ditches, a Temporary Water Storage Area, and four (4) on-Site Sedimentation Ponds. Surface water runoff from the Site flows toward: 1) Kersey Drain (Brown Creek) to the east, and 2) to drains and ditches associated with Bear Creek to the west.

Assessments of local groundwater and surface water have continued to achieve acceptable quality at the Site compliance boundaries. A list of historical monitoring reports is provided in **Table B-1**, **Appendix B**.

For reference to the Site construction design details, **Appendix L** contains construction details of the Existing and Expansion Sites, with the breakdown as outlined below.

Existing Site:

The construction details: *"Laidlaw Waste Systems (Warwick) Limited, Warwick Township Landfill Site, Development and Operations Plan"* from the Development & Operations Report, Canadian Waste Services Inc., Warwick Landfill, Warwick Township (Henderson, Paddon Environmental Inc., October 1997), which is Item 37 of Schedule A of the Waste ECA (included as **Appendix L-1**, **Appendix L**).

Expansion Site:

The construction details: *"Drawings 111 – 120, 125, and 127"* from the Development & Operations Plans, Warwick Landfill Expansion, Volume 1 of 3, which is Item 66 of Schedule A of the Waste ECA (included as **Appendix L-2**, **Appendix L**).

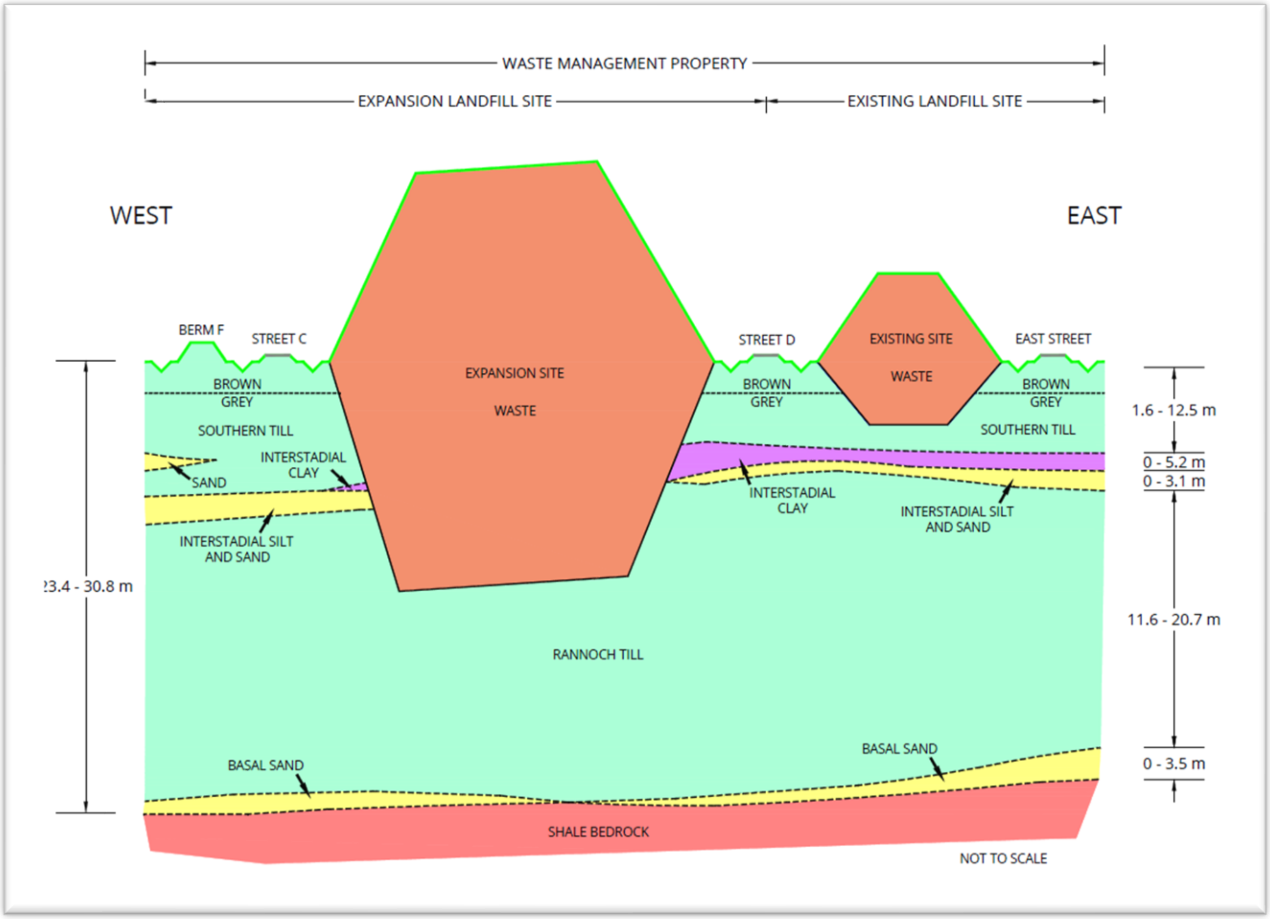
As-built Information for Waste Cells Constructed in 2021:

The CQA/CQC Liner System Summary Report (Cell 4C), as prepared by RWDI, dated August 4, 2021, respectively, can be found in **Appendix L-3, Appendix L**.

1.4 Site Hydrogeologic Setting

The landfill is located in southwestern Ontario within the southeastern portion of the Horseshoe Moraines physiographic region (Chapman and Putnam, 1984). The Horseshoe Moraines consist of a large horseshoe-shaped landform that includes a series of moraines aligned roughly parallel to the Lake Huron shoreline. Bear Creek to the west and Brown Creek to the east provide a slightly rolling topography around the Site. This rolling topography is further enhanced by the local tributaries and drainage swales.

For the purpose of this report, the local stratigraphy is subdivided into the following main units: 1) the Southern Till; 2) interstadial deposits; 3) the Rannoch Till; and 4) bedrock and the overlying basal sand. Each unit is shown in the following cross-section and is briefly discussed below.



The **Southern Till** unit consists of silty clay to clayey silt with trace amounts of disseminated sand and gravel. Occasional discontinuous layers or lenses of sand were observed within this unit. At the Site, this unit ranges in thickness from approximately 1.6 m to 12.5 m. The upper 1.6 m to 5.0 m of the Southern Till is weathered and is generally identified by a brown colour. Soil fractures are numerous near ground surface and decrease in frequency with depth. The underlying unweathered Southern Till is grey in colour and contains occasional fractures.

The **interstadial deposits** generally consist of two (2) distinct deposits: 1) an upper deposit of silt and clay, often varved, that is up to 5.2 m in thickness; and 2) a lower deposit of silt to sand that is up to 3.1 m in thickness. At some borehole locations, one or both deposits were not detected which indicates that these deposits are not continuous below the Site. Below the Site, the interstadial silt and sand ranges from 4.0 m to 10.7 m below ground surface where detected.

At about 4.0 m to 10.3 m below ground surface is the **Rannoch Till**. This till is a gritty to moderately stony clayey silt to silt till, although some textural variations occur. At some borehole locations, layers or lenses of silt to sand were detected within the till. The Rannoch Till was up to about 21.4 m thick below the Site.

Occasional discontinuous layers of sand and gravel between the Rannoch Till and underlying bedrock constitute the **basal sand**. The **bedrock** was encountered at a depth of between 23.4 m and 30.8 m below ground surface at the landfill and consists of the black bituminous shale of the Kettle Point Formation. The upper fractured portion of the bedrock and the overlying basal sand form the local bedrock aquifer.

The two (2) creeks that influence the physiography of the regional study area include Bear Creek to the west and Brown Creek to the east. The watershed for Bear Creek includes most of the Site and the area to the west. The Drainage Divide for the Bear Creek watershed cuts through the northeastern corner of the Site. Bear Creek is a tributary of the North Sydenham River and flows southwesterly to join the Sydenham River at Wallaceburg.

Surface water flow is ephemeral, with flow that typically occurs after snowmelt or prolonged periods of precipitation. Runoff from most of the east half of the Existing Site flows to Sedimentation Pond 1 (SP1), while runoff from the northern portion of Cell 11 and the west half of the Existing Site from north of approximately Cell 8/6 boundary flows to Sedimentation Pond 4 (SP4), drainage from most of Cell 6 flows into a Temporary Water Storage Area, while runoff from the remainder the west half of the Existing Site is directed to Sedimentation Pond 2 (SP2).

Sedimentation Ponds 1 through 4 are four (4) on-Site Sedimentation Ponds constructed in 2009 to manage surface water for the Site. Sedimentation Pond 2 discharges through culverts to the western Site boundary and into a tributary of Bear Creek on the east side of Lambton Road 79 (Nauvoo Road).

Upon completion of the Expansion Site, surface water runoff will be managed through Sedimentation Ponds 1, 2, 3, and 4. Surface water runoff originating from areas south of the Existing Site flows toward: 1) Kersey Drain (Brown Creek) to the east; and 2) to the west toward the Van Kessel Drain where it enters a municipal drainage tile at a catch basin (surface water monitoring station SS1), which is situated 60 m east of the western Site boundary. The municipal drainage tile subsequently drains into the discharge ditch of Sedimentation Pond 2, which ultimately flows westward to the Gilliand-Geerts Drain 'A', beneath Lambton Road 79.

The Brown Creek watershed drains the area east of the Site, including the northeast corner of the Existing Site. Brown Creek is a southwesterly flowing headwater of the Sydenham River, which it intersects about 1.3 kilometres (km) northeast of Alvinston.

Construction of the Sedimentation Pond network in the Expansion Site was completed by August 2009. The surface watercourse on the Expansion Site eventually discharges into a tributary of Bear Creek on the east side of Lambton Road 79 (Nauvoo Road). The surface water system around the Site is presented on **Figure 3**.

1.5 Water Budget

Water budgets are provided in **Tables C-1** through **C-7**, **Appendix C,** for the 30-year normal (1961-1990, 1971-2000, and 1981-2010) and the 2018 through 2021 climatic data for the area around the Site. The water budget information is based on the Thornthwaite Analytical Method (1957). A summary of precipitation data for the 30-Year Normal (1961-1990, 1971-2000, and 1981-2010) and the 1995 through 2021 annual climatic data for the area around the Site is provided in **Table C-9, Appendix C.** The 30-year normal and data to 1996 were collected at the Strathroy Climatological Station. Data from 1997 onward were collected from the Strathroy-Mullifarry Climatological Station, which is the nearest Environment Canada climatological station to the Site. As presented in **Table C-9, Appendix C**, a total of about 870.6 mm of precipitation was recorded from the on-Site climatological station during 2021, while the Strathroy-Mullifarry Climatological Station recorded about 1,028.4 mm of precipitation in 2021. Precipitation data collected from the on-Site climatological station from January 1 to December 31, 2021, is also provided in **Table C-8**, **Appendix C**.

Relative to the 30-Year Normal (1981-2010), 2021 was slightly wetter than normal as recorded at the climatological station. The 2002 to 2021 on-Site precipitation data from January 1 to December 31 indicates that the yearly precipitation received at the Site was consistently less than the regional total. For example, the precipitation recorded from the on-Site climatological in 2021 was approximately 15.3 % less than what was measured at the Strathroy-Mullifarry Climatological Station. This pattern of annually less precipitation recorded at the Site than recorded regionally, has typically been observed since on-Site precipitation monitoring began in 2003 (2003 was first full year of monitoring).

Based on the available historical data from the Environment Canada climatological stations, there is typically a water deficit (evapotranspiration exceeds precipitation) from May through September as expected during warmer climate. Therefore, there is a low potential for infiltration (lower accumulation of groundwater) or overland flow during this period. For January through April and from August through December in 2021, a water surplus (precipitation exceeds evapotranspiration) results in a greater potential for infiltration and overland flow.

1.6 Monitoring System & Schedule

Table 1 provides a schedule of the monitoring tasks completed in 2021. Also, provided in **Table 1** are rationales for monitoring requirements that were not completed in 2021. The annual monitoring program completed for the 2021 calendar year, including the relevant monitoring locations, parameters, and frequency, is outlined in **Table B-2**, **Appendix B**. **Table B-3**, **Appendix B**, provides a summary of changes to the Environmental Monitoring Plan (EMP) as approved by the Ministry of the Environment, Conservation and Parks (MECP). **Table B-4**, **Appendix B**, provides a summary of Compliance Point trigger concentration exceedances in 2021. Borehole logs and monitoring well information are provided in **Appendix D**. Monitoring well construction details are also summarized in tabular format as provided in **Table F-1**, **Appendix F**.

2 MONITORING METHODS

The 2021 Compliance Monitoring Program for groundwater, surface water, landfill gas, leachate, air quality and noise were completed by RWDI between January 1 and December 31, 2021. Liquid level monitoring of the primary drainage layer (PDL) and secondary drainage layer (SDL) of the Expansion Site was recorded automatically with pressure transducers and recorded by a SCADA system. Monitoring locations included in the annual monitoring program are listed in **Table 1** and presented on **Figure 2.**

Copies of the Chain of Custody Forms, as it relates to water, leachate, and soil, for samples submitted to the laboratory in 2021 are provided in **Table B-5**, **Appendix B**. A quality assurance and quality control (QA/QC) program was followed for each of the routine monitoring tasks completed. This program consists of procedures for the sampling of monitoring wells, the collection of samples, and ancillary tasks. A copy of the field sampling protocols is provided in **Appendix E**.

Monitoring well construction details are provided in **Table F-1**, **Appendix F**. Monitoring wells, which were included in the 2021 annual monitoring program, are designated as 'Active'. Other monitoring wells not included in the annual monitoring program are designated as 'Inactive'. Some historical monitoring wells that were recently removed and/or replaced from the monitoring program may be designated as 'Decommissioned'.

2.1 Liquid Level Measurements

Groundwater and leachate levels were manually measured at accessible monitoring wells, leachate wells, and maintenance holes located on the Site on May 17 and November 1, 2021.

Daily, during landfill operations, liquid levels for the leachate within the PDL at PS1, PS3, and PS5, as well as monthly groundwater levels for the water in the SDL at PS2, PS4, and PS6. Groundwater and leachate elevations are discussed in **Section 4**.

2.2 Leachate Sampling

Leachate samples were collected using dedicated disposable bailers for the relevant monitoring locations. Leachate samples were collected from select maintenance holes on May 18 and May 19, 2021.

Leachate from the Equalization Tank was conveyed into 20 litre (L) pails, which were rinsed with leachate prior to sample collection. The sampling point for the Equalization Tank is at the truck loading bay for PS10. The Equalization Tank is sampled on a quarterly basis. The leachate within the Equalization Tank represented leachate from: PS1 (Cell 1), PS3 (Cell 2), PS5 (Cell 4), most of the Existing Site, as well as partially derived from the condensate from the landfill gas collection systems installed in the Existing and Expansion Sites. During 2017, each cell with a leachate collection system within the Existing Site was automated for leachate transfer to the Equalization Tank, with the exception of the eastern portion of Cell 3S (MH3SA and MH3SB), and the northern portion of Cell 4 (MH4B). As such, leachate sampled from the Equalization Tank included leachate from the Existing Site throughout 2021.

Leachate was collected from PS1 (Cell 1), PS3 (Cell 2), and PS5 (Cell 4) via dedicated Waterra tubing equipped with a manual inertial-lift pump during the required annual sampling event in May. Leachate samples for soluble metals did not require field-filtering, but were preserved as required, while leachate samples for dissolved organic carbon (DOC) were field filtered and preserved. Leachate chemical results for the aforementioned various sampling locations are discussed in **Section 5.1**.

2.3 Monitoring Well Sampling

Groundwater samples were collected from May 18 to 21, 2021 for the spring semi-annual monitoring event. During the fall semi-annual monitoring event, groundwater sampling was completed from November 2 to 3, 2021.

Groundwater samples were collected using dedicated low flow bladder pumps.

The cemetery well is sampled annually in the spring by manually purging approximately 100 L using the existing old-water supply well manual inertial-lift pump. As the water from the cemetery well could be utilized as drinking water, metals sampling does not require field filtering.

As part of Site operations and to protect groundwater resources, some inactive monitoring wells were retained for potential future use as part of the monitoring program of the Expansion Site. This includes monitoring well OW59-10. Although monitoring well OW59-10 is considered an 'inactive' monitoring well, liquid levels are being assessed at OW59-10 to evaluate groundwater conditions near Cell 7 of the Existing Site. Idle monitoring wells OW39-6 and OW39-12 were decommissioned in 2017 during replacement activities related to damaged OW39-26. Monitoring locations OW61, OW62, OW75, OW76, OW77, OW78, and OW85 are currently inactive, as these monitoring wells are utilized to assess groundwater quality as it pertains to the operation of the Poplar Plantation. Since the Poplar Plantation has been inactive since its construction in 2009, groundwater quality assessment is not required to be completed in that location, which is also approved under Notice No.1 of the Sewage ECA.

In consultation with the Landfill Engineer and Hydrogeologist Reviewers of the Technical Review Team (TRT), WM had agreed post-2016 to supplement the existing leachate level monitoring. The supplemental leachate level monitoring locations (LW1 through LW6) were installed within the Existing Site in late 2017. The locations of the select landfill gas extraction wells from within the Expansion Site were determined in 2018 [EV229 in Cell 1A (Stage 1), EV268 in Cell 1A (Stage 2), EV022 in Cell 2B, and EV226 in Cell 2D], as shown on **Figure 2**. These supplemental leachate level monitoring wells are proposed to be monitored semi-annually together with the already established semi-annual spring and fall monitoring events for the Site to provide further insight toward leachate patterns within select waste cells of the Existing Site, as well as the Expansion Site.

2.4 Surface Water Sampling

2.4.1 Surface Water Flow

Surface water flow at the monitoring stations is precipitation dependent. Adequate flowing conditions to conduct surface water sampling were noted during Q1, Q2, Q3 and Q4 of 2021. After some precipitation events, some of the sampling stations did not produce the required flow for sampling. The observation of no flowing conditions after rain events ≥ 10mm/24hrs is expected and has been identified since precipitation monitoring began in 2003 at the Site. Verification surface water sampling events were also conducted, where required, in 2021.

As approval to discontinue monitoring the Poplar Plantation was received from the MECP on February 20, 2013, the surface water monitoring program for SS17A/B and SS18A/B remained inactive during the 2021 monitoring period.

2.4.2 Mechanism for Response Routine Monitoring

The surface water monitoring program adheres to the relevant Waste ECA, the Sewage ECA, as well as conditions stipulated within a MECP letter titled "RE: Request for Modification to Surface Water Monitoring/Assessment Process at Twin Creeks Landfill", dated February 27, 2014 (2014 MECP Letter). In general, the triggering mechanism for response monitoring is the receipt of ≥ 10 mm of precipitation in a 24-hour period from 08:00 to 08:00 hours. Flowing conditions permitting, the surface water stations are sampled within a 24-hour window following the receipt of ≥ 10 mm at the Site. Surface water is sampled once per quarter as part of the required routine monitoring for the Site. If a compliance monitoring station does not produce sufficient runoff to conduct sampling (or is dry), then the next precipitation event of ≥ 10 mm in a 24-hour period will trigger the assessment of those stations that were dry during the previous assessment. This response monitoring will continue throughout a quarterly monitoring period until the compliance stations have been sampled, or the quarter ends, in which monitoring of all the compliance stations will commence again for the next quarterly monitoring period.

2.4.3 Mechanism for Response Verification Monitoring

There are two (2) types of surface water monitoring stations at the Site. The first type of station consists of an open ditch where surface water flowing conditions heavily rely on precipitation. The second type of station consists of Sedimentation Ponds. When a Primary Leachate Indicator List (PLIL) parameter exceeds its trigger concentration at a surface water monitoring station, a verification monitoring response is triggered for that monitoring station.

For the 'ditch' type monitoring stations (e.g., SS1), verification monitoring can only occur after the receipt of ≥ 10 mm of precipitation in a 24-hour period where the precipitation was sufficient to generate flowing conditions to conduct sampling. Response monitoring continues throughout the quarter until a precipitation event is sufficient to conduct sampling. If insufficient flowing conditions continue at the ditch type station throughout a quarterly monitoring period, the verification event is postponed to the next quarterly monitoring period, and consequently, the postponed, monitoring event will consider both the routine quarterly monitoring event, as well as the verification monitoring event.

Similarly, for the Sedimentation Ponds, a verification monitoring event is triggered when one or more PLIL parameters exceed their relevant trigger concentrations following the routine quarterly sampling event. The verification monitoring for Sedimentation Ponds is completed within one (1) week of receipt of the routine monitoring event's chemical analytical results, independent of precipitation occurrences (Condition 5.4.) of the Sewage ECA).

Precipitation event monitoring, including biomonitoring testing is completed as outlined in the Waste and Sewage ECAs, as well as the conditions approved in the 2014 MECP Letter. An exceedance of a trigger concentration at one of the surface water monitoring compliance points would initiate verification monitoring, and if warranted, corrective action.

2.4.4 Precipitation Summary for Monitoring Events

Monitoring Station Locations and Sampling Details:

The surface water monitoring stations that formed part of the 2021 Compliance and Poplar System Monitoring Programs are summarized below.

Task	Monitoring Station Designations	Monitoring Station Description
Surface Water Environmental Monitoring Program	SS1	Downstream of landfill on WM property, 60 m east of Lambton Road 79 (Nauvoo Road) – Compliance Point
	SS10	Off-Site flow into East Ditch of the Existing Site – Background Surface Water Quality
	SS16	Flow onto expansion lands from Township land located south of the Site – Background Surface Water Quality
	SP1	Outlet Weir of Sedimentation Pond 1 – Internal assessment location
	SP2	Outlet Weir of Sedimentation Pond 2 – Compliance Point
	SP3	Outlet Weir of Sedimentation Pond 3 – Compliance Point
	SP4	Outlet Weir of Sedimentation Pond 4 – Compliance Point
Surface Water Poplar System Monitoring Program	SS14A (former SS14)	On-Site flow within East Ditch of the Existing Site, upstream of Poplar System
	SS14B (former SS15)	On-Site flow within West Ditch of the Existing Site, downstream of Poplar System as of June 2011.
	SS15A	South Ditch of the Existing Site and inlet point to Sedimentation Pond 1. Downstream of Poplar System.

Note: Former surface water monitoring stations SS14 and SS15, and revised/new surface water stations SS14A, SS14B, and SS15A as noted above, are required under the Waste and Sewage ECA's as part of the Poplar System Monitoring Program.

Details of the findings for the 2021 Poplar System surface water monitoring stations (SS14A, SS14B, and SS15A) can be found in **Volume 3** of the 2021 Annual Report.

A summary of the precipitation that triggered the surface water monitoring events is provided below. The precipitation amounts for the five days preceding the monitoring event are also provided. The data presented in the summary reflects that collected from the on-Site climatological station in 2021.

Quarter	Previous 5 Days of Precipitation (mm)	Sampling Events
1	0, 0, 0, 0.4, 28.0	March 26, 2021 – Routine monitoring event for the March 25, 2021 precipitation event
1	0, 3.0, 0, 0, 9.6	April 9, 2021 – Verification monitoring event for the March 26, 2021 routine precipitation monitoring event from Q1.
2	0, 0, 0, 0, 13.4	June 3, 2021 – Routine monitoring event for the June 2, 2021 precipitation event
2	0, 0, 0, 0, 19.2	June 26, 2021 – Routine monitoring event for June 25, 2021 precipitation event.
2	0, 0, 7.2, 8.0, 21.8	July 9, 2021 – Verification monitoring event for the June 26, 2021 routine precipitation monitoring event from Q2.
3	0, 0, 7.2, 8.0, 21.8	July 9, 2021 - Routine monitoring for July 8, 2021 precipitation event.
3	2.8, 0, 7.0, 0, 17.4	July 30, 2021 - Routine monitoring for July 29, 2021 precipitation event.
3	2.8, 0, 7.0, 0, 17.4	July 30, 2021 - Verification monitoring event for the July 9, 2021 routine precipitation monitoring event.
4	0, 0, 0, 6.2, 25.4	October 4, 2021 – Routine monitoring event for the October 3, 2021 precipitation event
4	9.8, 0.8, 0, 0, 15.6	October 15, 2021 – Verification monitoring event for the October 4, 2021 routine precipitation monitoring event.

Note: 1) N/A denotes verification monitoring event took place at a sedimentation pond and was therefore not precipitation event dependent.

Summary of Stations Monitored:

A summary of the surface water stations that were sampled in 2021, including a brief explanation as to why a station was not sampled, is provided below.

Surface Water Monitoring Station	Routine Monitoring	Verification Monitoring	Rationale for No Samples Being Collected
SS1	Q1, Q2, Q3, Q4	Q1, Q3, Q4	
SS10	Q1, Q3,		No flow in Q2 and Q4
SS16	Q1		No flow in Q2, Q3, and Q4
SP1	Q1, Q3, Q4		No flow in Q2
SP2	Q1, Q2, Q3, Q4	Q1, Q2, Q4	
SP3	Q1, Q2, Q3, Q4	Q4	
SP4	Q1, Q2, Q3, Q4		

For the first quarter (Q1), third quarter (Q3) and fourth quarter (Q4) monitoring periods, verification monitoring events were completed for compliance monitoring station SS1 on April 9, July 30, and October 15, 2021, respectively. For Q1, the second quarter (Q2), and Q4 monitoring periods, verification monitoring events were completed for compliance monitoring station SP2 on April 9, July 9, and October 15, 2021, respectively. For the Q4 monitoring period, a verification monitoring event was completed for compliance monitoring station SP3 on October 15, 2021.

Biological Monitoring:

The annual biomonitoring program was completed for the June 3 and June 26, 2021, spring surface water monitoring events per the EMP. Surface water samples were collected at stations SS1, SP2, SP3, and SP4 for the annual biomonitoring program. Surface water samples were not collected at stations SS10, SS16, and SP1 for the annual biomonitoring program due to no flow conditions.

Verification biomonitoring was also conducted at monitoring stations SS1 on April 9, July 30, and October 15, 2021, at SP2 on April 9, July 9 and October 15, 2021, and at SP3 on October 15, 2021 in accordance with conditions approved in 2014 MECP Letter. Details of the biological monitoring completed during the 2021 year are discussed in **Section 5.3.3 and 5.3.4**.

2.5 Landfill Gas Monitoring

Landfill gas monitoring was completed at gas probes GP1 to GP8 in January, February, March, April, July, November, and December 2021 per the EMP. Methane gas monitoring findings are discussed in **Section 5.4**.

2.6 Automobile Shredder Residue Monitoring

In accordance with Conditions 6.51 and 6.52 of the Waste ECA, automobile shredder residue (ASR) may be used at the Site as daily cover material on an ongoing basis. Samples of incoming ASR are collected on a semi-annual basis (when utilized) and submitted for analysis of the toxicity characteristic leachate procedure (TCLP) criteria in Schedule IV of Ontario Regulation 347. In 2021, ASR samples were collected on April 6 and October 1 in accordance with Conditions 6.51 and 6.52 of the Waste ECA. The ASR chemical analytical results satisfied the Schedule IV criteria within Ontario Regulation 347. Historical chemical analytical results are tabulated within **Table K-1**, **Appendix K**.

2.7 Contaminated Soil Monitoring

Per Conditions 6.53 to 6.61 of the amended Waste ECA, dated December 19, 2020, contaminated soil that meets the TCLP criteria in Schedule IV of Ontario Regulation 347 may be utilized as landfill cover material such that it is not placed on side slopes or above areas that are not underlain by waste (i.e., cannot store contaminated soil stockpiles on native soil). Contaminated soil for use as daily cover and/or intermediate cover was stockpiled in areas of the Site that have a leachate collection system installed below. Contaminated soil that meets the 10% TCLP criteria can be disposed within the monofill cells of the Existing Site (Cell 12 has available capacity). Contaminated soil was not disposed within the Existing Site monofill cells in 2021.

Samples of incoming contaminated soil are collected on a quarterly basis and submitted for analysis of the TCLP criteria in Schedule IV of Ontario Regulation 347. Contaminated soil samples were collected on March 16 (for Q1), May 5 (for Q2), August 12 (for Q3), and October 1 (for Q4) for laboratory analyses in 2021, with laboratory results verifying the samples satisfied Condition 6.57 of the Waste ECA. The relevant laboratory Certificates of Analysis, which detail the chemical analytical results, as well as a summary table of the chemical analytical results for the contaminated soil sampled in 2021, are included in **Table O-1** and **O-2**, **Appendix O**.

2.8 Field Sampling Parameters

Groundwater, leachate, and surface water field testing included the measurement of pH, electrical conductivity (EC), temperature, and turbidity (groundwater, surface water, and leachate), as well as dissolved oxygen (DO) (for surface water only). Surface water field parameters, including flow rates, were measured at each monitoring station, when water was present, during each monitoring event.

2.9 Laboratory Analytical Parameters

Analytical parameters are listed in **Table B-2**, **Appendix B**. In general, analyses were completed by Bureau Veritas Laboratories, previously known as Maxxam Analytics Inc., a Canadian Association of Laboratory Accreditation (CALA) accredited laboratory. Analyses for Automobile Shredder Residue and Contaminated Soil monitoring were completed by Eurofins Scientific, which is also a CALA accredited laboratory.

2.10 Field QA/QC Sampling

The field sampling QA/QC program is outlined in the following table. No equipment rinse blanks were collected due to the use of dedicated sampling equipment.

Media	Monitoring Event	Field-prepared Duplicate (Original Sample)
Leachate	May 18, 2021	LDUP (MH18)
Groundwater	May 18 to 21, 2021	GWDUP1 (OW54-10)
		GWDUP2 (OW16-6)
		GWDUP3 (OW57-4)
		GWDUP4 (OW40A-7)
	November 2 to 3, 2021	GWDUP1 (OW16-7)
		GWDUP2 (OW16-6)
		GWDUP3 (OW46-7)
Surface Water	March 26, 2021	SSDUP1 (SS1)
		SPDUP (SP1)
	June 3, 2021	SSDUP1 (SS1)
		SPDUP (SP4)
	July 9, 2021	SSDUP1 (SS1)
		SPDUP (SP1)
	October 4, 2021	SSDUP1 (SS1)
		SPDUP (SP2)

Notes: 1) Field and trip blanks were analyzed as part of the groundwater monitoring events during May and November 2021. Parameters are outlined in **Table B-2**, **Appendix B**.
2) Field prepared duplicate samples are not required for verification monitoring events.

3 QUALITY ASSURANCE & QUALITY CONTROL EVALUATION

The QA/QC program included field-prepared duplicate samples, field-prepared blanks, trip blanks, comparisons with field-determined analytical results, laboratory-prepared blanks, matrix spikes, duplicates, percent recoveries of analyses, and data review. Additionally, the QA/QC program consists of verifying that the correct parameters were assessed by the laboratory for each sampling event, and that they were assessed within their respective hold times (not beyond the sample expiration date). During 2021 the correct parameters were assessed within the allotted hold times.

The laboratory analyzed several control samples to verify that the analytical equipment was functioning properly and reporting results accurately at the time of analysis for the samples collected at the Site. The control samples had an expected target value, which was compared against pre-determined data quality objectives. For the laboratory control samples, the results were within acceptable laboratory data quality criteria.

Analytical results for the field-prepared duplicate samples, completed as detailed in **Section 2.9**, were evaluated for the relative percent difference (RPD) of parameter concentrations using the USEPA National Functional Guidelines (US EPA 540-R-10-011) as a general QA/QC RPD screening mechanism. The RPD screening mechanism is such that for concentrations greater than five times the laboratory reportable detection limit (RDL), a concentration difference of less than or equal to 20% is deemed acceptable. For concentrations less than or equal to five times the RDL, a concentration difference of equal to or less than the RDL is deemed acceptable. Where an exceedance of the general QA/QC RPD screening mechanism is identified, the results for the required parameters of analysis are evaluated against the applicable performance standards for sample duplicates noted in Tables 5.1 to 5.15 of the *Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act*, as prepared by the Ministry of the Environment (MOE), dated March 9, 2004, and amended to July 1, 2011. For the results found to exceed the criteria of each QA/QC evaluations, a laboratory data quality review (DQR) of the results is requested to verify that the concentrations are accurate as presented and are within acceptable laboratory data quality criteria.

Laboratory chemical results for the leachate, groundwater, and surface water are provided in **Appendices G**, **H** and **I**, respectively.

3.1 Leachate

For leachate samples collected for the 2021 Compliance Monitoring Program, the RPD were acceptable between original and duplicate samples, with the exception of select parameters as summarized below.

Sampling Date	Original Sample (Duplicate)	Parameter with QA/QC Exception
May 18, 2021	MH18 (LDUP)	Total Suspended Solids

A laboratory DQR of the aforementioned results indicated that the concentrations for the above noted parameters were accurate as presented and within acceptable laboratory data quality criteria. Therefore, the results for the leachate samples collected during the 2021 monitoring event were considered representative of actual leachate quality at the time of sample collection and were acceptable for inclusion into the database for interpretation.

The leachate field analytical results for temperature, pH, EC, turbidity, and DO, are provided for the Existing Site (CFA-Comp, Sump, and MH18), as well as the Expansion Site (PS1, PS3, and Equalization Tank) in **Table G-1**, **Appendix G**. Field leachate temperatures showed some variability reflective of the location the leachate is being stored/generated and the time of year the leachate was assessed. For example, the quarterly field temperature results for the Equalization Tank showed expected variability based on the time of year sampled with relatively lower temperatures for January and November, and higher temperatures for May and August.

The field analytical values recorded for pH across the Site varied between 6.8 and 8.2 pH units. EC values also varied, with a range of 6,590 to 9,260 micro-Siemens per centimetre (μS/cm) at the Existing Site, and 12,780 to >20,000 μS/cm for the Expansion Site. Turbidity values also expectedly varied with values between 28.5 and >1000 nephelometric turbidity units (NTU) for the Existing Site, and values between 173 and >1,000 NTU for the Expansion Site.

Ion balances were also calculated as a QA/QC procedure for the leachate. Considering major anions and cations, an ion balance difference of greater than 10% would initiate a more thorough review of the chemical results and laboratory procedures. The leachate chemical results obtained during the 2021 annual monitoring program satisfied the 10% ion balance target, except as noted in the summary below. The cause of the ion balance exceedances summarized below are reasonable for the noted parameters and the respective concentrations detected in the relevant samples.

Media	Station/Monitoring Well ID	Ion Balance Percentage and Date	Comments
Leachate	SUMP	13.9 – May 2021	High anion concentrations
	MH18	26.7 – May 2021	High anion concentrations
	CFA-COMP	14.4 – May 2021	High anion concentrations
	Equalization Tank	25.9 - May 2021	High anion concentrations
		20.7 – November 2021	High anion concentrations
	PS1	13.4 – May 2021	High anion concentrations
	PS3	20.9 – May 2021	High anion concentrations
	PS5	18.8 – May 2021	High anion concentrations

3.2 Groundwater

For the groundwater samples collected for the 2021 Compliance Monitoring Program, the RPD were acceptable between original and duplicate samples, with the exception of select parameters as summarized below.

Sampling Date	Original Sample (Duplicate)	Parameter with QA/QC Exception
May 18 to 21, 2021	OW54-10 (GWDUP1)	Total Ammonia Conductivity Dissolved Sulphate Alkalinity Nitrate Dissolved Boron Dissolved Calcium Dissolved Iron
	OW16-6 (GWDUP2)	Conductivity Total Dissolved Solids Total Kjeldahl Nitrogen Total Organic Carbon Dissolved Sulphate Alkalinity Dissolved Chloride Dissolved Barium Dissolved Boron Dissolved Magnesium Dissolved Sodium
	OW57-4 (GWDUP3)	Dissolved Iron
	OW40A-7 (GWDUP4)	Dissolved Iron
November 2 to 3, 2021	OW16-6 (GWDUP1)	Dissolved Iron

A laboratory DQR for each of the aforementioned results indicated that the concentrations for the above noted parameters were accurate as presented and within acceptable laboratory data quality criteria. Therefore, the results for the leachate samples collected during the 2021 monitoring event were considered representative of actual leachate quality at the time of sample collection and were acceptable for inclusion into the database for interpretation.

The groundwater field analytical results for temperature, pH, EC, and turbidity are provided for the active aquitard, the interstadial silt and sand, as well as the interface aquifer in **Tables H-1** to **H-3**, **Appendix H**, respectively. Shallow groundwater generally showed greater temperatures than the deeper groundwater during May and cooler temperatures compared to the deeper groundwater during November, indicative of seasonal influences on the shallower groundwater. The field analytical values recorded for pH varied between 6.6 and 8.3 pH units. As expected in clayey soil, both conductivity and turbidity values varied, with a range of 475 to 5,930 µS/cm for conductivity and 0.95 to >1,000 NTU for turbidity.

Ion balances were also calculated as a QA/QC procedure for the groundwater. Considering major anions and cations, an ion balance difference of greater than 10% would initiate a more thorough review of the chemical results and laboratory procedures. The groundwater chemical results obtained during the 2021 annual monitoring program satisfied the 10% ion balance target, except as noted in the summary below. The cause of the ion balance exceedances summarized below are reasonable for the noted parameters and the respective concentrations detected in the relevant samples.

Media	Station/Monitoring Well ID	Ion Balance Percentage and Date	Comments
Groundwater	OW16-6	10.2 – May 2021	High cation concentrations
	OW17-4	20.7 – November 2021	High cation concentrations
	OW40D-4	26.6 – May 2021	High cation concentrations
	OW60-4	10.3 – May 2021	High cation concentrations
	OW67-4	19.0 – May 2021	High cation concentrations
	OW80-3	18.5 – May 2021	High cation concentrations
	Cemetery Well	10.5 – May 2021	High cation concentrations

3.3 Surface Water

For the surface water samples collected for the 2021 Compliance Monitoring Program, the RPD were acceptable between original and duplicate samples, with the exception of select parameters as summarized below.

Sampling Date	Original Sample (Duplicate)	Parameter with QA/QC Exception
June 3, 2021	SP4 (SPDUP)	Total Kjeldahl Nitrogen
October 4, 2021	SS1 (SSDUP1)	Total Suspended Solids

A laboratory DQR for each of the aforementioned results indicated that the concentrations for the above noted parameters with RPDs were accurate as presented and within acceptable laboratory data quality criteria. Therefore, results for the surface water samples collected during the 2021 monitoring events were considered representative of actual groundwater quality at the time of sample collection and were acceptable for inclusion into the database for interpretation.

Surface water field analytical results are provided in **Table I-1**, **Appendix I**. During the 2021 monitoring events, the surface water temperatures reflected the ambient air temperature during sampling. Field pH, EC, turbidity, and DO values fluctuated with no notable anomalies.

Ion balances were also calculated as a QA/QC procedure for surface water. Considering major anions and cations, an ion balance difference of greater than 10% would initiate a thorough review of the chemical results and laboratory procedures. The surface water chemical results obtained during the 2021 annual monitoring program satisfied the 10% ion balance target, except as noted in the summary below. The cause of the ion balance exceedances summarized below are reasonable for the noted parameters and the respective concentrations detected in the relevant samples.

Media	Surface Water Monitoring Station	Ion Balance Percentage and Date	Comments
Surface Water	SS1	47.5 – March 2021	High cation concentrations
	SP1	15.5 – March 2021	High cation concentrations

In summary, the 2021 field and laboratory QA/QC results indicated that the chemical results were representative of actual conditions at the time of sample collection.

4 GROUNDWATER & LEACHATE ELEVATION RESULTS

To define the local groundwater setting below the landfill, the stratigraphic sequence described in **Section 1.4** can be associated with hydrostratigraphic units, as summarized below.

Stratigraphic Unit	Hydrostratigraphic Unit	Approximate Depth to top of Unit (m)
Brown Zone in the Southern Till	Active Aquitard	0.0
Grey Zone in the Southern Till	Upper Aquitard	1.6 to 7.9
Interstadial Clay and Silt		
Interstadial Silt and Sand	Interstadial Sand	4.0 to 10.7
Rannoch Till	Lower Aquitard	4.5 to 12.5
Fractured Bedrock and Basal Sand	Interface Aquifer	22.8 to 29.3

Although each stratigraphic unit is identified as part of a hydrostratigraphic unit, each unit has a hydraulic influence on the others. Groundwater monitoring wells developed within each hydrostratigraphic unit are summarized below and monitoring well construction details provided in **Table F-1**, **Appendix F**.

Hydrostratigraphic Unit	Monitoring Wells
Active Aquitard	OW16-6, OW17-4, OW40D-4, OW54A-4, OW56-4, OW57-4, OW58-6, OW59-6, OW60-4, *OW61-4, OW62-5*, OW67-4, OW68-5, OW69-5, OW70B-5, OW71A-5, OW72-6, OW73-6, *OW75-3, OW76-5, OW77-4, OW78-4,* OW79-5, OW80-3, OW81-5, *OW85-5*
Interstadial Silt and Sand	OW16-7, OW40A-7, OW46-7, OW47-6, OW54-10, OW57-15, OW58-17, OW60-8, *OW61-6, OW62-7*, OW67-11, OW72-10, OW73-9, *OW75-7, OW78-6,* OW79-7, OW80-6, OW81-7, *OW85-8*
Interface Aquifer	OW17-30, OW19-29, OW39A-26, OW40A-28, OW49-29, OW60-25, *OW61-26, OW62-30*, OW79-26, OW80-27, OW81-27, Cemetery Well

Note: *Italicized* denotes monitoring well is inactive as the monitoring well is to be used to evaluate the Poplar Plantation two (2) months prior to activation of the system.
Monitoring well OW58-14 was decommissioned in early fall 2016 and was replaced with monitoring well OW58-17.
Monitoring well OW39-26 was observed to have been damaged during the fall semi-annual monitoring event and was replaced in spring 2017 with OW39A-26.
Monitoring well nest OW81 installed in June 2019.

4.1 Leachate Elevations

Leachate elevations measured at the Existing Site during the 2021 annual monitoring program are presented with historical data in **Tables F-2** and **F-3**, **Appendix F**. Leachate elevation data from the pumping stations of the Expansion Site are presented with historical data in **Table F-6**, **Appendix F**.

4.1.1 Leachate Elevation Assessment - Existing Site

Monitoring Details:

Leachate elevations are plotted on **Figure 4**. Flow valves between maintenance holes for each cell of the Existing Site are left in a normally open position to facilitate the automated pumping of leachate to the Equalization Tank, as necessary to keep leachate levels at an acceptable elevation.

Collection System(s) Background:

To provide background for the understanding of the design of the waste cells within the Existing Site, Cells 3S, 4, 5, 6, 7, 8, 9, 10, and 11, as well as Cell 12 (only the southern third is constructed) contain waste underdrains that direct leachate to a perimeter collector system. Cells 10 and 12 are hydraulically connected, with leachate extraction typically occurring from MH12. The South Cell is completed with finger drains that direct leachate to a perimeter collection system. The West Cell is completed with a collection “Sump” to collect leachate for extraction purposes. Cell 3 does not have a leachate collection system, however, based on historical liquid levels the leachate in this cell is understood to be managed by the adjacent cells. For cells with waste underdrains, when the valve is open and leachate flows freely between a cell’s maintenance holes, the leachate elevation in the maintenance holes of that cell is expected to be similar, typically within 0.15 m.

Two (2) exceptions to this pattern can occur for cells with waste underdrains, which are for Cells 3S and 4. For Cell 3S, the leachate levels can be notably different in each maintenance hole, by the design of the collection system MH3SA and MH3SB are not hydraulically connected with a pipe and are the upper end of the system, which drain to the low end at MH3SC. MW3SC is connected with a pipe to MH3SD but is constructed with a sump ~2m deeper than the base of MH3SD. For Cell 4, there are two distinct (north third and south two-thirds) waste underdrain systems, which independently gravitationally drain to their respective low ends, MH4A (south system) and MH4B (north system). MH4B gravity drains through a toe drain to MH4A.

By the fall of 2017 each of the downstream maintenance holes for the Existing Site were updated to be operated as pumping stations. This pumping station conversion enables the leachate level in the maintenance hole to be automatically managed, year-round, via pumping leachate to either the equalization tank or to the Poplar System irrigation tanks.

Leachate Management:

As a general leachate best management practice, the extraction of leachate within the Existing Site is prioritized based on the leachate elevations for each individual waste cell to facilitate inward hydraulic gradients (as calculated considering the previous year’s seasonally relevant groundwater elevations). Exceptions occur since 2019 for leachate management practices where leachate is stored in the waste during late winter to spring, for volume availability for irrigation application to the Poplar System in the subsequent growing season. From an environmental stewardship perspective, the leachate generated from within the waste mound of the Existing Site was determined to generally be of more suitable use as irrigation liquid during the growing season as opposed to dedicating efforts for off-Site disposal and treatment between late winter 2021 and spring 2021. It is noted that storing leachate in this manner is suitable as environmental compliance for the Existing Site relies on groundwater and surface water quality monitoring, which were acceptable.

Leachate Level Assessment Details:

The hydraulic assessment of leachate compared to nearby shallow groundwater is utilized as an additional guidance tool toward managing leachate volumes in the waste cells and preventing the potential for releases to local water resources, such as surface water and groundwater. The leachate target elevations updated in 2020 were used to assist in lowering the liquid elevation within the maintenance holes and Sump during 2021. Most of the waste cells of the Existing Site are completed with waste underdrains such that leachate will percolate vertically downward through the waste and into the collection lines and be directed gravitationally toward the perimeter maintenance holes. As the waste mound is not likely uniform in nature, some leachate could be perched within the waste mound. As such, the potential for leachate seeps exists. In 2021, RWDI did not observe any seeps on the landfill cap during their respective Site inspections.

4.1.1.1 Leachate Elevation Patterns – Existing Site

It is apparent that leachate elevations varied across the Site. A comparison of the May and November 2021 leachate elevations with ground surface and inferred groundwater elevations outside the waste footprint is provided in **Table 2**. Overall, leachate elevations generally increased from November 2020 to May 2021 and then decreased from May 2021 to November 2021. This generalized pattern was expected for 2021 as discussed in more detail in the following sections. Exceptions to the generalized pattern generally were noted in the western portion of Cell 3S, Cell 4, Cell 5 and Cell 6 were leachate elevations slightly increased from May 2021 to November 2021. This was a result of a reduction in the application of leachate in 2021 compared to 2019 and 2020, in part, as a result of precipitation events during the 2021 application period were significantly greater, especially in September and October, which reduced the ability for the Poplar System to be operated. More details regarding the operation of the Poplar System are discussed in Volume 3 of this document. Additionally, the precipitation events would have also generated more leachate during this time of year than equivalent to during 2019 and 2020.

Based on 2021 leachate elevations, the hydraulically connected maintenance holes in the Existing Site generally showed an elevation difference that was equal within the same cell or that differed by less than 0.15 m. Exceptions to this occurred for Cell 3S (at MH3SC and MH3SD) and Cell 8 in 2021. The below summary outlines the noted differences, which are not a concern as the differences are either based on design or generally consistent with historical observations.

- Within Cell 3S, the leachate elevation at MH3SC for the May monitoring event was greater than the elevation at MH3SD by 0.30 m on May 17, 2021, whereas the leachate elevation at MH3SC for the November monitoring event was less than the elevation at MH3SD by 1.15 m on November 1, 2021. The observations noted at MH3SC and MH3SD are generally consistent with historical observations.
- Within Cell 8 the leachate elevations at MH8A for the May and November monitoring events were less than the elevations at MH8B by 0.31 m and 0.18, respectively, which is generally consistent with historical observations.

4.1.1.2 Leachate Levels Assessed Against Ground Surface

Leachate elevations/pressures that would have the potential to affect the groundwater systems are reflected by the leachate elevations within the associated maintenance holes of a given waste cell. As presented in **Table 2**, leachate elevations within the eastern and western waste cells were generally lower than the surrounding ground surface in May and November 2021. One (1) exception occurred in the West Cell (Sump) both during the May and November 2021 monitoring event. Since the November 2015 monitoring event, the leachate elevation within the Sump has generally exhibited an increasing trend until November 2019, which showed a significant decrease of 2.6 m as a result of leachate extraction. The leachate elevation in within the Sump showed a further decrease from November 2019 to November 2020 of 1.51 m, also as a result of leachate extraction. In November 2021, the leachate elevation within the Sump showed an increase of 1.63 m since November 2020 as a result of a temporary decrease in leachate extraction as noted herein.

As discussed above, the short-term increase of leachate levels from November 2020 to May 2021 was a result preparing to utilize the leachate volumes within the waste for irrigation application to the Poplar System beginning in May 2021. The further short-term increase from May 2021 to November 2021 was a result of a greater number of precipitation events during the growing season of 2021 compared to 2019 and 2020, which would both reduce the leachate extracted for application to the Poplar System and increase the amount of leachate generated as a result of rain infiltration. Overall, however, acceptable groundwater and generally acceptable surface water quality was noted around the Existing Site in 2021. Additionally, leachate seeps were not observed along the waste side slopes of the Existing Site in 2021. Therefore, the noted leachate elevations within the West Cell and the South Cell do not represent an immediate concern. Continued leachate extraction from the West Cell and South Cell via automated pumping is expected to further reduce the leachate mound in these cells. Ongoing monitoring will evaluate these locations over time.

4.1.1.3 Leachate Levels Assessed Against the Shallow Groundwater Table

Spring 2021:

In May 2021, leachate elevations were lower than the local and inferred shallow groundwater table for Cells 3, 4, 5, 7, 9, 10, 12, as well as Cell 3S. This comparison shows that the groundwater was being induced toward the waste and that leachate was hydraulically contained within the waste at these locations.

- Within Cell 6 (at MH6A), the leachate elevation was higher than the historical (pre-2008) local shallow groundwater elevation by 1.16 m. However, the May 2021 leachate elevation within MH6A is 0.09 m lower than observed in May 2020.
- Within Cell 8 (at MH8B), the leachate elevation was higher than the historical local shallow groundwater elevation to the west by 0.64 m. It is noted that the May 2021 leachate elevation within MH8B is reflective of leachate storage practices for use onto the Poplar System.
- Within Cell 11 (at MH11A), the leachate elevation was higher than the historical local shallow groundwater elevation to the west by 2.26 m. It is noted that the May 2021 leachate elevation within MH11 is reflective of leachate storage practices for use onto the Poplar System.

- Within the West Cell (Sump), the leachate elevation was higher than the historical local shallow groundwater elevations by 4.78 m. However, the May 2021 leachate elevation within the SUMP is 3.22 m lower than the peak elevation observed in May 2019.
- Within the South Cell (at OW22A-10 and OW53-10), the leachate elevations were higher than the historical local shallow groundwater elevation to the west by 0.22 m, and 1.54 m, respectively. It is noted that the May 2021 leachate elevations within OW22A-10 and OW53-10 are within the historical ranges for these locations.

Fall 2021:

In November 2021, the leachate elevations throughout select cells of the Existing Site expectedly showed a decreased since May 2021 as a result of leachate extraction for irrigation onto the Poplar System. For a few waste cells, the leachate elevations remained elevated with respect to the historical shallow groundwater elevations to the west and south of the Existing Site. However, leachate elevations were lower than the local and inferred shallow groundwater table for Cells 3, 5, 7, 8, 9, 10, 11, and 12.

- Within Cell 4 (at MH4A and MH4B), the leachate elevations were higher than the historical shallow groundwater elevation by 0.63 m and 0.54 m, respectively. It is noted that the November 2021 leachate elevation within MH4B is within the historical range for this location. The elevated November 2021 leachate elevation within MH4A is a result of a greater number of precipitation events during the growing season of 2021 compared to 2019 and 2020, which would both reduce the leachate extracted for application to the Poplar System and increase the amount of leachate generated as a result of rain infiltration.
- The leachate elevation within Cell 6 (at MH6A) was higher than the historical shallow groundwater elevation by 3.10 m. The elevated November 2021 leachate elevation within MH6A is similar to observed at Cell 4 and is a result of increased precipitation events preventing leachate extraction for irrigation purposes and a corresponding increase in leachate generated during this timeframe.
- Within the West Cell (Sump), the leachate elevation was higher than the historical local shallow groundwater elevations by 5.52 m. However, the November 2021 leachate elevation within the SUMP is 2.48 m lower than observed in May 2019.
- Within the South Cell (OW53-10) the leachate elevation was higher than the local shallow groundwater elevation by 2.98 m. It is noted that the November 2021 leachate elevation within OW53-10 is within the historical range for this location.

Overall, as discussed herein, acceptable groundwater and surface water quality was demonstrated at the compliance points during 2021. Also, leachate seeps were not observed along the waste side slopes of the Existing Site in 2021. Therefore, the noted leachate elevations that were higher in 2021 than the local groundwater elevations within select leachate monitoring wells and maintenance holes of the Existing Site did not represent a concern.

4.1.1.4 Leachate Elevation Trends – Existing Site

Hydrographs of leachate elevations are presented on **Figures F-1** through **F-12**, **Appendix F**. Long-term trends are summarized in **Table 3**. For the purpose of assessing elevation trends, a constant elevation trend is defined as having 0.1 m or less of seasonal variation.

In the long-term, leachate elevations have mostly fluctuated with some exceptions, as noted in **Table 3**. The historically increasing leachate elevations trends that were noted in 2019 for Cell 3S (at MH3SC and MH3SD), Cell 6 (at MH6A and MH6B), and the West Cell (Sump) that were noted to have decreased in 2020 from their respective elevated leachate elevations, have generally become elevated again in 2021. As previously noted, the elevated leachate elevations were a result of a greater number of precipitation events during the growing season of 2021 compared to 2019 and 2020, which would both reduce the leachate extracted for application to the Poplar System and increase the amount of leachate generated as a result of rain infiltration.

Over the long-term, leachate elevations are expected to continue to decrease since the Existing Site is capped and leachate is extracted from cells within the Existing Site for the operation of the Poplar System and for off-Site disposal. It should be noted that over time, the amount of leachate removed from storage will likely increase with the operation of the expanded Poplar System, as the system matures. The volume of leachate managed from the Site in 2021 is summarized in Section **4.1.5.1**.

4.1.1.5 Supplemental Leachate Level Assessment

As discussed in **Section 2.3**, supplemental leachate level monitoring wells were installed in 2017 and were monitored semi-annually in 2021 together with the already established semi-annual spring and fall monitoring events at the Site. The leachate elevations for the leachate level monitoring wells (LW1 to LW6) are presented in **Table F-3**, **Appendix F.**

Existing Site:

The May and November 2021 data indicates that select waste cells have leachate stored within the waste that may not be directed to, or captured by, the leachate underdrain collection systems. As such, this leachate does not represent a hydraulic loading to the respective cell's floor/liner and therefore, does not have a direct influence on the groundwater system (i.e. potentiometric influences).

During 2021, the leachate elevations within select maintenance holes were generally drawn down throughout the majority of the application period and fluctuated significantly as a result of leachate extraction for irrigation to the Poplar System. As noted herein, the significant amount of precipitation that the Site received in September and October contributed to the elevated fall leachate elevations. With respect to draw down as a result of leachate extraction, the liquid elevations in leachate monitoring wells LW1 to LW6 did not definitively correlate to the elevations in their counterpart maintenance hole (within the same waste cell). This observation indicates that leachate within the waste mound that may not be directed to, or captured by the leachate underdrain collection system (i.e. perched, low hydraulic conductivity, or some other cause) is therefore, not having an effect to the groundwater system (i.e. potentiometric pressures). This effect is observed in waste cells that are both positioned under and not under the Poplar System, indicating that the operation of the Poplar System is not the cause of this leachate elevation differential effect.

There was no observable negative affect observed to the sideslope of the Existing Site, such as leachate seeps, soil staining, stress vegetation, soil slumping or erosion, as a result of this leachate elevation differential. At this time the exact cause of the leachate differential is unknown, but it is not causing a detrimental effect to the operation of the Poplar System, excluding limiting leachate volume availability from select waste cells, and is not casing visible stress to the landfill cap and as such does not represent an immediate concern. Ongoing leachate level monitoring will enable an evaluation if this leachate differential is a long-term (i.e. over 5 years) situation, or has the potential to represent a concern (i.e. increasing trends with time, or stress to the landfill cap, etc.).

In summary, the Existing Site requires the ongoing leachate level monitoring program to enable input such that the leachate is managed environmentally effective in consideration of the destination target (e.g. off-Site vs. on-Site treatment).

4.1.1.6 Leachate Storage Volume – Existing Site

Overall, between May 2020 and May 2021 there was a slight increase in the calculated theoretical total leachate volume stored above the local groundwater table (23,609 m^3) and within the waste (24,693 m^3) of the Existing Site, as summarized in **Table 5**. Between November 2020 and November 2021 there was also an increase in the calculated theoretical total leachate volume stored above the local groundwater table (97,275 m^3) and within the waste (136,557 m^3) of the Existing Site, as summarized in **Table 5**. It is noted that these volumes are only theoretical in nature, as the total Site leachate volume removed for treatment in 2021 was 50,687.86 m^3 of which 11,479.81 m^3 was removed from the Existing Site and there is routinely insufficient weaker strength leachate available for irrigation purposes during the growing season. For consistency comparison purposes of 2010 data to historical data, the calculation method used for leachate volume (refer to **Table 5**) has not been changed for this report.

As discussed, and as presented in **Table 2**, after the 2021 irrigation season in November 2021, the leachate elevations in some of the cells of the Existing Site were determined to be lower than the May 2021 elevations whereas, a number of the cells were determined to be slightly greater. As previously noted, the elevated leachate elevations in November 2021 were a result of a was a result of a greater number of precipitation events during the growing season of 2021 compared to 2019 and 2020, which would both reduce the leachate extracted for application to the Poplar System and increase the amount of leachate generated as a result of rain infiltration.

Over the long-term, leachate volumes within cells of the Existing Site are expected to continue to decrease as more leachate is extracted for the operation of the expanded Poplar System and off-Site disposal.

The calculation method or input variables for the theoretical leachate storage volume will be revisited in an effort to have more accurate theoretical values compared to actual values based on field data interpretations/expectations.

4.1.2 Leachate Elevation Assessment – Expansion Site

Leachate level monitoring within the Expansion Site is completed to assess leachate pressures on the liner and the effectiveness of the leachate management system. Leachate levels for PS1, PS3, and PS5 are tabulated in **Table F-6** and graphically represented on **Figure F-26 to F-28**.

Collection System Background:

Leachate within each cell is directed to a sump where it is managed by pumping stations PS1, PS3, and PS5 (Cell 1, Cell 2, and Cell 4A, respectfully) for conveyance to the Equalization Tank. The operation of the pumps in the aforementioned pumping stations is SCADA-controlled (automated) with liquid level sensors that control pump 'on' and 'off' depending on the leachate level within the relevant sump. Leachate retrieval from the Equalization Tank is controlled by pump station PS10. It is noted that pumping station PS7 is not yet installed.

Trigger Mechanism Assessment Process:

The trigger mechanism for implementation of groundwater contingency measures for the Expansion Site is the loss of hydraulic containment of the landfill waste footprint. The loss of hydraulic containment occurs when leachate levels within the PDL are higher than the surrounding groundwater elevation for the active aquitard and the groundwater pressures for the interface aquifer. Hydrogeological impact predictions indicated trigger leachate levels should be no more than 6 m above the base of the PDL. The leachate target level for each pumping station of the Expansion Site is noted in Condition 14.1 of the Waste ECA. For the installed pumping stations PS1, PS3, and PS5, the target elevations are 232.7 metres above sea level (m ASL), 232.6 m ASL, and 232.8 m ASL, respectively. Pumping station PS1 began operation on November 16, 2009. PS3 began operation on November 21, 2013. PS5 began operation on October 1, 2019.

In addition, Condition 7.18 of the Waste ECA requires that a hydraulic trap be maintained beneath the Expansion Area at a maximum leachate head of 300 mm (or 0.30 m) on the landfill liner, as measured from the leachate pumping stations.

During the 2021 monitoring period, the leachate elevations at PS1, PS3, and PS5 remained well below their respective trigger leachate elevations, as outlined in Condition 14.1 in the Waste ECA.

It is noted that periodic elevated leachate occurrences are described in the MECP-approved Development and Operations Report (D&O Report) (Henderson Paddon, 2008). A temporary increase of the leachate head under such circumstances is not considered a non-compliance issue with the Waste ECA. Notwithstanding this consideration, WM has implemented an Expansion Landfill Leachate Level Contingency Plan (RWDI, April 30, 2021). The aforementioned plan was implemented so that WM is aware of a leachate level elevation that could be indicative of a pending operating scenario that could cause the leachate head to exceed 300 mm. Notification process will enable WM to be aware of a level of possible concern and enable WM to evaluate if the leachate level is a concern or not. If the level is of concern, then WM will be able to evaluate the leachate level operational system to identify the cause of the leachate level of concern and implement the relevant remedial measures detailed in the D&O to address operational issues for leachate level management. The notifications are denoted below.

- Electronic issuance (email and/or text) to relevant WM operations personnel that a leachate level for a given waste cell of the Expansion Landfill is at 80% (240 mm) of the 300 mm leachate head limit.

- A visual notification (i.e., light) on the leachate pumping stations when the leachate level for the respective waste cell of the Expansion Landfill is at 80% (240 mm) of the 300 mm leachate head limit.

The leachate elevations within Cell 1, 2, and 4 of the Expansion Site were below the historical groundwater elevation in the active aquitard and the interstadial silt and sand groundwater flow systems.

Therefore, the leachate in Cells 1, 2, and 4 was hydraulically contained from the afore-mentioned groundwater flow systems.

Leachate levels within PS1, PS3, and PS5 satisfied the aforementioned Waste ECA conditions during 2021. The level sensor within PS3 was determined to be faulty in mid-October 2021 and is awaiting replacement. WM notified the Ministry of the Environment, Conservation and Parks (MECP) that the level sensor was faulty, and that WM set the pump in PS3 to run every 10 minutes until the level sensor is replaced. Every 10 minutes the pump will run until no flow is detected in the pump for a total of 10 seconds, thus triggering it to shut off until the start of the next cycle 10 minutes later. The frequent run cycles allow the pump to prevent any significant leachate build up on the cell liner, thus maintaining compliance with requirements of the Waste ECA. The leachate levels at PS3 throughout this time period are noted to be false sensor readings as the pump runs in frequent cycles and the leachate sensor readings would still remain elevated and fluctuating. Further details are included in **Appendix Q.**

4.1.2.1 Leachate Elevation trends – Expansion Site

Leachate levels for PS1, PS3, and PS5 are presented in **Table F-6** and on **Figure F-26 to F-28**, **Appendix F**. As expected, leachate levels vary with time as a result of the gradual accumulation of leachate and pumping activities to maintain acceptable leachate levels at each pumping station.

4.1.2.2 Supplemental Leachate Level Assessment

Expansion Site:

The leachate elevations for the Expansion Site were collected from landfill gas extraction wells, otherwise known as early vertical gas wells (EVGW) [EV229 in Cell 1A (Stage 1), EV268 in Cell 1A (Stage 2), EV022 in Cell 2B, and EV226 in Cell 2D] are presented in **Table F-8, Appendix F**.

Leachate elevations for the EV229, EV022, and EV226 were unable to be measured during 2021 semi-annual monitoring events. For the EVGW's that could not be assessed for liquid levels, similar to the 2020 semi-annual monitoring events, debris was encountered at elevations that were higher than the EVGW base, thus precluding access to deeper portions of the EVGW's. The obstructing debris could not be identified in the field. It is noted that in 2018 these same EVGWs were assessed to be dry to each of their respective bottom elevations (approximately 1.0 to 1.5 m above the liner floor). Accessible EVGW EV268 was determined to be dry to its depth extent, which is within 1 m above the liner floor.

4.1.3 Leachate Management

4.1.3.1 Leachate Volume

Leachate Generation:

The primary leachate source is from precipitation infiltrating into and percolating through the waste. The groundwater contribution is negligible. Between January 1 and December 31, 2021, a total of 44,284.83 m^3 of leachate was removed and transported off-Site for treatment and disposal at the Chatham Water Pollution Control Plant or Canflow Environmental Services, while 6,403.03 m^3 was irrigated onto the Poplar system during the 2021 growing season. Details regarding the 2021 Poplar System irrigation activities are discussed in **Volume 3** of the 2021 Annual Report.

A breakdown of the leachate volume treated in 2021 is presented below.

Area of Leachate Extraction	Treatment (m^3)
Off-Site Treatment Management	
Existing Site MHs	639.75
Pumping Station PS10	43,645.08
Sub-Total	***44,284.83***
On-Site Poplar System Management	
Existing Site MHs	6,338.53
Pumping Station PS10	64.50
Sub-Total	***6,403.03***
TOTAL	**50,687.86**

Note:
1) m^3 denotes cubic metre. 1 m^3 is equivalent to 1,000 L (litres).
2) Existing site denotes leachate extracted by tanker truck directly from one of, or a combination of, Cell 3S, 4, 5, 6, 7, 8, 9, 10/12, 11, South Cell, &/or West Cell (Sump).
3) The source cell leachate make-up in the Equalizations Tank, as sampled from PS10, changes over time, as outlined in Section 2.2.

Of the 50,687.86 m^3 noted above, the approximate breakdown of leachate source location between the Existing Site and the Expansion Site is 23% (11,479.81 m^3) and 77% (39,208.05 m^3), respectively. This breakdown is based on the leachate source distribution noted for the 2021 monitoring period which incorporates the separate approximate volumes of leachate extracted from the Existing Site (41% of area) and Expansion Site (59% of area) for either off-site or on-site treatment as discussed above.

4.1.4 Leachate Seeps & Stains

Leachate seeps or potentially ponded water within waste that were noted by WM during daily inspections were generally limited to areas adjacent to the active landfilling working area (e.g. waste mound, haul roads) of the Expansion Site in 2021. Although select observed occurrences may have been ponded water within waste, WM treated them as seeps and they were generally repaired the same day. No significant leachate seeps or stains were noted by the MECP, RWDI, or WM for the Expansion Site throughout the 2021 monitoring period. As discussed, no leachate seeps were observed for the Existing Site during 2021.

4.2 Secondary Drainage Layer Hydraulic Containment

Liquid levels were recorded monthly for the SDL of Cell 1, Cell 2, and Cell 4 in 2021. Liquid elevations from the SDL are provided in **Table F-7** and graphically represented on **Figure F-25**, **Appendix F**.

Hydraulic Containment Assessment:

Water levels within the SDL of Cell 1, Cell 2, and Cell 4A continued to be below surrounding groundwater levels and pressures and therefore, groundwater was induced to flow toward the SDL of Cell 1, Cell 2, and Cell 4. As the water elevations in the SDL for Cell 1, Cell 2, and Cell 4 (PS2, PS4, and PS6, respectively) are greater than the leachate elevations within the PDL of Cell 1, Cell 2, and Cell 4 the leachate in the PDLs are hydraulically contained within the PDLs from the SDLs. SDL pumping station PS8 has yet to be constructed.

Historical SDL Elevation Trends of Note:

The initial slow increase over time in the SDL elevation within Cell 1 since its installation is a result of the large pore volume for water to accumulate within the 0.3 m thick granular layer that comprises the SDL within the western half of Cell 1. The rapid increases in SDL elevation within Cell 2 and Cell 4 are reflective of the very small pore volume within the 0.01 m thick Geonet that is installed as the SDL for Cell 2 and Cell 4 (and the eastern portion of Cell 1). It is noted that the historical periodic short duration decreasing pattern in the SDL for Cell 1, Cell 2, and Cell 4 represents water taking activities for cell-to-cell connection activities and/or soil moisture conditioning of the clayey soil liner material used in the construction of the cell liner system. These periodic SDL level decreases are expected during the Expansion Site construction and as discussed, do not represent a concern as once a cell is excavated, groundwater movement is toward the cell excavation, thereby hydraulically containing any liquid (both in SDL and PDL) in the cell.

4.3 Active Aquitard Groundwater Movement

The active aquitard represents a shallow groundwater flow system whereby precipitation infiltrates into soil fractures, root casts, and other weathering features and moves in a dominantly lateral direction. The low permeability of the surrounding silty clay to clayey silt matrix reduces the volume of groundwater movement through the active aquitard. The low volume of water within the active aquitard is also evident by the slow recovery of monitoring wells after purging and sampling.

Groundwater elevations measured during the 2021 annual monitoring program are presented with historical data in **Table F-4**, **Appendix F**.

4.3.1 Groundwater Elevation Patterns

Groundwater elevations measured for the Active Aquitard on May 17, 2021, are presented on **Figure 4**. Considering the north-south flow divide through the Poplar Plantation and historical patterns of groundwater movement, an easterly and westerly direction of groundwater movement is inferred. Surficial features such as ditches, waste cells, excavations, ponds, berms, and the leachate management systems, as well as precipitation amounts, will locally influence the groundwater flow direction.

4.3.2 Groundwater Elevation Trends

Groundwater elevation hydrographs for the active aquitard are presented on **Figures F-13** through **F-18**, **Appendix F**. Long-term trends are summarized in **Table 4**. For the purpose of assessing elevation trends, a constant elevation trend is defined as having 0.1 m or less seasonal variation.

In the long-term within the active aquitard, groundwater elevations have continued to fluctuate. Overall, fluctuating patterns in groundwater elevation were noted across the Site in the Active Aquitard, which are attributed to seasonal effects from precipitation and snowmelt. Overall, groundwater elevations were generally noted to be within their historical ranges. The groundwater elevation at OW58-6 was noted to have increased to a new high in November 2021, likely as a result of significant precipitation totals in the fall of 2021.

4.4 Interstadial Silt & Sand Groundwater Movement

The interstadial silt and sand hydrostratigraphic unit consists of silt and sand layers or lenses within the interstadial deposit that overlies the Rannoch Till. Groundwater movement within the interstadial silt and sand will be controlled by hydraulic gradients and the soil texture. For the purpose of the landfill compliance assessment, it is assumed that the silt and sand layers or lenses are hydraulically connected and that groundwater movement is in the direction of the inferred hydraulic gradient.

Groundwater elevations measured during the 2021 annual monitoring program are presented with historical data in **Table F-4**, **Appendix F**. Hydrographs for the interstadial silt and sand are provided on **Figures F-19** through **F-22**, **Appendix F**.

4.4.1 Groundwater Elevation Patterns

Groundwater elevations measured for the Interstadial Silt and Sand on May 17, 2021, are presented on **Figure 5**. Groundwater pressures suggest a consistent pattern to the historical interpretation of an easterly and westerly groundwater flow direction from a north-south groundwater divide that extends from Confederation Line to Zion Line (Jagger Hims Limited, 2005). However, the excavation of Cell 1, Cell 2, and Cell 4 has reduced the groundwater potentiometric pressures within the interstadial silt in these areas and locally induces groundwater to move toward and into the SDL of the cells. These lowered groundwater pressures are expected to return to pre-existing conditions as the soil mass is replaced with waste mass. Higher groundwater pressure elevations relative to other areas may occur below the Central Fill Area (defined as waste cells: Cell 3S, Cell 3 through Cell 7, as well as Cell 9 and Cell 11) of the Existing Site due to the mass of the overlying waste and leachate, thereby hydraulic gradients are expected to be upward toward the waste.

4.4.2 Groundwater Elevation Trends

Long-term elevation trends are summarized in **Table 4**. For the purpose of assessing elevation trends, a constant elevation trend is defined as having 0.1 m or less seasonal variation.

Groundwater elevations within the interstadial silt and sand have generally fluctuated in the long-term, with the elevations at OW54-10, OW67-11, OW72-10, and OW73-9 exhibiting generally decreasing and fluctuating trends over time. It is noted that the groundwater elevations at the aforementioned monitoring wells appear to be stabilizing. Ongoing monitoring will evaluate the noted trends over time.

For the monitoring wells where seasonal fluctuations in the groundwater elevation have historically been observed, this trend generally continued in 2021. For these wells, the November 2021 groundwater elevations within the interstadial silt and sand were generally lower or similar compared to those observed in May 2021. It is noted that a relatively wet fall was observed in comparison to previous years which resulted in the November 2021 groundwater elevations being similar or slightly greater than those observed in May 2021 at a number of the monitoring wells. Within the interstadial silt and sand flow system, the overlying waste and leachate levels, as well as the Cell 1, Cell 2, and Cell 4 excavations, induced localized potentiometric pressure increases and decreases, which also resulted in variations in the local flow direction. Overall, with the exception of where decreasing trends continued to be observed in 2021, groundwater elevations were generally noted to be within their historical ranges.

4.4.3 Vertical Hydraulic Gradients

Vertical hydraulic gradients below the Site in the active aquitard to the interstadial silt and sand hydrostratigraphic unit were calculated for the May 17 and November 1, 2021, data.

The hydraulic gradients that were calculated are presented in **Table F-5**, **Appendix F**. In summary, vertical hydraulic gradients continued to be dominantly downward toward the interface aquifer around the waste footprints and below the Existing Site. However, localized upward hydraulic gradients occurred to the active aquitard from the interstadial silt and sand at the monitoring well locations summarized in the table below. Ongoing monitoring will continue to evaluate these trends over time.

May 2021	November 2021
OW40D-4 OW60-4 OW80-3	OW80-3

4.5 Interface Aquifer Groundwater Movement

Occasional discontinuous layers of sand and gravel between the Rannoch Till and underlying bedrock constitute the basal sand. For the purpose of the landfill compliance assessment, it is assumed that groundwater movement is in the direction of the inferred hydraulic gradient. The upper fractured portion of the bedrock and the overlying basal sand form the local bedrock aquifer and are generally referred to as the interface aquifer.

Groundwater elevations measured during the 2021 annual monitoring program are presented with historical data in **Table F-4**, **Appendix F**. Hydrographs are provided on **Figures F-23** to **F-24**, **Appendix F**.

4.5.1 Groundwater Elevation Patterns

Groundwater elevations measured for the Interface Aquifer on May 17, 2021, are presented on **Figure 6**. Overall, a southwesterly groundwater flow direction was apparent below the Existing Site and the Expansion Site. This flow direction is consistent with the historical inferred direction of groundwater movement within the interface aquifer (Jagger Hims Limited, 2005). Of note, as more overburden soil is removed during landfill cell construction, interface aquifer pressures are expected to decrease temporarily. As more waste is deposited within the waste cells of the Expansion Site, the increase in overlying mass will increase the groundwater pressures of the bedrock aquifer.

4.5.2 Groundwater Elevation Trends

Long-term elevation trends are summarized in **Table 4**. For the purpose of assessing elevation trends, a constant elevation trend is defined as having 0.1 m or less seasonal variation. Groundwater pressure elevation trends and patterns for the interface aquifer continue to be generally consistent with historical findings with a fluctuating trend with time. Additionally, the majority of monitoring wells in the interface aquifer have also been showing a fluctuating and decreasing trend since about 2010. This pattern at these locations was expected as it indicates a response to depressurization from the removal of overlying soil within the Expansion Site waste footprint. It is anticipated that these decreasing elevation trends will be temporary, and pressures will begin to increase once a sufficient waste mass is landfilled to replace the excavated clayey soil mass. As expected, monitoring wells OW39A-26, OW79-26, OW80-27, and OW81-27 are showing a fluctuating and increasing trend since about 2018 as a significant waste mass has been progressively landfilled into the southern half of the Expansion Site. Overall, with the exception of where a more dominant fluctuating trend continued to be observed in 2021, groundwater liquid levels were generally noted to be within their historical ranges.

4.5.3 Vertical Hydraulic Gradients

Vertical hydraulic gradients below the Site in the interstadial silt and sand to the interface aquifer hydrostratigraphic unit were calculated for the May 17 and November 1, 2021 data. The hydraulic gradients that were calculated are presented in **Table F-5**, **Appendix F**. In summary, vertical hydraulic gradients were noted to be downward during both the May and November 2021 monitoring events for the Interstadial Silt and Sand layer to the Interface Aquifer owing to the low leachate and groundwater levels within Cells 1 and 2. Ongoing monitoring will continue to evaluate these trends over time.

5 CHEMICAL & GAS MONITORING RESULTS

5.1 Leachate

In accordance with the landfill EMP, leachate sampling from within select maintenance holes across the Existing Site was completed on May 17, 2021, as part of the annual monitoring requirement. A leachate sample was obtained from the Sump that is located within the West Cell. A second leachate sample designated CFA-Comp consisted of the collection of a composite sample obtained from MH3SA-F, MH4B, MH5A, MH6A, MH7A, MH9A, and MH11A to represent leachate within the Central Fill Area. Leachate is also sampled from MH18 to represent leachate from the South Cell.

Samples were also collected from PS1, PS3, and PS5 during the spring monitoring event on May 18 and 19, 2021. PS1, PS3, and PS5 samples were collected directly from the pumping station sump. Chemical results are summarized in **Appendix G**.

Table 6 provides a chemical summary of the long-term leachate characteristics for the Existing Site and the Expansion Site to November 2021. The 2021 leachate chemical results were generally within the respective historical ranges for the parameters analyzed.

As shown on **Figure G-1**, **Appendix G**, the chloride concentrations in leachate from the Equalization Tank show a fluctuating trend since 2013. Concentration fluctuations over time are expected due to the nature of leachate, as well as to the variations in the relative contribution of weaker leachate from new waste (i.e., new waste in Cell 4C) or from the monofill cells (i.e., Cells 10/12) of the Existing Site to stronger leachate from the aging waste (i.e., waste in Cell 1) or from the West Cell (Sump) of the Existing Site. Chloride concentrations in leachate from the Equalization Tank will continue to be monitored during future sampling events.

5.1.1 Leachate Indicator List

In general, leachate concentrations vary across the Site, with stronger leachate within Cell 6 and the West Cell compared to other cells of the Existing Site. Leachate constituent concentrations for the Expansion Site are generally within the low range for concentrations detected in the Existing Site. This difference is attributed to the relatively young age of the waste (compared to waste in the Existing Site) and the onset of waste decomposition. The 2021 and historical ranges in chemical concentrations for the leachate, as well as the background groundwater and surface water, are presented in **Table 6**. Based on a comparison of the leachate concentrations to the background groundwater and surface water concentrations, the following parameters have had notably elevated concentrations within the leachate.

- EC
- Alkalinity
- Calcium
- Magnesium
- Sodium

- Potassium
- Chloride
- Dissolved Organic Carbon
- Ammonia
- Total Kjeldahl Nitrogen
- Boron
- BTEX Compounds (Benzene, Toluene, Ethylbenzene, and Xylenes)

A landfill leachate effect on groundwater or surface water quality is defined as leachate mixing with the water and migrating in the direction of water movement beyond the Site boundary. To differentiate landfill leachate effects from natural water quality variability, a group of parameters indicative of landfill leachate was selected based on the following items.

- Elevated concentrations in leachate.
- Mobility and stability in groundwater and surface water.
- Representative of a larger chemical group (e.g., boron for metals).
- Applicable Ontario Drinking Water Standard (ODWS) or PWQO.

A group of indicator parameters selected for this landfill, termed the Primary Leachate Indicator List (PLIL), are summarized below.

Primary Leachate Indicator List (PLIL)	
PLIL – Groundwater	**PLIL – Surface Water**
Chloride Nitrate (as N) Boron	Chloride Ammonia (unionized) Phenols Boron Nickel Chromium (total) Zinc

A supplemental group of parameters, termed the Secondary Leachate Indicator List (SLIL), is selected based on elevated concentrations within the leachate. The SLIL is used for quality assurance of the chemical database, for input to establish trigger concentrations, and for further data analyses in the event of trigger concentration exceedances. The SLIL parameters are summarized below.

Secondary Leachate Indicator List (SLIL)			
SLIL – Groundwater		**SLIL – Surface Water**	
Alkalinity Sulphate Calcium Magnesium Potassium Sodium Barium Iron DOC TDS	Ammonia (total) TKN pH Conductivity Cadmium Lead Benzene Toluene Ethylbenzene Xylenes	Alkalinity Sulphate Calcium Magnesium Potassium Sodium Iron Nitrate TKN Phosphorus (total)	TDS pH Conductivity Turbidity Dissolved Oxygen

The concentrations of leachate constituents will vary with time. Leachate quality monitoring will continue at the Existing Site and the Expansion Site to assess the changing leachate characteristics for a landfill impact assessment and for leachate management.

5.2 Groundwater

Field groundwater chemical results for the May, November, and supplemental monitoring events are presented in **Tables H-1** to **H-3**, **Appendix H**. The 2021 laboratory chemical results are presented in **Tables H-4** and **H-5**, **Appendix H**. Historical data are provided for comparison. Laboratory reports of analysis and QA/QC documentation are included as **Table H-6**, **Appendix H**.

Groundwater quality monitoring occurred at the required monitoring locations in consideration of the groundwater monitoring schedule within the approved landfill EMP. An updated monitoring schedule is presented within **Table B-2**, **Appendix B**, which shows the monitoring wells required for sampling, the sampling frequency, and the parameters for analytical testing. Monitoring well designations and locations are presented on **Figure 2**. Monitoring well nest OW81 was installed in June 2019; with monitoring beginning in November 2019. Future monitoring well nests OW82 to OW84 will be installed during their respective stages of landfill construction as presented in Table 2 of the landfill EMP.

5.2.1 General Chemical Trends

To assess long-term chemical trends with time, time-concentration graphs for chloride, nitrate, and boron were prepared. Based on the background concentrations presented in **Table 6**, concentrations were considered constant where results varied by less than 15 milligrams per litre (mg/L) for chloride, 0.5 mg/L for nitrate, and 0.2 mg/L for boron. Concentration trends that varied by greater than these concentration ranges were interpreted as increasing, decreasing, or fluctuating.

Concentration trends for the time-concentration graphs on **Figures H-1** to **H-13**, **Appendix H**, are summarized in **Table 7**. Typically, the long-term concentration trends indicate constant or fluctuating concentrations with time, with some exceptions, which are discussed below. It is noted that the below observations do not represent immediate concerns, but as a matter of diligence will be evaluated over time to verify that a trend of concern does not develop or corrective measures, if required can be implemented.

Active Aquitard:

- At monitoring well OW16-6, the chloride concentrations have been generally stable after the short-term historical high concentration of 77 mg/L noted in May 2015, which subsequently decreased to an approximate average of 45 mg/L since then. It is noted that the chloride concentrations discussed are notably less than the trigger concentration of 106 mg/L.
- At monitoring well OW17-4, the chloride concentrations have been generally stable after the short-term historical high concentration of 71 mg/L noted in May 2016, which subsequently decreased to an approximate average of 30 mg/L since then. It is noted that the chloride concentrations discussed are notably less than the trigger concentration of 106 mg/L.

- At monitoring well OW54A-4, chloride concentrations have been increasing and fluctuating since late 2014. It is noted that the aforementioned chloride concentrations have shown an approximate stabilization at 26 mg/L since 2018 and are notably less than the trigger concentration of 106 mg/L.
- At monitoring well OW56-4, nitrate concentrations have generally been low and constant, however, isolated elevated concentrations have been detected over time; with the most recent event occurring in 2018. It is likely that the nitrate concentrations are a result of effects resulting from fertilizer application to the adjacent field. Nitrate concentrations have continued to be low and constant since 2018.
- At monitoring well OW67-4, the concentrations of chloride, nitrate, and boron have exhibited generally decreasing and fluctuating trends over time. Periodic increases in concentrations for each parameter have occurred over time, however, the overall trend for each parameter has been decreasing and fluctuating since monitoring began at OW67-4. It is noted that the concentrations of chloride, nitrate, and boron were below their respective trigger concentrations in 2021.
- At monitoring well OW69-5, boron concentrations continue to show a generally constant but slightly fluctuating trend with concentrations hovering around the shallow groundwater trigger concentration of 1.1 mg/L. At this time the boron concentrations at OW69-5 are not a concern as it is expected the more mobile parameter chloride would be observed first if the source of the boron were leachate. It is likely that, similar to observations for monitoring well OW58-14, that was decommissioned in 2016, bentonite seal is moving into the filter screen material of the monitoring well, and as such may require decommissioning and replacement in the future depending on chemical results.
- At monitoring well OW71A-5, the chloride concentrations are showing an increasing trend to a historical high of 29 mg/L in May 2021. However, the chloride concentrations are notably less than the Active Aquitard trigger concentration of 106 mg/L. It is noted that monitoring well OW71A-5 is not a compliance monitoring well for the Site but was added to supplement historically dry conditions at OW67-4. The recent chloride concentrations at OW71A-5 and OW67-4 are generally similar and the concentrations of the other PLIL parameters are not showing a similar trend.

Interstadial Silt and Sand:

- At monitoring well OW46-7 the concentration of boron has been observed to have been fluctuating since November 2019, which is similar to the short-term increase in 2015. However, the boron concentrations are notably less than the historical concentrations prior to 2003. The boron concentrations remain below the trigger concentration of 2.1 mg/L. The other PLIL parameters are not elevated or showing an increasing trend. It is likely that the observed periodic increases in boron concentrations is an effect from the bentonite seal moving into the filter pack of the monitoring well. At historical monitoring well OW58-14, the observed boron concentrations were proven to be related to bentonite seal impacts from the monitoring well seal moving into the sand filter pack. Consequently, per MECP approval, OW58-14 was decommissioned and replaced as OW58-17, which has shown constant and acceptable concentrations of boron since its installation in 2014.

- At monitoring well OW67-11, chloride concentrations showed an increasing trend between about 2009 and 2013 and have since showed a generally fluctuating trend. Nitrate concentrations have continued to fluctuate since monitoring began. Boron concentrations have fluctuated and decreased since about 2011. The chloride concentrations are notably below the trigger concentration of 116 mg/L for the interstadial silt and sand hydrostratigraphic unit.
- At recently installed monitoring well OW81-7, chloride concentrations are elevated as a result of effects road salting along Nauvoo Road, similar to as observed at OW80-6. Per MECP approval OW80-6 is no longer used as part of the trigger assessment. Based on groundwater flow towards the landfill in this hydrostratigraphic unit and similar chemical results at similarly place monitoring well OW80-6, a request will be issued to the MECP to remove chloride from the trigger assessment at OW81-7.

5.2.2 Organic Chemistry

The 2021 and historical organic chemical results are provided in **Table H-5**, **Appendix H**. Tested organic chemical constituents at each monitoring location were not detected at concentrations greater than their respective laboratory RDL during 2021. Exceptions were noted during the May 2021 monitoring event for dichloromethane at monitoring wells OW60-8 (13 micrograms per litre (μg/L)), OW80-6 (6.3 μg/L), and OW81-7 (9 μg/L). It is noted that the May 2021 detected concentrations of dichloromethane at OW80-6 and OW81-7 were less than 5 times their respective RDL (2.0 μg/L), whereas OW60-8 was only slightly greater than 5 times its RDL (2.0 μg/L). The detected concentrations of dichloromethane were also below their respective ODWS (50 μg/L). Additionally, dichloromethane historically has been intermittently detected at other groundwater monitoring wells with no established pattern. Dichloromethane concentrations will continue to be evaluated over time for possible trends of concern. Organic constituents have historically been infrequently detected at low concentrations at various groundwater monitoring wells. No corrective measures are required to address the noted 2021 organic chemical results.

5.2.3 Trigger Mechanisms

Groundwater compliance is assessed based on criteria calculated with respect to the Ministry of the Environment and Energy’s (MOEE) Guideline B-7 Reasonable Use Concept (Guideline B-7) and evaluated at the Site boundaries (Points of Compliance). Trigger concentrations are used to assess potential sources of concentration changes. The groundwater trigger concentrations are based on 80% of the calculated Guideline B-7 criteria for the reasonable use of groundwater (MOE, 1994), in accordance with Condition 14.2 of the ECA. When background groundwater quality satisfies the ODWS, background groundwater quality cannot be degraded by more than 25% of the ODWS for health-related parameters (e.g., nitrate) or by more than 50% of the ODWS for aesthetic-related parameters (e.g., sodium). Where background concentrations naturally exceed the ODWS, background groundwater quality becomes the criteria.

Historical background groundwater quality for local monitoring wells was used to calculate the trigger concentrations at the Site. As a screening process, trigger concentrations for the PLIL were calculated and assessed as provided in Table 3 of the landfill EMP.

5.2.3.1 Points of Compliance

An assessment of potential landfill leachate effects on groundwater quality is completed at the Site boundary to encompass the Expansion Site footprint and operations, as well as to consider potential effects of the Existing Site on groundwater quality. Monitoring wells are used at strategic locations around the Site to obtain an acceptable representation of groundwater quality moving beyond the Site boundary. These strategic locations are called the Points of Compliance and are assessed in accordance with Guideline B-7.

To account for the natural groundwater quality variability, the trigger concentrations consider the PLIL parameters discussed in **Section 5.1.1**. Exceedance of the trigger concentrations at the monitoring wells initiates the assessment process, which is detailed within Figure 3 of the landfill EMP. **Tables 8** to **10** provide the groundwater trigger concentration comparison and the 2021 chemical concentrations for the PLIL parameters.

Verification groundwater monitoring at the Site adheres to Condition 14.4 of the Waste ECA, which references the landfill EMP. Groundwater verification is required to be completed for two (2) subsequent events separated by six months with the first verification monitoring event taking place within one month of the initial sampling event.

5.2.3.2 Trigger Concentration Assessment

Primary Leachate Indicator List Comparison:

Based on the chemical analytical results for the 2021 monitoring events, the concentrations of the PLIL parameters at the groundwater monitoring wells, including the Points of Compliance, within the active aquitard, the interstadial silt and sand, as well as the interface aquifer satisfied the relevant trigger concentrations, with one (1) exception at OW81-7.

At monitoring well OW81-7, a concentration of chloride was detected that was greater than the respective trigger concentration during the spring monitoring event.

Shallow groundwater quality at the location of monitoring nests OW80 and OW81 are interpreted to be impacted by nearby road salting activities on Nauvoo Road. The MECP approved the discontinuation of utilizing the parameter chloride as a trigger mechanism OW80-3 and OW80-6 in 2010 following their installation in 2009. Given its similar construction and proximity to Nauvoo Road, the groundwater at interstadial silt and sand monitoring well OW81-7 is interpreted to also be influenced by road salting activities. As such, the chloride concentration of 220 mg/L in this monitoring well that was detected in May 2021 is not attributed to landfill leachate related impacts. This is also evidenced by the fact that the liquid level elevation noted at monitoring well OW81-7 was higher in elevation (234.90 mASL) than the secondary drainage layer (SDL) at pumping stations PS4 (229.59 mASL) and PS6 (226.63 mASL) in May 2021, indicating groundwater flow toward the landfill.

As noted in the 2021 Spring Groundwater Quality Monitoring Letter of Notification, prepared by RWDI and submitted to the MECP on June 17, 2021, a groundwater trigger concentration exceedance for chloride was identified within the newly installed (2019) groundwater monitoring well OW81-7. Based on this noted chloride groundwater trigger concentration exceedance, per the process outlined in the Environmental Monitoring

Program (Jagger Hims Limited, 2007) (EMP), a verification monitoring event for the primary and secondary leachate indicator list parameters was initiated on June 9, 2021. Verification monitoring confirmed the initial assessment findings that the groundwater quality at OW81-7 is being impacted by road salting effects along Nauvoo Road. A second verification sample was collected during the fall groundwater monitoring event in November 2021, which also confirmed the initial assessment findings.

Per Figure 3 of the EMP, the if the trigger concentration exceedance is confirmed, then an Alternate Source Evaluation is to be completed, which is outlined below along with the associated findings.

- **Confirm QAQC data** – Laboratory review of QAQC data confirms initial result reported.
- **Confirm chemical trends of primary and secondary leachate indicator list parameters** – Verification events were the second and third samples collected at this monitoring location. There is no identifiable chloride concentration trend of concern as the concentrations are fluctuating over time. The chloride concentration for initial spring routine sample was 220 mg/L (May 20, 2021) and the verification sample was 260 mg/L (June 9, 2021)
- **Inspect condition of monitoring well** – An assessment of the monitoring well denoted it is in good condition. Of note, OW81-7 is approximately 10 m east of Nauvoo Road at a lower elevation near the roadside ditch/toe of slope of screening berm.
- **Inspect Chain-of-Custody Form** – The field information form and chain of custody were reviewed, both of which are satisfactory and include all the required information.

Per Figure 3 of the EMP, a request will be submitted to the MECP to remove chloride as a PLIL parameter at monitoring location OW81-7.

Secondary Leachate Indicator List Assessment:

Based on the chemical analytical results for the 2021 monitoring events, the concentrations of the SLIL parameters at the groundwater monitoring wells, including the Points of Compliance, within the active aquitard, the interstadial silt and sand, as well as the interface aquifer satisfied the relevant trigger concentrations, with one (1) exception at OW60-8.

At monitoring well OW60-8, a concentration of dichloromethane was detected that was greater than the respective trigger concentration during the spring semi-annual monitoring event in May 2021. The detected dichloromethane concentration at monitoring well OW60-8 is not a concern as dichloromethane is a secondary leachate indicator list parameter, and the primary leachate indicator list parameters (chloride, boron, and ammonia) were not detected at elevated concentrations. Monitoring well OW60-8 is also distantly removed from the waste and groundwater quality that is closer to the waste was acceptable at monitoring well nests OW16 and OW69. Dichloromethane historically has been intermittently detected at other groundwater monitoring wells with no established pattern. The noted dichloromethane concentration is also less than its ODWS (0.050 mg/L). In consideration of the aforementioned discussion, the detected dichloromethane concentration at OW60-8 is not a concern and dichloromethane concentrations will continue to be evaluated over time for possible trends of concern.

With respect to the elevated lead concentration noted within the groundwater at monitoring well OW60-4 the past six (6) consecutive sampling events, the MECP approved to discontinue the use of lead as a SLIL parameter for groundwater at the location of OW60-4 per a letter dated October 2, 2020. Therefore, similar to chloride removal from the trigger concentration assessment process at a few monitoring wells, lead will be removed from the trigger concentration assessment at OW60-4 and the detected values will be documented for tracking purposes.

During the 2021 monitoring events, VOCs tested within the groundwater at the monitoring well locations satisfied their respective trigger concentrations.

In summary, based on the chemical analytical results for the 2021 monitoring events, the concentrations of the PLIL and SLIL parameters at the groundwater monitoring wells, including the Points of Compliance, within the active aquitard, the interstadial silt and sand, as well as the interface aquifer generally satisfied the relevant trigger concentrations.

5.3 Surface Water

Surface water chemical results are summarized in **Tables I-1** to **I-4**, **Appendix I**. Laboratory reports and documentation of quality control are provided in **Table I-5**, **Appendix I**.

5.3.1 General Chemical Trends

As discussed in **Section 5.1.1,** there are seven (7) surface water PLIL parameters that represent effective indicators of landfill leachate effects on surface water quality for the Site. To assess chemical trends with time, time-concentration graphs for chloride, un-ionized ammonia, boron, and zinc were prepared.

Data were analyzed for long-term trends, which considered the historical data. Concentrations were considered constant where results varied by less than 15 mg/L for chloride, 0.02 mg/L for un-ionized ammonia, 0.2 mg/L for boron, and 0.02 mg/L for zinc. Concentrations trends that varied by greater than these concentration ranges were interpreted as increasing, decreasing, or fluctuating. A minimum of three (3) to five (5) data points are required to determine a chemical trend with time. Concentration trends are summarized in **Table 11**. Time-concentration graphs are presented on **Figures I-1** to **I-4**, **Appendix I**.

Long-term concentration trends indicate both constant and fluctuating concentrations with time. Fluctuating concentrations generally showed a seasonal pattern for boron and chloride concentrations at stations SS1 and SP1. Chloride concentrations at SP2 and SP4 appear to have a fluctuating pattern in the long-term. Additionally, in the long-term, unionized ammonia concentrations continued a constant trend of being below their respective laboratory RDL and/or less than the respective PWQO (0.02 mg/L), with occasional historical exceedances at SS1, SP1, and SP2. Details pertaining to individual surface water monitoring events conducted in 2021 are provided in **Section 5.3.5**.

Concentrations of chloride, boron, unionized ammonia, and zinc in surface water within the Sedimentation Ponds and at compliance point SS1 were typically similar to each other, with some recent exceptions where elevated and fluctuating concentrations of boron have generally been noted at SS1 and SP2. The noted boron concentrations in 2021 at SS1 and SP2 are not a concern as they are not landfill leachate related but are a result of short-term effects from crushed glass (used as an aggregate bedding for landfill gas piping) being temporarily stored near the southeast corner of Sedimentation Pond 2, as well as the resurfacing and ditch regrading activities of Street C (from Street B to the southern high access ramp) from spring to fall of 2021.

5.3.2 Organic Chemistry

Organic chemical results are provided in **Table I-3**, **Appendix I**. Tested organic chemical constituents at the downstream compliance monitoring stations SS1, SP2, SP3, and SP4, as well as the internal compliance monitoring station SP1, were generally not detected at concentrations greater than their respective laboratory RDL. Two (2) exceptions were noted which occurred during the 2021 Q1 and Q2 monitoring periods.

Volatile organic compound (VOC) and semi-volatile organic compound (SVOC) concentrations for the Q1 and Q2 2021 surface water samples were generally below their respective laboratory reportable detection limits (RDLs).

- For the Q1 verification monitoring event on April 9, 2021, the SVOC phenol (0.63 µg/L) was detected at compliance surface water monitoring station SS1. The detected concentration of phenol was less than five (5) times the laboratory reportable detection limit (RDL) (0.5 µg/L). Additionally, phenol was detected at SS1 on one (1) prior occasion in 2008.
- For the Q2 monitoring event on June 3, 2021, the SVOC parameter phenol (3.7 µg/L) was detected at compliance surface water monitoring station SP4. The detected concentration of phenol was less than five (5) times the laboratory reportable detection limit (RDL) (2.0 µg/L). Additionally, phenol was detected at SP4 on one (1) prior occasion in 2013.

As there are not any concentration trends of concern occurring for phenol at SS1 and SP4, the above-noted SVOC concentrations are interpreted to be insignificant. The concentrations of phenol will continue to be evaluated to verify that concentration trends of concern are not occurring. There are no trigger concentrations for SVOC parameters.

5.3.3 Biomonitoring Program – Annual Spring Routine Event

The laboratory results for the biomonitoring monitoring events completed in 2021 are provided within **Table I-6, Appendix I**. The sample aliquots collected to assess biological conditions were assessed for surface water quality toxicity to *daphnia magna* and rainbow trout. The biological testing results showed that there was not a potential for detrimental effects to aquatic life in the discharge water.

5.3.4 Biomonitoring Program – Verification Events

Biomonitoring was also conducted in 2021 in accordance with conditions approved in the 2014 MECP Letter. Surface water verification sampling included the collection of a grab sample for analysis of the toxicity to rainbow trout and *daphnia magna* associated with verification surface water monitoring events for compliance monitoring discussed in **Section 2.4.4**.

During the verification sampling events, the verification biological results indicated that the surface water was of acceptable quality for continued discharge.

5.3.5 Trigger Concentration Assessment

Table 12 provides the Post 2020 trigger concentrations utilized to assess surface water quality during 2021, as well as the Post 2021 trigger concentrations that will be utilized in 2022 to assess the chemical quality of surface water.

A comparison of the 2021 surface water quality with the Post 2021 trigger concentrations is provided in **Table I–4**, **Appendix I**. Outlined below is a detailed discussion of the trigger concentration assessments for each surface water monitoring event, by calendar quarter for 2021. A quality comparison for background stations SS10 and SS16 is also provided where applicable.

First Quarter – January 1 to March 31, 2021

March 26, 2021:

Surface water samples were collected at compliance monitoring stations SS1, SP2, SP3, and SP4, as well as internal assessment monitoring location SP1 and background monitoring stations SS10 and SS16 on March 26, 2021, as part of the routine monitoring program following a precipitation event of greater than 10 mm in the 24-hour period from 8:00 AM March 25 to 8:00 AM March 26. The surface water quality at the required monitoring stations generally satisfied the relevant trigger concentrations, with two (2) exceptions.

- For the surface water sample collected at SS1, the concentrations of boron (0.7 mg/L), nickel (1.6 mg/L), total chromium (1.1 mg/L), and zinc (2.7 mg/L) were greater than their respective trigger concentrations (0.20 mg/L, 0.025 mg/L, 0.028 mg/L, and 0.060 mg/L, respectively).
- For the surface water sample collected at SP2, the concentration of boron (0.21 mg/L) exceeded the relevant trigger concentration (0.20 mg/L).

In consideration of the aforementioned, verification monitoring was required for SS1 and SP2, which details are discussed below for April 9, 2021.

The elevated boron, nickel, chromium, and zinc concentrations noted at the location of surface water monitoring station SS1 are interpreted to dominantly be as a result of erosional effects due to re-surfacing of the street directly west and south of Cell 1 and Cell 2 of the Expansion Site (Street C) that was on-going, which included the re-grading of the surface water drainage ditches along Street C. These construction works would result in temporary increased erosional effects as the work requires the removal of much of the established vegetation and straw-bale check dams that would normally provide erosion control in this area. As shown on **Figure 3**, the surface water drainage ditch on the south side of Street C leads directly to surface water monitoring station SS1. In addition to the Street C construction works, of the significant amount of precipitation (28.0 mm) that occurred prior to sampling, it is noted that the majority of the precipitation fell within 12 hours of sample collection and precipitation was also occurring during sample collection. The visually identifiable turbid waters for the streamflow at SS1 was confirmed as such through field measurements for turbidity. It is noted that the short-term temporary storage of crushed glass (used as an aggregate bedding for landfill gas piping) near the southwest corner of Sedimentation Pond 2 also likely contributed to the noted boron concentrations at this location.

The elevated total boron concentration at SP2 is also interpreted to be dominantly as a result of the aforementioned Street C reconstruction and lesser degree to the short-term storage of crushed glass based on the area of disturbed surface for reconstruction versus the area used for short-term storage of crushed glass. As shown on **Figure 3**, the surface water drainage ditch on the north side of Street C leads directly to Sedimentation Pond 2 and thus surface water monitoring station SP2.

Though elevated, the laboratory and field chemical constituent concentrations were noted to be within the historical range for surface water collected at monitoring stations SS1 and SP2, with the exception of nickel, chromium, and zinc at SS1. These historical high concentrations of nickel, chromium, and zinc at SS1 are interpreted to be a result of the non-routine Street C reconstruction activities. The elevated concentrations are expected to return to within historical ranges after the completion of the Street C reconstruction activities and associated remediation of the vegetation and re-installing straw-bale check dams in the surface water drainage ditches. Thus, it is interpreted that the elevated boron, nickel, chromium, and zinc concentrations at monitoring station SS1 and elevated boron concentration noted at monitoring station SP2 are not as a result of a landfill leachate effect, but dominantly from the Street C reconstruction activities and related soil erosional effects.

April 9, 2021:

To address the boron, nickel, total chromium, and zinc concentrations at SS1 and the boron concentration at SP2, a surface water verification monitoring event (including chemical and biological monitoring) was required. The verification monitoring event for surface water station SS1 indicated acceptable concentrations of nickel, total chromium, and zinc. The boron concentrations detected at SS1 and SP2 were again, greater than their respective trigger concentrations (0.20 mg/L). However, the verification monitoring event denoted acceptable biological results indicating that the surface water quality does not pose a detrimental effect to aquatic life and that the surface water was of acceptable quality for continued discharge and that no further verification monitoring was required (refer to Section 5.3.4).

Second Quarter – April 1 to June 30, 2021

June 3, 2021:

Surface water samples were collected at compliance monitoring stations SS1, SP3 and SP4, as part of the routine monitoring program following a precipitation event of greater than 10 mm in a 24-hour period from 8:00 AM June 2 to 8:00 AM June 3. Surface water samples were not collected at compliance monitoring station SP2 as well as internal assessment monitoring location SP1 and background monitoring stations SS10 and SS16 due to there not being flowing conditions to initiate sample collection. The surface water quality at the required monitoring stations satisfied the relevant trigger concentrations.

June 26, 2021:

A surface water sample was collected at compliance monitoring station SP2, as part of the routine monitoring program following a precipitation event of greater than 10 mm in a 24-hour period from 8:00 AM June 25 to 8:00 AM June 26. Surface water samples were not collected at internal assessment monitoring location SP1 and background monitoring stations SS10 and SS16 due to there not being flowing conditions to initiate sample collection. The surface water quality at the required monitoring stations generally satisfied the relevant trigger concentrations, with one (1) exception. For the surface water sample collected at SP2, the concentration of boron (0.31 mg/L) was greater than the trigger concentration (0.20 mg/L). As such verification monitoring was required for SP2 and is discussed below for July 9, 2021.

The elevated boron concertation noted at SP2 was dominantly a result of the aforementioned Street C reconstruction and lesser degree to the short-term storage of crushed glass based on the area of disturbed surface for reconstruction versus the area used for short-term storage of crushed glass.

July 9, 2021:

To address the boron concentration at SP2, a surface water verification monitoring event was completed for surface water station SP2. The verification monitoring event denoted acceptable chemical and biological results indicating that the surface water quality does not pose a detrimental effect to aquatic life and that the surface water was of acceptable quality for continued discharge and that no further verification monitoring was required (refer to **Section 5.3.4**).

Third Quarter – July 1 to September 30, 2021

July 9, 2021:

Surface water samples were collected at compliance monitoring stations SS10, SS1, SP3, and SP4, as well as internal assessment monitoring location SP1 on July 9, 2021, as part of the routine monitoring program following a precipitation event of greater than 10 mm in a 24-hour period from 8:00 AM July 8 to 8:00 AM July 9. A sample was not collected at surface water monitoring station SS16 due to there not being flowing conditions to initiate sample collection. A sample was also not collected at surface water monitoring station SP2 as a one (1) month period is required between quarterly samples at each monitoring location. As such, monitoring of SP2 remained required to be completed. The surface water quality at the required monitoring stations satisfied the relevant trigger concentrations with one (1) exception at compliance monitoring station SS1, where the concentration of boron (0.26 mg/L) was greater than its respective trigger concentration (0.20 mg/L). Therefore, verification monitoring was required for SS1 and as discussed below was completed on July 30, 2021.

Though elevated, the laboratory and field chemical constituent concentrations were noted to be within the historical range for surface water collected at monitoring station SS1. Thus, it is interpreted that the elevated boron concentration at monitoring station SS1 is attributable to the Street C reconstruction and lesser degree to the short-term storage of crushed glass based on the area of disturbed surface for reconstruction versus the area used for short-term storage of crushed glass.

July 30, 2021:

To address the boron concentration at SS1, a surface water verification monitoring event was completed for surface water station SS1, which again, indicated a boron concentration greater than its trigger concentration (0.20 mg/L). However, the verification monitoring event denoted acceptable biological results indicating that the surface water quality does not pose a detrimental effect to aquatic life and that the surface water was of acceptable quality for continued discharge and that no further verification monitoring was required (refer to **Section 5.3.4**).

In addition, on July 30, 2021, as part of the routine monitoring program following a precipitation event of greater than 10 mm in a 24-hour period from 8:00 AM July 29 to 8:00 AM July 30, a sample at surface water monitoring station SP2 was collected. A sample was again not collected at surface water monitoring station SS16 due to there not being flowing conditions to initiate sample collection. The surface water quality at monitoring station SP2 satisfied the relevant trigger concentrations.

Fourth Quarter – October 1 to December 31, 2021

October 4, 2021:

Surface water samples were collected at compliance monitoring stations SS1, SP2, SP3, and SP4, as well as internal assessment monitoring location SP1, on October 4, 2021, as part of the routine monitoring program following a precipitation event of greater than 10 mm in a 24-hour period from 8:00 AM October 3 to 8:00 AM October 4. Surface water samples were not collected at background monitoring stations SS10 and SS16 due to there not being flowing conditions to initiate sample collection. The surface water quality at the required monitoring stations generally satisfied the relevant trigger concentrations, with three (3) exceptions. For the surface water samples collected at SS1, SP2, and SP3, the concentrations of boron (0.26 mg/L, 0.22 mg/L, and 0.22mg/L), respectively, were greater than their respective trigger concentrations (0.20 mg/L). As such verification monitoring was required for SS1, SP2, and SP3 and is discussed below was completed on October 15, 2021.

Though elevated, the laboratory and field chemical constituent concentrations were noted to be within the historical range for surface water collected at monitoring stations SS1 and SP2. In addition, straw-bale check dams were re-installed upstream of monitoring stations SS1 and SP2 prior to this event. As a result, the surface water quality was observed to have generally improved indicating that once the vegetation for the surface water drainage ditches along Street C is re-established, water quality at these locations should return to the quality observed prior to the Street C reconstruction activities.

The elevated total boron concentration at SP3 is interpreted to be as a result of soil erosional effects related to earthworks to one of the inlet flow paths into the pond. Though elevated, the laboratory and field chemical constituent concentrations were noted to be within the historical range for surface water collected at monitoring station SP3. Thus, it is interpreted that the elevated boron concentration noted at monitoring station SP3 is not as a result of a landfill leachate effect, but rather from soil erosional effects.

October 15, 2021:

To address the boron parameter concentrations at SS1, SP2, and SP3 respectively, a surface water verification monitoring event was completed. The verification monitoring indicated an acceptable concentration of boron at SP3. The boron concentrations detected at SS1 and SP2 were again, greater than their respective trigger concentrations. However, the biological results for SS1, SP2, and SP3 indicated that the surface water quality does not pose a detrimental effect to aquatic life and that the surface water was of acceptable quality for continued discharge and that no further verification monitoring was required (refer to **Section 5.3.4**).

To address erosion effects related to Street C construction upstream of SS1 and SP2, and earthworks to one of the inlet flow paths into the SP3, efforts were completed throughout 2021 and will continue to be undertaken by WM to install additional straw-bale check dams at various locations within the surface water drainage network.

5.4 Landfill Gas Monitoring

Consistent with historical observations, methane gas was not detected within the gas probes in 2021. This observation indicates that landfill gas is not migrating in the subsurface beyond the waste footprint and is therefore, being effectively captured by the landfill gas collection system. Therefore, mitigation measures that would address a potential landfill gas migration in the shallow subsurface beyond the waste footprint are not required. The 2021 landfill gas monitoring results are presented in **Table J-1**, **Appendix J**.

6 SITE OPERATIONS SUPPLEMENTAL TESTING & MONITORING

6.1 Construction Activities

6.1.1 Existing Site

On June 25, 2021, a landfill cap repair was completed at the northeast corner of the Existing Site to address Total Hydrocarbon (THC) survey findings. This repair was completed with a geosynthetic bentonite composite layer placed approximately 0.3 m below final cap surface that was then hydrated, and subsequently the clayey soil cap material was replaced and re-compacted. Validation of the ground level THC (as methane) level was completed for the repair location on August 6, 2021. The ground level THC concentration was less than 500 ppm indicating that the repairs were successful. Refer to **Volume 4** of the 2021 Annual Report for details regarding the THC Survey monitoring.

6.1.2 Expansion Site

The Site was formally approved for expansion on August 5, 2008. During 2021, waste disposal occurred in Cell 4A, Cell 4B and Cell 4C of the Expansion Site. Waste disposal in Cell 4C commenced on August 10, 2021, as the landfill liner system was approved to accept waste. Cell 6A pre-excavation activities related to the future construction of the Cell 6A landfill liner system of the Expansion Site commenced in 2021 and are ongoing into 2022. Upon completion of the landfill liner system of Cell 6A, waste disposal is scheduled to also occur in Cell 6A in 2022.

Interim cover was placed on the southern, eastern and western side slopes of Cell 1, the eastern and western side sloped of Cell 2, and the northern and western side slopes of Cell 4A during 2021.

Additionally, the installation of the horizontal landfill gas collection system conveyance piping was completed in Cell 4A in January 2021.

6.1.3 Groundwater Monitoring Wells

In 2021, there were no new groundwater monitoring wells or gas probes installed at the Site. There were also no groundwater monitoring wells or gas probes decommissioned and/or replaced in 2021.

The 2021 monitoring well and gas probe installation/decommissioning status summary is provided in **Appendix M**.

6.1.4 On-Site Surface Water Management

Upon completion of cell construction and filling in the Expansion Site, surface water runoff will be managed through Sedimentation Ponds 1, 2, 3, and 4. Surface water runoff originating from areas south of the Existing Site flows toward: 1) Kersey Drain (Brown Creek) to the east; and 2) to the west toward the Van Kessel Drain and enters a municipal drainage tile at a catch basin (SS1), which is situated 60 m east of the western Site boundary. The municipal drainage tile subsequently drains into the discharge ditch for SP2, which ultimately flows to the Gilliand-Geerts Drain 'A', beneath Lambton Road 79.

During the 2021 operating period, maintenance to the on-Site surface water flow system was required, which is detailed in **Appendix R**.

Only water that satisfied the Criteria for On-Site Surface Water Management (D&O, 2008) was used on-Site for dust control and road cleaning purposes in 2021.

6.1.5 MECP Site Inspection Reports

A MECP Inspector provided inspection reports on a quarterly basis, at a minimum in 2021. The MECP inspection frequency was completed, at a minimum, in accordance with the Waste ECA, as well as in consideration of the MECP's policy regarding field inspections during the COVID Pandemic. The Site inspections were conducted to assess Site operation compliance with the applicable approval documentation. The 2021 quarterly MECP Inspection Reports, received by WM to date, are presented in **Appendix N**. Where action items were required, they were addressed by WM.

6.1.6 Contaminated Soil

Contaminated soil was received at the Site throughout 2021 and therefore, contaminated soil sampling was completed for each quarterly monitoring period.

Per Conditions 6.53 to 6.61 of the Waste ECA dated December 19, 2020, quarterly testing results for contaminated soil used as daily and/or intermediate cover, where applicable, are included in **Appendix O**. Confirmatory testing of the contaminated soil satisfied the TCLP criteria within Schedule IV of Ontario Regulation 347. Therefore, the contaminated soil was acceptable for disposal in the landfill. Contaminated soil that meets the 10% TCLP criteria can be disposed within the monofill cells of the Existing Site (Cell 12 has available capacity). Contaminated soil was not disposed within the Existing Site monofill cells in 2021.

6.1.7 Automobile Shredder Residue

ASR was received and used for daily cover at the Site in 2021 and was therefore, tested per the Waste ECA requirements. The ASR laboratory results satisfied the TCLP criteria within Schedule IV of Ontario Regulation 347 and was therefore acceptable for use as daily cover in 2021. The spring and fall laboratory test results are contained in **Appendix K**.

It is noted that on November 15, 2021, WM received its last load of ASR material onsite as they agreed to temporarily discontinue its use until they can evaluate other options.

7 AMBIENT AIR QUALITY MONITORING PLAN

7.1 Total Suspended Particulate (TSP) Monitoring

Monitoring of Total Suspended Particulate (TSP) for the 2021 monitoring period was completed as required. Findings of the TSP monitoring program is detailed within **Volume 4** of the 2021 Annual Report.

7.2 Volatile Organic Compounds (VOCs) Monitoring

The ambient air volatile organic compound (VOC) monitoring is to be completed during the summer period, which begins on June 21 and ends September 21 of every year. Findings of the VOC monitoring program, completed during the 2021 monitoring period, are detailed within **Volume 4** of the 2021 Annual Report.

7.3 Total Hydrocarbon (THC) Landfill Cap Surveys

The landfill final cap surface of the Existing Site is surveyed for Total Hydrocarbon (THC) vapour releases as part of the Ambient Air Quality Monitoring Plan twice annually in the spring and the fall. The landfill final cap surface of the Existing Site was surveyed by RWDI in the spring and fall of 2021 for Total Hydrocarbon (THC) vapour releases, as required. The THC Landfill Cap survey and associated details are presented within **Volume 4** of the 2021 Annual Report.

8 NOISE MONITORING PLAN

The Environmental Noise Monitoring Program (Aercoustics, 2007) was implemented in 2009. The survey is required under Condition 13.10 of the Waste ECA. The Noise Monitoring Plan (NMP) report as it relates to the 2021 monitoring period is presented within **Volume 5** of the 2021 Annual Report.

9 BEST MANAGEMENT PRACTICES

9.1 Dust

The Best Management Practices Plan (Dust) for the Twin Creeks Environmental Centre was utilized by WM for its operations during the 2021 monitoring period. The Dust Inspection and Dispatch Log for each event as filled out by WM are maintained on file.

Complaints related to dust were not received by WM during the 2021 monitoring period.

Details of the Ambient Air Quality Monitoring Program for the Site are presented within **Volume 4** of the 2021 Annual Report.

9.2 Litter

WM operated the Site in accordance with its Best Management Practices Plan (Litter) during the 2021 monitoring period. The Litter Inspection and Dispatch Logs for each event, as filled out by WM, are maintained on file.

Details related to litter complaints received and the associated response actions(s) by WM during the 2021 monitoring period are outlined in **Section 10**.

9.3 Odour

Odour control is achieved through the Best Management Practices Plan (Odour). The Odour Control Plan was implemented during the 2021 monitoring period. Additionally, an odour suppression system is available to manage refuse odours during normal operating procedures as identified by WM.

Details related to odour complaints received during the 2021 monitoring period are outlined in **Section 10**.

Further explanation of odour as it relates to the Ambient Air Quality Monitoring Program for the Site is presented within **Volume 4** of the 2021 Annual Report.

10 COMPLAINTS

Where complaints were received during the 2021 monitoring period, Waste Management completed the required steps in response, including notification to the MECP and other stakeholders as required. This included logging the complaint, completing the appropriate investigation into the potential source of the complaint, any required corrective action or mitigation and complainant follow up, as well as filing a formal complaint log (**Complaint Log**). The **Complaint Logs**, which detail the above-noted steps are summarized in **Table P-1, Appendix P**, as well as themselves included in **Appendix P**.

WM received a total of 36 complaints during the 2021 operating period (1 general, 9 litter, 26 odour). Of the complaints received, they represented a total of 29 complaint driven events which occurred on 26 separate days during 2021.

Noise:

No complaints related to noise were received by WM during 2021.

General/Litter:

WM received a total of ten (10) general/litter complaints (1 front gates, 9 litter) during the 2021 operating period.

For the complaint about the front gates, it is noted that authorized personnel were onsite at the time the gates were observed to be open.

For the noted litter complaints, WM either continued with ongoing road sweeping or reallocated personnel to clean up the litter that same day. It is noted that the majority of the litter complaints were related to ASR material being tracked out of the Site. WM implemented a number of abatement strategies to manage ASR material track out as outlined in the Automobile Shredder Residue Abatement Plan dated, August 4, 2021. On November 15, 2021, WM received its last load of ASR material onsite as they agreed to temporarily discontinue its use until they can evaluate other options.

Odour:

Of the 29 complaint driven events, 19 of the events were related to odour. Of these 19 odour events, 15 of the events were documented from 10 discrete physical locations such as a residence or commercial building. The other 4 events represent transient (drive-by) occurrences in which the complainant observed an odour while in transit along a road near to the Site. Transient (drive-by) complaints of this nature along roads are identified as not having a negative impact to sensitive receptor locations such as residential or commercial properties near the Site. A breakdown of the number of events where odour complaints were documented from a physical location and were received by WM on a quarterly basis during the 2021 operating period can be seen below.

Number of Odour Events per Quarter in 2021			
Q1	Q2	Q3	Q4
2	0	10	3

As presented in the summary above, the greatest number of events where odour complaints were received by WM in 2021 was during the third quarter operating period.

WM has reviewed the odour related complaints that were received during the 2021 operating period to assess for any trends and to identify corrective actions, as required. Of the odours that were identified as being related to Site operations, it was determined that the majority of the odours that were associated with the Site were related to temporary power outages to the landfill gas (LFG) collection system or a LFG well observed to be releasing LFG to the atmosphere. In response to each power outage, WM would promptly focus their efforts to regain power to the LFG collection system. In response to each instance where a LFG well observed to be releasing LFG to the atmosphere, WM would promptly have the LFG well repaired.

As shown in the above complaint summary for 2021, there was an increase in events where odour complaints were received in Q3 and Q4 compared to Q1 and Q2 of 2021. The portion of the LFG collection system that was extended beginning near the end of 2020 and was completed in January 2021, began to collect gas from Cell 4A in December 2020 which is evidenced by the low number of events where complaints were received in Q1 and Q2 of 2021. The increase in events where odour complaints were received in Q3 and Q4, may in part, be a result of the progression of landfilling of waste in Cell 4B and Cell 4C, which pending sufficient waste height achievement, have yet to have the early vertical gas collection wells fully connected to the landfill gas collection system.

It is expected that the number of events in which odour complaints are received will continue to decrease overall as upgrades and expansion of the LFG collection system, along with additional interim cover placement continue into the 2022 operating period.

11 WATER TAKINGS

Reporting of 2021 water takings is required to be completed for Sedimentation Ponds 1 to 4 and the SDL per Ontario Regulation 387/04: Water Taking and Transfer (O. Reg. 387/04), as well as Amended PTTW No. 4430-8PLMKV, dated January 17, 2012, and PTTW No. 4682-BLJRYJ, dated November 8, 2021. A report indicating water takings during 2021 from the Sedimentation Ponds and the SDL will be submitted to the MECP by March 31, 2022, in accordance with O. Reg. 387/04, and is provided under separate cover, and/or submitted using the online Water Taking Reporting System (WTRS).

In 2021, water was taken from Sedimentation Ponds 2 and 3, as well as pumping stations PS4 and PS6. Water that was taken from the aforementioned ponds was used mainly for dust control for landfill operations. Water was also taken from the aforementioned pumping stations for use as recompacted clayey liner soil conditioning. During 2021, the water taking activities were in compliance with the PTTW limits for the Site, as summarized below.

Pond 2		
PTTW Regulatory Components	**PTTW Value Limits**	**2021 Water Taking Values**
Max. Taken per Minute (L/min)	2,400	2,132
Max. Hours Taken per Day	10	1.86
Max. Litres Taken Per Day	246,700	238,000
Max. Days Taken per Year	105	46
Total Litres Taken in 2021	N/A	7,490,400
Pond 3		
PTTW Regulatory Components	**PTTW Value Limits**	**2021 Water Taking Values**
Max. Taken per Minute (L/min)	2,400	2,054
Max. Hours Taken per Day	10	0.86
Max. Litres Taken Per Day	110,100	105,994
Max. Days Taken per Year	105	62
Total Litres Taken in 2021	N/A	3,902,068
PS4		
PTTW Regulatory Components	**PTTW Value Limits**	**2021 Water Taking Values**
Max. Taken per Minute (L/min)	1,325	234
Max. Hours Taken per Day	24	14.5
Max. Litres Taken Per Day	1,907,640	203,580
Max. Days Taken per Year	365	10
Total Litres Taken in 2021	N/A	840,996
PS6		
PTTW Regulatory Components	**PTTW Value Limits**	**2021 Water Taking Values**
Max. Taken per Minute (L/min)	1,325	234
Max. Hours Taken per Day	24	17.3
Max. Litres Taken Per Day	1,907,640	242,892
Max. Days Taken per Year	365	14
Total Litres Taken in 2021	N/A	1,382,940

12 WASTE DISPOSAL INFORMATION

Waste disposal area Cell 4C was constructed in 2021. For reference, design drawings for the Existing and Expansion Sites are presented in **Appendix L**. Details of the 2021 landfill operations are summarized in the relevant sections of **Appendix Q**. **Appendix R** provides the 2021 performance report for the sewage works.

13 EAA MONITORING & ANNUAL REPORTING

13.1 Mitigation Measures

No mitigation measures related to hydrogeology were required beyond the mitigation built into the Site design.

13.2 Monitoring Measures

Monitoring requirements at the landfill evolved in accordance with the EMP as construction progressed in 2021. No changes occurred in 2021 from the previous monitoring period.

13.3 Contingency Measures

Based on the groundwater and surface water quality results presented in **Sections 5.2** and **5.3**, the detailed development and implementation of contingency plans is not required.

13.4 Annual Reporting

Reporting requirements for the Site are addressed and detailed in **Appendix Q**, per the Waste and Sewage ECAs, as well as the amended PTTW.

14 2022 MONITORING PROGRAM

The 2022 Monitoring Program reflects the EMP approved for the Site and incorporates the requirements of the Waste ECA, Sewage ECA, Air ECA, as well as the PTTW. Details of the proposed 2022 Monitoring Program are presented in **Table 13**.

15 CONCLUSIONS

Based on the findings presented in this report, the following conclusions are provided.

- Overall, generally leachate elevations increased from November 2020 into May 2021 and then decreased from May 2021 to November 2021. This generalized pattern was expected for 2021 with the short-term increase of leachate levels in May 2021 resulting from utilizing the leachate volumes within the waste for irrigation application to the Poplar System beginning in May. From an environmental stewardship perspective, the leachate generated from within the waste mound of the Existing Site was determined to be of more suitable use as irrigation liquid during the growing season as opposed to dedicating efforts for off-Site disposal and treatment between late winter and spring. This storage practice began in 2019 and will continue into the future such that there is sufficient weak-strength leachate volume for irrigation purposes during the growing season. There was a short-term increase in leachate elevation noted at a number of the leachate maintenance holes from May 2021 to November 2021 which was a result of a greater number of precipitation events during the growing season of 2021 compared to 2019 and 2020, which would both reduce the leachate extracted for application to the Poplar System and increase the amount of leachate generated as a result of rain infiltration.

- Environmental compliance at the Site as it relates to the Existing Site relies on groundwater and surface water quality monitoring, which once again verified at the Site in 2021. As an additional guidance tool toward managing leachate volumes in the waste cells a hydraulic gradient assessment of leachate compared to nearby shallow groundwater is utilized to further protect local water resources. May 2021 leachate levels were reflective of leachate storage for utilization onto the Poplar. However, by November 2021, the leachate elevation data within the waste of the Existing Site indicated that groundwater flow was inward toward the waste at Cells 3, 5, 7, 8, 9, 10, 11, 12, as well as the southern and eastern portions of the South Cell.
- In 2021, leachate elevations within the eastern portion of Cell 3S (at MH3SA and MH3SB), Cell 6, Cell 8, Cell 11, the western portion of the South Cell (at OW22A-10 and OW53-10), and the West Cell (Sump) were higher in elevation compared to groundwater during the May monitoring event. Leachate elevations within Cell3S (at MH3SA, MH3SB and at MH3SD), Cell 4 (at MH4A and MH4B), Cell 6, the western portion of the South Cell (at OW53-10), and the West Cell (Sump) were higher in elevation compared to groundwater during the November monitoring event. However, acceptable water quality was demonstrated at the Site during 2021 and therefore, the elevated leachate elevations that showed the potential for outward migration were not negatively affecting the water resources at the Site. Also, leachate seeps were not observed along the waste side slopes of the Existing Site in 2021. Continued leachate management of the leachate via automated pumping is expected to continue to reduce the leachate mound in these cells overtime.
- During November 2021, leachate elevation in the West Cell (Sump) was greater than the surrounding natural ground surface elevation. However, the leachate elevation in the West Cell (Sump) was lowered by approximately 2.48 m between its historical high in May 2019 through leachate transfer to the Expansion Site Leachate Equalization Tank. The noted leachate elevation within the Sump does not represent a concern based on acceptable surface water quality at compliance stations and no visible leachate seeps on the sideslope. Continued leachate extraction from the West Cell over time is expected to further reduce the potential for outward leachate seepage in this area.
- For the Existing Site in May 2021, the total theoretical leachate volume stored above the local groundwater table was approximately 166,024 m^3 and within the waste was approximately 400,084 m^3, which both represent a slight increase from May 2020 and a significant decrease from May 2019. For the Existing Site in November 2021, the total theoretical leachate volume stored above the local groundwater table was approximately 209,083 m^3 and within the waste was approximately 421,707 m^3, which both represent an increase from November 2020 and a slight decrease from November 2018. Over the long-term, leachate volumes within cells of the Existing Site are expected to further decrease as more leachate is extracted for the operation of the expanded Poplar System and for off-Site disposal. It is noted that these theoretical values are not representative of actual conditions as many maintenance holes are pumped to a near-dry state during the growing season and a fraction of the calculated theoretical leachate volume available in a given cell is actually able to be extracted for irrigation purposes. The use of theoretical leachate volume calculations is to track patterns of leachate volume from year to year and does not represent a compliance assessment.
- The trigger mechanism for implementation of groundwater contingency measures for the Expansion Site is the loss of hydraulic containment of the landfill waste footprint. During 2021, the leachate target level for each pumping station of the Expansion Site as noted in Condition 14.1 of the Waste ECA was satisfied.

- The operation of the primary leachate collection system is designed to maintain a liquid level of no more than 300 mm (or 0.30 m) above the primary clay liner (bottom of the landfill). Occasionally, after major storm events when a part of the active waste disposal area within the Expansion Site is not final capped, a large percentage of precipitation will move to the cell floor and the leachate pumping rates for PS1, PS3, and PS5 would be less than the incoming volume of liquid. There were no periods of time during 2021, as outlined in **Appendix Q** where there were occurrences of this nature, which are understood to normally occur and are described in the D&O Report.
- Between January 1 and December 31, 2021, a total of 44,284.83 m^3 of leachate was removed and transported off-Site for treatment and disposal at the Chatham Water Pollution Control Plant or Canflow Environmental Services, while 6,403.03 m^3 was irrigated onto the Poplar system during the 2021 growing season.
- Of the 50,687.86 m^3 of leachate managed for treatment during 2021, the approximate breakdown of leachate source location between the Existing Site and the Expansion Site is 23% (11,479.81 m^3) and 77% (39,208.05 m^3), respectively. This breakdown is based on the leachate source distribution noted for the 2021 monitoring period, which incorporates the separate approximate volumes of leachate extracted from the Existing Site (41% of area) and Expansion Site (59% of area) for either off-site or on-site treatment as discussed above.
- Considering a north-south groundwater drainage divide at the Site, shallow groundwater movement within the active aquitard was in an easterly and westerly direction away from the divide with local variations as a result of surficial feature influences, such as ditches, waste cells, excavations, ponds, berms, and the leachate management systems. Groundwater movement within the interstadial silt and sand also typically moves toward the east and west, away from the drainage divide. Influences from the excavation of the Expansion Site as well as landfilling of waste in the Expansion Site were noted to the south (at monitoring well OW79) where the groundwater in the active aquitard, as well as the interstadial silt and sand was induced toward the north. The groundwater pressures within the interface aquifer have also appeared to be affected by the removal of the overlying soil mass, whereby pressures were observed to be slightly decreasing recent years, which are expected to return to pre-existing conditions as the soil mass is replaced with waste mass. As expected, monitoring wells OW39A-26, OW79-26, OW80-27, and OW81-27 are showing a fluctuating and increasing trend since about 2018 as a significant waste mass has been progressively landfilled into the southern half of the Expansion Site. Groundwater movement within the interface aquifer is in a southwesterly direction.
- The groundwater monitoring results for the active aquitard, the interstadial silt and sand, as well as the interface aquifer satisfied the relevant PLIL and SLIL trigger concentrations. One (1) exception occurred for the PLIL parameter chloride at OW81-7, which as discussed in **Section 5.2.3.2** is not landfill related. Overall, groundwater quality did not show an unacceptable landfill leachate or operations effect in 2021.
- At monitoring wells OW69-5 (Active Aquitard) and OW46-7 (Interstadial Silt and Sand), the concentrations of boron show infrequent spikes, but concentrations are less than the respective trigger concentration at each location. At this time the boron concentrations are not a concern as it is expected the more mobile parameter chloride would be observed first if the source of the boron were leachate. It is likely that, similar to observations for monitoring well OW58-14, the bentonite seal for these locations is likely moving into the filter screen material of the monitoring well, and as such may require decommissioning and replacement in the future depending on chemical results.

- The routine quarterly surface water monitoring results satisfied the relevant trigger concentrations, with seven (7) exceptions. The exceptions are discussed in detail **in Section 5.3.5**, with verification results indicating acceptable chemical and biological results and no further verification monitoring was required. Overall, surface water quality did not show an unacceptable landfill leachate or operations effect in 2021.
- The annual spring biomonitoring showed that there was not a potential for detrimental effects to aquatic life in the discharge water and was acceptable for continued discharge.
- Water takings at the Site from the Sedimentation Ponds were used as a dust suppressant related to landfill operations. The water taking activities in 2021 satisfied the requirements of the Site's PTTW. Documentation will be submitted to the MECP, as required by the PTTW, under separate cover.
- No methane gas was detected within the gas probes in 2021. Therefore, mitigation measures that would address a potential landfill gas migration in the shallow subsurface beyond the waste footprint are not required.
- WM received a total of 36 complaints during the 2021 operating period (1 general, 9 litter, and 26 odour). Of the complaints received, they represented a total of 29 complaint driven events which occurred on 26 separate days during 2021. Of the 29 complaint driven events, 19 of the events were related to odour. Of these 19 odour events, 15 of the events were documented from 10 discrete physical locations such as a residence or commercial building. The other 4 events represent transient (drive-by) occurrences in which the complainant observed an odour while in transit along a road near to the Site. \

16 CLOSURE

We trust that this 2021 Fourth Quarter and Annual Monitoring Report for the Twin Creeks Environmental Centre is satisfactory. Should there be any questions or comments, please contact us.

Yours very truly,

RWDI AIR Inc.

Jeff Cleland, B.Eng., EIT	Brent J. Langille, B.Sc., P.Geo.
Scientist | Geoscience	Technical Director | Principal

JCL/BJL/kta

Attach.

TABLES

Table 1
Monitoring Schedule - 2021
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Task	Monitoring Locations	Monitoring Dates	Notes
First Quarter Monitoring Period (January 1 to March 31, 2021)			
Precipitation Event Surface Water Monitoring/Sampling	SS1, SS10, SS16, SS19 (new), SP1, SP2, SP3, SP4	March 26, 2021 - Routine monitoring for March 25, 2021 precipitation event.	SS19 not monitored since the compost facility is not yet constructed.
	SS1, SP2	April 9, 2021 - Verification monitoring event based on the results for the March 26, 2021 routine monitoring event.	
Biomonitoring	SS1, SP2	April 9, 2021 - Verification monitoring event based on the results for the March 26, 2021 routine monitoring event.	
Secondary Drainage Layer (SDL) Liquid Levels	PS2, PS4, PS6, and PS8(new)		PS8 was not monitored as it is not yet constructed.
Leachate Sampling	Equalization Tank	Quarterly, and Semi-Annually in May and November. A quarterly sample was collected on January 12, 2021.	
Gas Monitoring	GP1A, GP2, GP3, GP4, GP5, GP6, GP7, GP8, GP9 (new), GP10 (new)	Monthly gas monitoring from November to April and in July. Perimeter gas probes were monitored on January 7, February 4, and March 5, 2021.	Gas probes GP9, and GP10 are not yet installed.
Poplar System Monitoring Program			
Precipitation Event Surface Water Monitoring/Sampling	SS14A, SS14B, and SS15A	March 26, 2021 - Routine monitoring for March 25, 2021, precipitation event.	
Ambient Air Quality Monitoring Program			
Total Suspended Particulate - Dust	Stations West, Northeast, and Southeast	Every sixth day - NAPS Schedule (October 1 to May 31) Every third day - NAPS Schedule (June 1 to September 30)	
Noise Monitoring System			
Noise monitoring	Stations - M1, M2, M3, and M4	Ongoing - Quarterly Reporting	
Operational Monitoring			
Contaminated Soil	Landfill Daily Cover/Disposed Material	Quarterly, if utilized: March 16, 2021	
Automobile Shredder Residue (ASR)	Landfill Daily Cover/Disposed Material	Semi-Annually (Spring and Fall), if utilized.	Monitoring not required as ASR was not utilized during the Q1 monitoring period.
Second Quarter Monitoring Period (April 1 to June 30, 2021)			
Precipitation Event Surface Water Monitoring/Sampling	SS1, SS10, SS16, SS19 (new), SP1, SP2, SP3, SP4	June 3, 2021 - Routine monitoring for June 2, 2021 precipitation event.	SS19 not monitored since the compost facility is not yet constructed. SS10, SS16, SP1 and SP2 not monitored due to no flow conditions.
	SS10, SS16, SS19 (new), SP1, SP2	June 26, 2021 - Routine monitoring for June 25, 2021 precipitation event.	SS19 not monitored since the compost facility is not yet constructed. SS10, SS16 and SP1 not monitored due to no flow conditions.
	SP2	July 9, 2021 - Verification monitoring event based on the results for the June 26, 2021 routine monitoring event.	
Biomonitoring	SS1, SS10, SS16, SS19 (new), SP1, SP2, SP3, SP4	June 3, 2021 - Routine monitoring for June 2, 2021 precipitation event.	SS19 not monitored since the compost facility is not yet constructed. SS10, SS16, SP1 and SP2 not monitored due to no flow conditions.
	SS10, SS16, SS19 (new), SP1, SP2	June 26, 2021 - Routine monitoring for June 25, 2021 precipitation event.	SS19 not monitored since the compost facility is not yet constructed. SS10, SS16, and SP1 not monitored due to no flow conditions.
	SP2	July 9, 2021 - Verification monitoring event based on the results for the June 26, 2021 routine monitoring event.	
Leachate Liquid Level Measurements	PS1, PS3, PS5, PS7(new), MH3S, MH4, MH5, MH6, MH7, MH8, MH9, MH10, MH11, MH12, MH16, MH17, MH18, OW22A-10, OW51A-15, OW53-10, Sump	Semi-annually in May and November: May 17, 2021. Daily during operation for PS1, PS3, and PS5.	PS7 was not monitored as it is not yet constructed.
Leachate Sampling	PS1, PS3, PS5, PS7(new), South Fill Area (MH18), West Central Fill Area (Sump), Central Fill Area (Composite of MH3S, MH4, MH5, MH6, MH7, MH8, MH9, MH10, MH11, MH12)	Annually in May: May 18 and 19, 2021.	PS7 was not monitored as it is not yet constructed.
	Equalization Tank	Semi-Annually sampled in May and November: May 19, 2021.	
Secondary Drainage Layer (SDL) Liquid Levels	PS2, PS4, PS6, and PS8(new)	Monthly - April 7, May 5, June 16, 2021 - PS2, PS4, and PS6	PS8 was not monitored as it is not yet constructed.
Groundwater Liquid Level Measurements	ACTIVE AQUITARD OW16-6, OW17-4, OW40B-4r, OW54A-4, OW56-4, OW57-4, OW58-6, OW59-6, OW60-4, OW67-4, OW68-5, OW69-5, OW70B-5, OW71A-5*, OW72-6, OW73-6, OW79-5, OW80-3, OW81-5, OW82(new), OW83(new), OW84(new) INTERSTADIAL SILT AND SAND OW16-7, OW40A-7, OW46-7, OW47-6, OW54-10, OW57-15, OW58-17, OW60-8, OW67-11, OW72-10, OW73-9, OW79-7, OW80-6, OW81-7, OW82(new), OW83(new), OW84(new) INTERFACE AQUIFER OW17-30, OW19-29, OW39-26, OW40A-28, OW49-29, OW60-25, OW79-26, OW80-27,	Semi-annually in May and November: May 17, 2021.	Monitoring well nests OW82, OW83, and OW84 are not yet constructed.
Piezometer Liquid Level Measurements	PS1, PS2, PS3	Semi-annually in May and November: May 17, 2021.	
Groundwater Sampling	ACTIVE AQUITARD OW16-6, OW17-4, OW40B-4r, OW54A-4, OW56-4, OW57-4, OW58-6, OW59-6, OW60-4, OW67-4, OW68-5, OW69-5, OW70B-5, OW71A-5*, OW72-6, OW73-6, OW79-5, OW80-3, OW81-5, OW82(new), OW83(new), OW84(new) INTERSTADIAL SILT AND SAND OW16-7, OW40A-7, OW46-7, OW47-6, OW54-10, OW57-15, OW58-14, OW60-8, OW67-11, OW72-10, OW73-9, OW79-7, OW80-6, OW81-7, OW82(new), OW83(new), OW84(new) INTERFACE AQUIFER OW19-29, OW39-26, OW49-29, OW79-26, OW80-27, OW81-27, OW82(new), OW83(new), OW84(new), Cemetery Well	Semi-annually in May and November: May 18, 19, 20 and 21, 2021. June 9, 2021 - OW81-7 verification monitoring	Monitoring well nests OW82, OW83, and OW84 are not yet constructed.
Gas Monitoring	GP1A, GP2, GP3, GP4, GP5, GP6, GP7, GP8, GP9 (new), GP10 (new)	Monthly gas monitoring from November to April and in July. Perimeter gas probes were monitored on April 6, 2021.	Gas probes GP9, and GP10 are not yet installed. .
Poplar System Monitoring Program			
Precipitation Event Surface Water Monitoring/Sampling	SS14A, SS14B, and SS15A	June 3, 2021 - Routine monitoring for June 2, 2021 precipitation event.	SS14A and SS15A not sampled due to no flow conditions.
Ambient Air Quality Monitoring Program			
Total Suspended Particulate - Dust	Stations West, Northeast, and Southeast	Every sixth day - NAPS Schedule (October 1 to May 31) Every third day - NAPS Schedule (June 1 to September 30)	
Total Hydrocarbon Landfill Cap Survey	Final Capped Areas	Between the Spring and Fall: June 1, 2021	
Noise Monitoring Program			
Noise Monitoring	Stations - M1, M2, M3, and M4	Ongoing - Quarterly Reporting	
Operational Monitoring			
Contaminated Soil	Landfill Daily Cover/Disposed Material	Quarterly, if utilized: May 5, 2021.	
Automobile Shredder Residue	Landfill Daily Cover/Disposed Material	Semi-Annually (Spring and Fall), if utilized: April 6, 2021.	
Third Quarter Monitoring Period (July 1 to September 30, 2021)			
Compliance Monitoring System			
Precipitation Event Surface Water Monitoring/Sampling	SS1, SS10, SS16, SS19(new), SP1, SP2, SP3, SP4	July 9, 2021 - Routine monitoring for July 8, 2021 precipitation event.	SS19 not monitored since the compost facility is not yet constructed. SS16 not monitored due to no flow conditions. SP2 not monitored as a 1 month period is required between quarterly samples at each monitoring location.
	SP2	July 30, 2021 - Routine monitoring for July 29, 2021 precipitation event.	SS19 not monitored since the compost facility is not yet constructed.

Table 1
Monitoring Schedule - 2021
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Task	Monitoring Locations	Monitoring Dates	Notes
	SS1	July 30, 2021 - Verification monitoring event based on the results for the July 9, 2021 routine monitoring event.	
Biomonitoring	SS1	July 30, 2021 - Verification monitoring event based on the results for the July 9, 2021 routine monitoring event.	
Leachate Sampling	Equalization Tank	Quarterly, and semi-annually in May and November. A quarterly sample was collected on August 11, 2021.	
Secondary Drainage Layer (SDL) Liquid Levels	PS2, PS4, PS6, and PS8(new)	Monthly - July 12, August 6, September 3, 2021 - PS2, PS4, and PS6	PS8 was not monitored as it is not yet constructed.
Gas Monitoring	GP1A, GP2, GP3, GP4, GP5, GP6, GP7, GP8, GP9 (new), GP10 (new)	Monthly gas monitoring from November to April and in July. Perimeter gas probes were monitored on July 21, 2021.	Gas probes GP9, and GP10 were not installed during this time period.
Poplar System Monitoring Program			
Precipitation Event Surface Water Monitoring/Sampling	SS14A, SS14B, and SS15A	July 9, 2021 - Routine monitoring for July 8, 2021 precipitation event.	SS14A not monitored due to no flow conditions.
	SS14A	September 23, 2021 - Routine monitoring for September 22, 2021 precipitation event.	
Storm Event Surface Water Monitoring	SS14A, SS14B, and SS15A	Two (2) events during the irrigation season and after a storm event (>25 mm in 24 hrs): September 8, 2021 - Storm event monitoring for September 7, 2021 precipitation event	SS14A and SS15A not monitored due to no flow conditions.
	SS14A, SS14B, and SS15A	September 23, 2021 - Storm event monitoring for September 22, 2021 precipitation event.	
Ambient Air Quality Monitoring Program			
Total Suspended Particulate - Dust	Stations West, Northeast, and Southeast	Every sixth day - NAPS Schedule (October 1 to May 31) Every third day - NAPS Schedule (June 1 to September 30)	
Volatile Organic Compounds	Upwind/downwind Monitoring	June 21 to September (5 sets): July 20, July 23, August 4, August 5, and September 3, 2021.	
Total Hydrocarbon Landfill Cap Survey	Final Capped Areas	Between the Spring and Fall: October 20, 2021.	
Noise Monitoring System			
Noise Monitoring	Stations - M1, M2, M3, and M4	Ongoing - Quarterly Reporting	
Operational Monitoring			
Contaminated Soil	Landfill Daily Cover/Disposed Material	Quarterly, if utilized: August 12, 2021.	
Automobile Shredder Residue	Landfill Daily Cover/Disposed Material	Semi-Annually (Spring and Fall), if utilized:	Monitoring not completed during the 2021 third quarter monitoring period.
Fourth Quarter Monitoring Period (October 1 to December 31, 2021)			
Precipitation Event Surface Water Monitoring/Sampling	SS1, SS10, SS16, SS19(new), SP1, SP2, SP3, SP4	October 4, 2021 - Routine monitoring for October 3, 2021 precipitation event.	SS19 not monitored since the compost facility is not yet constructed. SS10 and SS16 not monitored due to no flow conditions.
	SS1, SP2, SP3	October 15, 2021 - Verification monitoring event based on the results for the October 4, 2021 routine monitoring event.	
Biomonitoring	SS1, SP2, SP3	October 15, 2021 - Verification monitoring event based on the results for the October 4, 2021 routine monitoring event.	
Leachate Liquid Level Measurements	PS1, PS3, PS5, PS7(new), MH3S, MH4, MH5, MH6, MH7, MH8, MH9, MH10, MH11, MH12, MH16, MH17, MH18, OW22A-10, OW51A-15, OW53-10, Sump	Semi-annually in May and November: November 1, 2021. Daily during operation for PS1, PS3, and PS5.	PS7 was not monitored as it is not yet constructed.
Leachate Sampling	Equalization Tank	Quarterly, and semi-annually in May and November. A quarterly sample was collected on November 4, 2021.	
Secondary Drainage Layer (SDL) Liquid Levels	PS2, PS4, PS6, and PS8(new)	Monthly - July 12, August 6, September 3, 2021 - PS2, PS4, and PS6	PS8 was not monitored as it is not yet constructed.
Groundwater Liquid Level Measurements	ACTIVE AQUITARD OW16-6, OW17-4, OW40D-4, OW54A-4, OW56-4, OW57-4, OW58-6, OW59-6, OW60-4, OW67-4, OW68-5, OW69-5, OW70B-5, OW71A-5*, OW72-6, OW73-6,OW79-5, OW80-3, OW81-5, OW82(new), OW83(new), OW84(new) INTERSTADIAL SILT AND SAND OW16-7, OW40A-7, OW46-7, OW47-6, OW54-10, OW57-15, OW58-14, OW58-17, OW60-8, OW67-11, OW72-10, OW73-9, OW79-7, OW80-6, OW81-7, OW82(new), OW83(new), OW84(new)	Semi-annually in May and November: November 1, 2021.	Monitoring well nests OW82, OW83, and OW84 are not yet constructed.
Piezometer Liquid Level Measurements	PS1, PS2, PS3	Semi-annually in May and November: November 1, 2021.	
Groundwater Sampling	ACTIVE AQUITARD OW16-6, OW17-4, OW40B-4r, OW54A-4, OW56-4, OW57-4, OW58-6, OW59-6, OW60-4, OW67-4, OW68-5, OW69-5, OW70B-5, OW71A-5*, OW72-6, OW73-6, OW79-5, OW80-3, OW81-5, OW82(new), OW83(new), OW84(new) INTERSTADIAL SILT AND SAND OW16-7, OW40A-7, OW46-7, OW47-6, OW54-10, OW57-15, OW58-14, OW60-8, OW67-11, OW72-10, OW73-9, OW79-7, OW80-6, OW81-7, OW82(new), OW83(new), OW84(new) INTERFACE AQUIFER OW19-29, OW39-26, OW49-29, OW79-26, OW80-27, OW81-27, OW82(new), OW83(new), OW84(new), Cemetery Well	Semi-annually in May and November: November 2 and 3, 2021. November 2, 2021 - OW81-7 verification monitoring	Monitoring well nests OW82, OW83, and OW84 are not yet constructed.
Gas Monitoring	GP1A, GP2, GP3, GP4, GP5, GP6, GP7, GP8, GP9(new), GP10(new)	Perimeter gas probes monitored on November 17 and December 8, 2021	Gas probes GP9, and GP10 are not yet installed.
Poplar System Monitoring Program			
Precipitation Event Surface Water Monitoring/Sampling	SS15A	October 4, 2021 - Routine monitoring for October 3, 2021 precipitation event.	
	SS14A, SS14B	October 26, 2021 - Routine monitoring for October 25, 2021 precipitation event.	
Ambient Air Quality Monitoring Program			
Total Suspended Particulate - Dust	Stations West, Northeast, and Southeast	Every sixth day - NAPS Schedule (October 1 to May 31) Every third day - NAPS Schedule (June 1 to September 30)	
Noise Monitoring Program			
Noise Monitoring	Stations - M1, M2, M3, and M4	Ongoing - Quarterly Reporting	
Operational Monitoring			
Contaminated Soil	Landfill Daily Cover/Disposed Material	Quarterly (if utilized), October 1, 2021	
Automobile Shredder Residue	Landfill Daily Cover/Disposed Material	Semi-Annually (Spring and Fall), if utilized: October 1, 2021	

NOTES:
1) (new) denotes monitoring station/wells to be installed per the Environmental Monitoring Plan (EMP) dated December 20, 2007.
2) OW71A-5* denotes groundwater well monitored at the request of the Public Liaison Committee.

Table 2
Leachate Elevation Comparison
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitoring Location	Groundwater Monitoring Wells Compared	Existing Ground Surface Elevation (m ASL)	Exisiting Bottom of Ditch Elevation (m ASL)	Current Local Groundwater Elevation (m ASL)	Leachate Elevation (m ASL)	Leachate Elevation Compared to Ground Surface Elevation	Leachate Elevation Compared to Groundwater Elevation
May 17, 2021							
Cell 3S							
MH3SA	OW17-4 and OW56-4	240.71	240.68	239.23	239.43	LOWER	HIGHER
MH3SB	OW17-4 and OW56-4	240.46	240.31	239.23	239.51	LOWER	HIGHER
MH3SC	*OW7-5*	239.66	239.42	*236.85*	236.79	LOWER	LOWER
MH3SD	*OW7-5*	239.87	239.93	*236.85*	236.49	LOWER	LOWER
Central Fill Area							
Sump	*OW7-5 and OW8-5*	240.81	240.28	*237.14*	241.92	HIGHER	HIGHER
OW51A-15	OW17-4	240.24	239.68	239.36	236.47	LOWER	LOWER
MH4A	OW17-4 and OW69-5	240.33	239.71	239.22	238.59	LOWER	LOWER
MH4B	OW57-4	240.95	240.17	240.04	239.44	LOWER	LOWER
MH5A	OW58-6	241.51	240.78	240.01	238.50	LOWER	LOWER
MH6A	*OW65-4/OW65A-4*	241.90	241.20	*237.34*	238.50	LOWER	HIGHER
MH7A	OW73-6	242.07	241.34	240.71	237.92	LOWER	LOWER
MH8B	*OW74-6*	242.54	242.46	*239.33*	239.97	LOWER	HIGHER
MH9A	OW72-6	242.33	241.89	240.50	239.17	LOWER	LOWER
MH10	*OW74-6*	241.80	241.43	*239.33*	237.13	LOWER	LOWER
MH11A	OW54A-4	242.34	241.94	237.89	240.15	LOWER	HIGHER
MH12A	*OW66-4*	241.90	241.37	*241.79*	237.12	LOWER	LOWER
MH12B	*OW66-4*	241.90	241.37	*241.79*	237.12	LOWER	LOWER
South Cell							
MH16	*OW63A-6*	239.77	238.38	*238.12*	237.82	LOWER	LOWER
MH17	*OW63A-6*	238.07	238.05	*238.12*	237.83	LOWER	LOWER
MH18	*OW63A-6*	238.86	238.79	*238.12*	237.81	LOWER	LOWER
OW22A-10	*OW6-4*	239.38	238.76	*238.11*	238.33	LOWER	HIGHER
OW53-10	*OW44-5 and OW64-4/OW64A-4*	239.47	238.45	*236.77*	238.31	LOWER	HIGHER
Expansion Site Cell 1							
PS1	*OW38-6*	240.88		*236.73*	226.86	LOWER	LOWER
Expansion Site Cell 2							
PS3	*OW38-6*	240.18		*236.73*	226.62	LOWER	LOWER
Expansion Site Cell 4							
PS5	*OW38-6*	240.73		*236.73*	226.91	LOWER	LOWER

Notes: 1) Leachate elevations from May 17, 2021.
2) m ASL denotes meters above sea level.
3) *Italics* denotes historic information used to calculate data.
4) ***Bold and italics*** denotes elevation presented is the maintenance hole bottom elevation as it was dry at the time of monitoring.
5) For waste cells with two maintenance holes, the maintenance hole farthest into the waste cell was utilized for comparison.
6) Revised measuring point elevations for Existing Site manholes and leachate wells, as well as updated ground surface elevations reflect the findings of an updated survey (2016).

Table 2
Leachate Elevation Comparison
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitoring Location	Groundwater Monitoring Wells Compared	Existing Ground Surface Elevation (m ASL)	Exisiting Bottom of Ditch Elevation (m ASL)	Current Local Groundwater Elevation (m ASL)	Leachate Elevation (m ASL)	Leachate Elevation Compared to Ground Surface Elevation	Leachate Elevation Compared to Groundwater Elevation
November 1, 2021							
Cell 3S							
MH3SA	OW17-4 and OW56-4	240.71	240.68	239.17	239.74	LOWER	HIGHER
MH3SB	OW17-4 and OW56-4	240.46	240.31	239.17	239.58	LOWER	HIGHER
MH3SC	*OW7-5*	239.66	239.42	*236.85*	236.82	LOWER	LOWER
MH3SD	*OW7-5*	239.87	239.93	*236.85*	237.97	LOWER	HIGHER
Central Fill Area							
Sump	*OW7-5 and OW8-5*	240.81	240.28	*237.14*	242.66	HIGHER	HIGHER
OW51A-15	OW17-4	240.24	239.68	239.50	236.29	LOWER	LOWER
MH4A	OW17-4 and OW69-5	240.33	239.71	239.29	239.92	LOWER	HIGHER
MH4B	OW57-4	240.95	240.17	239.42	239.95	LOWER	HIGHER
MH5A	OW58-6	241.51	240.78	240.92	239.95	LOWER	LOWER
MH6A	*OW65-4/OW65A-4*	241.90	241.20	*237.34*	240.44	LOWER	HIGHER
MH7A	OW73-6	242.07	241.34	240.17	237.08	LOWER	LOWER
MH8B	*OW74-6*	242.54	242.46	*239.33*	239.05	LOWER	LOWER
MH9A	OW72-6	242.33	241.89	240.46	238.78	LOWER	LOWER
MH10	*OW74-6*	241.80	241.43	*239.33*	236.75	LOWER	LOWER
MH11A	OW54A-4	242.34	241.94	241.34	238.77	LOWER	LOWER
MH12A	*OW66-4*	241.90	241.37	*241.79*	236.74	LOWER	LOWER
MH12B	*OW66-4*	241.90	241.37	*241.79*	236.75	LOWER	LOWER
South Cell							
MH16	*OW63A-6*	239.77	238.38	*238.12*	238.01	LOWER	LOWER
MH17	*OW63A-6*	238.07	238.05	*238.12*	238.00	LOWER	LOWER
MH18	*OW63A-6*	238.86	238.79	*238.12*	237.99	LOWER	LOWER
OW22A-10	*OW6-4*	239.38	238.76	*238.24*	238.23	LOWER	LOWER
OW53-10	*OW44-5 and OW64-4/OW64A-4*	239.47	238.45	*235.30*	238.28	LOWER	HIGHER
Expansion Site Cell 1							
PS1	*OW38-6*	240.88		*236.73*	226.88	LOWER	LOWER
Expansion Site Cell 2							
PS3	*OW38-6*	240.18		*236.73*	232.99	LOWER	LOWER
Expansion Site Cell 4							
PS5	*OW38-6*	240.73		*236.73*	227.41	LOWER	LOWER

Notes: 1) Leachate elevations from November 1, 2021.
2) m ASL denotes meters above sea level.
3) *Italics* denotes historic information used to calculate data.
4) ***Bold and italics*** denotes elevation presented is the maintenance hole bottom elevation as it was dry at the time of utilized for monitoring.
5) For waste cells with two maintenance holes, the maintenance hole farthest into the waste cell was monitored.
6) Revised measuring point elevations for Existing Site manholes and leachate wells, as well as updated ground surface elevations reflect the findings of an updated survey (2016).

Table 3
Leachate Elevation Trends
Twin Creeks Environmenal Centre - 2021 Annual Monitoring Report

Monitor Designation	Long-Term Trend (Includes Historical Data)				
	Constant	Decreasing	Increasing	Fluctuating	Comments
Cell 3S					
MH3SA				X	Increasing to 2018 and since fluctuating
MH3SB				X	Decreasing to 2017 and since fluctuating.
MH3SC			X	X	Decreasing to 2010 and since increasing to fluctuating.
MH3SD			X	X	Decreasing to 2012 and since increasing to fluctuating.
MH3SE	X			X	Increasing to 2017 and since constant to fluctuating.
MH3SF	X			X	Decreasing to 2017 and since constant to fluctuating.
Central Fill Area					
OW51A-15	X			X	Constant to fluctuating since 2005.
MH4A				X	Fluctuating since 2004.
MH4B				X	Fluctuating since 2015.
MH5				X	Fluctuating since 2007.
MH6			X	X	Decreasing to 2017 and since increasing to fluctuating.
MH7		X		X	Fluctuating to decreasing since 2009.
MH8				X	Fluctuating since 2005.
MH9				X	Decreasing to 2012 and since fluctuating.
MH10		X		X	Fluctuating to 2018 and since decreasing.
MH11				X	Decreasing to 2011 and since fluctuating.
MH12		X		X	Fluctuating to 2018 and since decreasing.
SUMP			X	X	Fluctuating to 2016 and since increasing to fluctuating
South Fill Area					
OW22A-10				X	Fluctuating since 2005.
OW53-10				X	Increasing to 2014 and since fluctuating.
MH16				X	Increasing to 2010 and since fluctuating.
MH17				X	Increasing to 2010 and since fluctuating.
MH18				X	Increasing to 2010 and since fluctuating.

NOTES:

1) Elevations can show more than one trend.
2) For waste cells with two maintenance holes, the maintenance hole furthest within the waste was utilized for comparison.

Table 4
Groundwater Elevation Trends
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitor Designation	Long-Term Trend (Includes Historical Data)				
	Constant	Decreasing	Increasing	Fluctuating	Comments
Active Aquitard					
OW16-6*				X	Seasonal
OW17-4				X	Seasonal
OW40D-4*				X	Seasonal
OW54A-4*			X	X	Seasonal
OW56-4			X	X	Seasonal
OW57-4			X	X	Seasonal
OW58-6*			X	X	Seasonal
OW59-6*				X	Seasonal
OW60-4				X	Seasonal
OW67-4				X	
OW68-5				X	Seasonal
OW69-5				X	
OW70B-5*				X	Seasonal
OW71A-5*				X	Seasonal
OW72-6				X	Seasonal
OW73-6				X	Seasonal
OW79-5				X	Seasonal
OW80-3				X	
OW81-5				X	
Interstadial Silt and Sand					
OW16-7				X	Seasonal
OW40A-7*				X	Seasonal
OW46-7			X	X	
OW47-6				X	
OW54-10		X		X	Decreasing since 2009
OW57-15				X	
OW58-14				X	Decommissioned 2016
OW58-17				X	Installed April 2014
OW60-8				X	Seasonal
OW67-11				X	Fluctuating since 2018
OW72-10				X	Fluctuating since 2018
OW73-9				X	Fluctuating since 2018
OW79-7				X	Seasonal
OW80-6				X	Seasonal
OW81-7				X	
Interface Aquifier					
OW17-30				X	
OW19-29				X	
OW39-26				X	Well damaged in 2016
OW39A-26			X	X	Seasonal
OW40A-28*		X		X	Decreasing since 2015
OW49-29		X		X	Decreasing since 2009
OW60-25		X		X	
OW79-26			X	X	Increasing since 2018
OW80-27			X	X	Increasing since 2018
OW81-27				X	

Notes:
1) Seasonal - denotes a seasonal trend with elevated elevations during prolonged periods of precipitation, typically in the spring and summer months, and lower elevations during drier periods, typically the fall and winter months.
2) Water elevations can show more than one trend.
3) Ins - denotes insufficient data. At least three data points are required to establish a trend.
4) * denotes trends consider historical data from former monitoring wells at that location.
5) Monitoring well OW58-14 was decomissioned prior to the fall 2016 monitoring event.
6) Monitoring well OW39-26 was noted to have been damaged during the fall 2016 monitoring event and decomissioned April 2017.
7) OW81-5, OW81-7 and OW81-27 installed in June 2019. Insufficient data collected yet to track trend.

Table 5
Estimated Leachate Storage Volumes
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Fill Area	Approximate Area (ha)	Approximate Original Ground Surface Elevation (m asl)	Groundwater Reference Elevation (m asl)	Estimated Average Base of Waste (m asl)	May 2021 Average Leachate Elevation (m asl)	Estimated Volume in Waste Cells (Measured from Cell Base) (m^3)												Change in Volume Within the Waste Cells From May 2020 to May 2021 (m^3)
						MAY 2010	MAY 2011	MAY 2012	MAY 2013	MAY 2014	MAY 2015	MAY 2016	MAY 2017	MAY 2018	MAY 2019	MAY 2020	MAY 2021	
West Cell (Sump)	6.3	238.3	237.1	235.5	241.9	103,320	118,440	110,628	136,332	87,948	71,568	148,680	164,052	195,552	242,928	122,724	161,784	39,060
Cell 3 (OW51A-15)	1.5	239.9	239.2	235.2	236.5	4,200	4,980	5,220	5,100	7,800	6,180	4,800	4,920	5,100	6,360	5,640	7,620	1,980
Cell 4 (MH4B)	2.1	240.8	238.5	234.1	239.4	52,080	62,664	29,148	36,120	30,492	37,212	46,200	46,452	40,404	46,368	43,848	44,856	1,008
Cell 5 (MH5A)	2.2	241.2	237.0	236.5	238.5	7,040	0	7,832	28,776	22,264	0	14,520	28,160	0	28,512	27,984	17,600	-10,384
Cell 6 (MH6A)	2.0	240.0	237.3	236.5	238.5	4,000	8,080	5,280	9,680	10,880	1,600	0	0	3,840	28,880	16,720	16,000	-720
Cell 7 (MH7A)	1.9	240.7	238.8	236.5	237.9	15,960	10,564	19,076	2,736	5,548	17,784	9,576	18,848	12,920	23,484	13,984	10,792	-3,192
Cell 8 (MH8B)	1.9	240.0	239.3	237.0	240.0	760	10,108	19,380	17,480	3,496	1,672	9,880	18,392	17,252	27,968	29,868	22,572	-7,296
Cell 9 (MH9A)	1.9	241.2	239.0	237.5	239.2	15,200	17,936	8,816	7,296	7,296	8,968	5,700	13,072	1,064	19,456	14,440	12,692	-1,748
Cell 10 (MH10)	1.9	241.5	239.3	236.5	237.1	7,600	22,496	21,280	5,320	5,092	8,588	28,500	34,200	28,120	34,276	4,636	4,788	152
Cell 11 (MH11A)	1.9	244.3	240.8	237.8	240.2	20,520	7,068	15,884	14,516	15,352	19,076	23,560	21,584	20,292	25,156	11,324	17,860	6,536
Cell 12 (MH12A)	0.6	242.5	241.8	236.5	237.1	2,400	7,152	6,768	4,008	1,512	2,640	8,880	10,800	8,856	11,016	1,488	1,488	0
Cell 3S (MH3SA/B/C/D/E/F)	1.1	238.6	238.3	235.2	240.0	7,964	16,060	13,640	16,588	5,412	10,340	14,520	4,752	16,368	21,831	17,431	21,120	3,689
South Cell (MH16/17/18)	5.4	239.4	238.1	235.0	237.8	54,000	62,640	62,640	67,176	55,296	60,912	49,680	46,224	55,296	70,992	65,304	60,912	-4,392
					Total	**295,044**	**348,188**	**325,592**	**351,128**	**258,388**	**246,540**	**364,496**	**411,456**	**405,064**	**587,227**	**375,391**	**400,084**	24,693

Fill Area	Volume Above Groundwater Reference Level (m^3)												Change in Volume Above Groundwater Reference Level From May 2020 to May 2021 (m^3)
	MAY 2010	MAY 2011	MAY 2012	MAY 2013	MAY 2014	MAY 2015	MAY 2016	MAY 2017	MAY 2018	MAY 2019	MAY 2020	MAY 2021	
West Cell (Sump)	63,000	78,120	70,308	96,012	47,628	31,248	108,360	123,732	155,232	202,608	82,404	121,464	39,060
Cell 3 (OW51A-15)	0	0	0	0	0	0	0	0	0	0	0	0	0
Cell 4 (MH4B)	11,760	25,704	0	0	0	252	9,240	9,492	3,444	9,408	6,888	7,896	1,008
Cell 5 (MH5A)	0	0	3,432	24,376	17,864	0	10,120	23,760	0	24,112	23,584	13,200	-10,384
Cell 6 (MH6A)	0	1,680	0	3,280	4,480	0	0	0	0	22,480	10,320	9,600	-720
Cell 7 (MH7A)	1,520	0	1,596	0	0	304	0	1,368	0	6,004	0	0	0
Cell 8 (MH8B)	0	0	1,900	0	0	0	0	912	0	10,488	12,388	5,092	-7,296
Cell 9 (MH9A)	6,080	6,536	0	0	0	0	0	1,672	0	8,056	3,040	1,292	-1,748
Cell 10 (MH10)	0	1,216	0	0	0	0	7,220	12,920	6,840	12,996	0	0	0
Cell 11 (MH11A)	9,120	0	0	0	0	0	760	0	0	2,356	0	0	0
Cell 12 (MH12A)	0	0	0	0	0	0	0	0	0	0	0	0	0
Cell 3S (MH3SA/B/C/D/E/F)	0	2,420	0	2,948	0	0	880	0	2,728	8,191	3,791	7,480	3,689
South Cell (MH16/17/18)	0	0	0	0	0	0	0	0	0	4,032	0	0	0
Total	**91,480**	**115,676**	**77,236**	**126,616**	**69,972**	**31,804**	**136,580**	**173,856**	**168,244**	**310,731**	**142,415**	**166,024**	23,609

Notes:

1) Average leachate elevations are from May 17, 2021.

2) Assumes a waste porosity of 40%.

3) NA indicates data not available, owing to date of manhole installation.

4) Revised original ground surface elevations reflect the findings of an updated survey in 2016.

5) Estimated Leachate Storage Volume (m^3) for Total in Waste Cell = Average Leachate Elevation (m) - (Estimated Average Base of Waste (ha) * 10,000 (m^2)) * 0.4 (assumed porosity).

6) Groundwater Reference Elevation is a fixed value as of 2011 based on historic (2003-2007) data.

7) Volume Above Groundwater Reference Level based on similar reference level for post-2010 volumes. Pre-2010 volumes based on spring average level.

Table 5
Estimated Leachate Storage Volumes
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Fill Area	Approximate Area (ha)	Approximate Original Ground Surface Elevation (m asl)	Groundwater Reference Elevation (m asl)	Estimated Average Base of Waste (m asl)	Nov 2021 Average Leachate Elevation (m asl)	Estimated Volume in Waste Cells (Measured from Cell Base) (m3)				Change in Volume Within the Waste Cells From Nov 2020 to Nov 2021 (m^3)	Volume Above Groundwater Reference Level (m3)				Change in Volume Above Groundwater Reference Level From Nov 2020 to Nov 2021 (m^3)
						NOV 2018	NOV 2019	NOV 2020	NOV 2021		NOV 2018	NOV 2019	NOV 2020	NOV 2021	
West Cell (Sump)	6.3	238.3	237.1	235.5	242.7	217,224	177,408	139,356	180,432	41,076	176,904	137,088	99,036	140,112	41,076
Cell 3 (OW51A-15)	1.5	239.9	239.2	235.2	236.3	5,040	6,000	6,840	6,540	-300	0	0	0	0	0
Cell 4 (MH4B)	2.1	240.8	238.5	234.1	240.0	47,376	40,572	44,772	49,140	4,368	10,416	3,612	7,812	12,180	4,368
Cell 5 (MH5A)	2.2	241.2	237.0	236.5	240.0	26,136	0	0	30,360	30,360	21,736	0	0	25,960	25,960
Cell 6 (MH6A)	2.0	240.0	237.3	236.5	240.4	2,560	30,640	11,360	31,520	20,160	0	24,240	4,960	25,120	20,160
Cell 7 (MH7A)	1.9	240.7	238.8	236.5	237.1	10,412	3,952	456	4,408	3,952	0	0	0	0	0
Cell 8 (MH8B)	1.9	240.0	239.3	237.0	239.1	17,556	6,992	6,308	15,580	9,272	76	0	0	0	0
Cell 9 (MH9A)	1.9	241.2	239.0	237.5	238.8	4,712	7,752	1,596	9,728	8,132	0	0	0	0	0
Cell 10 (MH10)	1.9	241.5	239.3	236.5	236.8	33,668	0	0	1,900	1,900	12,388	0	0	0	0
Cell 11 (MH11A)	1.9	244.3	240.8	237.8	238.8	22,952	7,296	4,484	7,372	2,888	152	0	0	0	0
Cell 12 (MH12A)	0.6	242.5	241.8	236.5	236.7	10,632	0	0	576	576	0	0	0	0	0
Cell 3S (MH3SA/B/C/D/E/F)	1.1	238.6	238.3	235.2	239.6	19,323	21,685	11,730	19,351	7,621	5,683	8,045	0	5,711	5,711
South Cell (MH16/17/18)	5.4	239.4	238.1	235.0	238.0	59,760	58,608	58,248	64,800	6,552	0	0	0	0	0
					Total	**477,351**	**360,905**	**285,150**	**421,707**	136,557	**227,355**	**172,985**	**111,808**	**209,083**	97,275

Notes:

1) Average leachate elevations are from Nov 1, 2021.

2) Assumes a waste porosity of 40%.

3) NA indicates data not available, owing to date of manhole installation.

4) Revised original ground surface elevations reflect the findings of an updated survey in 2016.

5) Estimated Leachate Storage Volume (m^3) for Total in Waste Cell = Average Leachate Elevation (m) - (Estimated Average Base of Waste (ha) * 10,000 (m^2)) * 0.4 (assumed porosity).

6) Groundwater Reference Elevation is a fixed value as of 2011 based on historic (2003-2007) data.

7) Volume Above Groundwater Reference Level based on similar reference level for post-2010 volumes. Pre-2010 volumes based on spring average level.

Table 6
Leachate Chemical Summary
Twin Creeks Environmental Centre – 2021 Annual Monitoring Report

Parameter	Leachate Concentrations			Background Concentrations		
	West Central Fill Area (Existing Site) (2008-2021)	Typical Waste Areas (Existing Site) (2008-2021)	Equalization Tank (Expansion Site) (2010-2021)	Groundwater (1984-2001)	Surface Water (2001-2021) SS10	Surface Water (2008-2021) SS16
pH (pH units)	**7.3 - 8.0**	**7.4 - 8.2**	**7.0 - 8.1**	7.0 – 8.3	6.7 - 8.7	7.4 - 8.4
Conductivity (μS/cm)	**880 - 16,400**	**501 – 31,100**	**2,000 - 26,000**	443 – 2,550	62 - 1200	109 - 620
Alkalinity	**290 - 7,060**	**160 - 18,300**	**1,820 - 10,000**	100 - 581	22 - 203	45 - 228
Calcium	**76 - 150**	**19 - 380**	**79- 1,400**	19 - 250	5.4 - 170	15 - 1300
Magnesium	**22 - 390**	**19 - 450**	**130 - 530**	9 - 261	1.6 - 33	3.3 - 85
Sodium	**57 - 2,100**	**19 - 6,300**	**270 - 2,700**	48 - 199	0.49 - 20	1.4 - 18
Potassium	**12 - 620**	**6.7 - 1,100**	**81 - 900**	1 - 9	1 - 17	3.1 - 60
Chloride	**68 - 2,600**	**11 - 1,000**	**330 - 3,400**	1 - 15	1 - 46	1.2 - 20
Sulphate	**0.5 - 81**	**10 - 410**	**10 - 220**	100 – 1,330	0.5 - 220	<1 - 220
Iron	**2.2 - 54**	**<0.05 - 33**	**1.6 - 120**	<0.1 - 3.3	0.25 - 79	0.3 - 540
DOC	**25 - 462**	**8.3 - 1,480**	**234 - 4,500**	0.7 - 9.8	<0.02 - 0.26	
Ammonia (total)	**11.1 - 857**	**8 - 3,540**	**57 - 2,000**	<0.05 – 7.1	<0.02 - 18.4	0.05 - 0.3
TKN	**11 - 930**	**11 - 3,500**	**26 - 2,700**	<0.1 – 10.9	0.41 - 33	<0.7 - 7.2
Nitrate	**<0.1 - <2.0**	**<0.1 - 6.7**	**<0.1 - <5.0**	<0.1 – 2.7	<0.01 - 102	<0.01 - 1.5
Boron	**1.3 - 70**	**0.67 - 560**	**1.3 - 24**	0.09 – 0.99	0.02 - 0.48	<0.02 - 0.4
Benzene (μg/L)	**<0.2 - 361**	**<0.1 - 12.0**	**<1 - <10**	<1.3		
Toluene (μg/L)	**<0.2 - 782**	**<0.2 - 550**	**20 - 2400**	<1.5		
Ethylbenzene (μg/L)	**<0.2 - 318**	**<0.1 - 891**	**<0.5 - 21**	<1.6		
m/p - xylenes (μg/L)	**<0.2 - 1,990**	**<0.1 - 200**	**7.5 - 48**	<3.4		
o - xylene (μg/L)	**<0.2 - 1140**	**<0.1 - 97.4**	**<0.5 - 22**	<2.7		

Notes:

1) Background concentrations for groundwater are established from 1984 to 2001 for monitoring wells 250 metres or greater to the west of the Existing Site: OW1-5, OW5-6, OW38-6, OW38-10, OW39-6, OW39-12, OW42-6, OW42-9.
2) Background concentrations for surface water (SS10 and SS16) are established for 2001-2021 data, where available.
3) All data are mg/L unless otherwise specified.
4) Blank denotes parameter not tested.

Table 7
Indicator Parameter Concentration Trend Summary - Groundwater
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitor Designation	Long-Term Trend (Includes Historic Data)		
	Chloride	Nitrate	Boron
Active Aquitard			
OW16-6*	C	C	C
OW17-4	F	C	C
OW40D-4	C	C	D/F
OW54A-4*	I/F	C	C
OW56-4	C	F	F
OW57-4	C	C	C
OW58-6	C	C	C
OW59-6	C	C	F
OW60-4	C	C	C
OW67-4	D/F	F	D/F
OW68-5	C	C	C
OW69-5	C	C	F
OW70B-5*	C	C	C
OW71A-5*	I	C	C
OW72-6	C	C	C
OW73-6	C	C	F
OW79-5	F	C	C
OW80-3	F	C	C
OW81-5	ID	ID	ID
Interstadial Silt and Sand			
OW16-7	C	C	C
OW40A-7	C	C	C
OW46-7	C	C	F
OW47-6	C	F	F
OW54-10	C	C	C
OW57-15	C	C	C
OW58-17*	C	C	F
OW60-8	C	C	F
OW67-11	F	F	F
OW72-10	C	C	C
OW73-9	C	C	F
OW79-7	F	C	C
OW80-6	F	C	C
OW81-7	ID	ID	ID
Interface Aquifer			
OW19-29	C	C	F
OW39A-26*	F	C	F
OW49-29	C	C	F
OW79-26	C	F	C
OW80-27	C	C	F
OW81-27	ID	ID	ID
Cemetery Well	C	F	C

Notes:
1) C denotes constant trend.
2) D denotes decreasing trend.
3) I denotes increasing trend.
4) F denotes fluctuating trend.
5) S denotes seasonal pattern.
6) ID denotes insufficient data for interpretation.
7) Data are presented in Table H-4 Appendix H .
8) Historic data trends assume nitrate+nitrite represents nitrate.
9) Concentrations can show more than one trend.
10) * denotes considers historic data from decommissioned monitoring well.

Table 8
Groundwater Trigger Concentration / Comparison Summary - Active Aquitard
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitor Designation		Chloride	Nitrate	Boron
Active Aquitard				
	Trigger Concentration (mg/L)	**106**	**2.3**	**1.1**
OW16-6	May 2021	48	<0.10	0.18
	November 2021	45	<0.10	0.16
OW17-4	May 2021	35	<0.10	0.23
	November 2021	32	0.29	0.26
OW40D-4	May 2021	4.6	0.34	0.4
OW54A-4	May 2021	24	<0.10	0.23
	November 2021	23	<0.10	0.23
OW56-4	May 2021	8.6	0.31	0.4
	November 2021	7.6	0.11	0.49
OW57-4	May 2021	6.6	<0.10	0.37
	November 2021	6.4	<0.10	0.39
OW58-6	May 2021	6.1	<0.10	0.62
	November 2021	5.3	<0.10	0.59
OW59-6	May 2021	7.0	<0.10	0.8
	November 2021	6.5	<0.10	0.72
OW60-4	May 2021	6.5	<0.10	0.03
OW67-4	May 2021	12	1.21	0.17
	November 2021	18	0.78	0.21
OW68-5	May 2021	9.1	<0.10	0.08
	November 2021	8.5	<0.10	0.09
OW69-5	May 2021	11	<0.10	1.0
	November 2021	11	<0.10	0.94
OW70B-5	May 2021	7.0	<0.10	0.43
	November 2021	6.4	<0.10	0.46
OW71A-5	May 2021	29	<0.10	0.12
	November 2021	29	<0.10	0.14
OW72-6	May 2021	5.1	<0.10	0.62
	November 2021	4.7	<0.10	0.67
OW73-6	May 2021	7.3	<0.10	0.9
	November 2021	8.6	<0.10	0.84
OW79-5	May 2021	26	<0.10	0.09
OW80-3	May 2021	*160*	0.12	0.04
OW81-5	May 2021	20	<0.10	0.54

NOTES:

1) Trigger Concentrations based on Table 4 of the 2007 Landfill EMP.

2) Bolded text and shading denotes concentration exceeds trigger concentration.

3) Italics denotes that per MECP approval the parameter's concentration is not evaluated against the trigger concertation.

4) Monitoring well nests OW82, OW83, and OW84 have yet to be constructed.

5) Monitoring well nest OW81 installed in June 2019.

6) N/A denotes not applicable as chloride is not used as part of the trigger assessment process at this location.

Table 9
Groundwater Trigger Concentration Comparison Summary - Interstadial Silt and Sand
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitor Designation		Chloride	Nitrate	Boron
Interstadial Silt and Sand				
	Trigger Concentration (mg/L)	**116**	**2.3**	**2.1**
OW16-7	May 2021	7.1	0.12	0.28
	November 2021	5.3	<0.10	0.27
OW40A-7	May 2021	6.7	0.20	0.59
OW46-7	May 2021	14	<0.10	0.34
	November 2021	13	0.15	0.7
OW47-6	May 2021	6.4	0.37	0.91
	November 2021	5.4	0.38	0.96
OW54-10	May 2021	8.9	0.18	0.96
	November 2021	8.5	0.35	0.95
OW57-15	May 2021	8.8	0.44	1.1
	November 2021	8.4	<0.10	1.1
OW58-17	May 2021	9.5	<0.10	1.3
	November 2021	8.4	<0.10	1.3
OW60-8	May 2021	8.8	<0.10	0.85
OW67-11	May 2021	24	0.14	0.51
	November 2021	31	<0.10	0.53
OW72-10	May 2021	6.3	0.34	1.1
	November 2021	5.3	<0.10	1.1
OW73-9	May 2021	8.9	0.45	1.1
	November 2021	8.1	0.60	1.2
OW79-7	May 2021	*140*	<0.10	0.22
OW80-6	May 2021	*190*	<0.10	0.21
OW81-7	May 2021	**220**	0.10	0.53

Notes:

1) Trigger Concentrations based on Table 4 of the 2007 Landfill EMP.

2) Bolded text and shading denotes concentration exceeds trigger concentration.

3) Italics denotes that per MECP approval the parameter's concentration is not evaluated against the trigger concertation.

4) Chloride trigger concentration of 116mg/L is not applicable to OW79-7 and OW80-6

5) Monitoring well nests OW82, OW83, and OW84 have yet to be constructed.

6) Monitoring well nest OW81 installed in June 2019.

Table 10
Groundwater Trigger Concentration Comparison Summary - Interface Aquifer
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitor Designation		Chloride	Nitrate	Boron
Interface Aquifer				
	Trigger Concentration (mg/L)	**134**	**2.3**	**2.6**
OW19-29	May 2021	28	<0.10	2.2
OW39A-26	May 2021	57	<0.10	1.8
OW49-29	May 2021	29	<0.10	1.5
OW79-26	May 2021	28	<0.10	1.7
OW80-27	May 2021	47	<0.10	1.8
OW81-27	May 2021	48	<0.10	1.9
Cemetery Well	May 2021	4.4	0.98	0.03

Notes:

1) Trigger Concentrations based on Table 4 of the 2007 Landfill EMP.

2) Bolded text and shading denotes concentration exceeds trigger concentration.

3) Monitoring well nests OW82, OW83, and OW84 have yet to be constructed.

4) Monitoring well nest OW81 installed in June 2019.

Table 11
Indicator Parameter Concentration Trend Summary - Surface Water
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitoring Station	Long-Term Trend (Includes Historic Data)			
	Chloride	Ammonia	Boron	Zinc
SS1	F	C	F	F
SS10	F	C	F	F
SS16	C	C	C	C
SP1	F	C	F	C
SP2	F	F	F	F
SP3	F	F	C	C
SP4	F	F	C	C

Notes:

1) C denotes constant trend.
2) D denotes decreasing trend.
3) I denotes increasing trend.
4) F denotes fluctuating trend.
5) S denotes seasonal pattern.
6) Data are presented in Table I-2, Appendix I.
7) INS - denotes there is insufficient data available for interpretation.
8) NC denotes sampling station not yet constructed.

Table 12
Surface Water Trigger Concentrations
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Parameter	Units	PWQO	Background Station SS10 and SS16 90% Trigger Concentration	Number of Samples for Background Station SS10	Number of Samples for Background Station SS16	Post 2020 Trigger Concentration	Post 2021 Trigger Concentration
Trigger Concentrations/Levels for Compliance Points							
Chloride	mg/L	210*	20.3	63	45	210	210
Ammonia (unionized)	mg/L	0.020	0.010	63	45	0.020	0.020
Phenols	mg/L	0.001	0.004	63	45	0.004	0.004
Boron	mg/L	0.20	0.17	63	45	0.20**	0.20**
Nickel	mg/L	0.025	0.027	63	45	0.028	0.027
Chromium (total)	mg/L	0.0089	0.024	63	45	0.025	0.024
Zinc	mg/L	0.02	0.06	63	45	0.06	0.06

Notes:

1) PWQO denotes Provincial Water Quality Objectives (1994) with updates.

2) * denotes recommended concentration by Environment Canada.

3) ** It is noted that the boron trigger concentration for SP1 is 0.39 mg/L, per the MOECC letter dated May 18, 2012.

4) Trigger concentrations are calculated annually from SS10 and SS16, per MOECC letter dated February 27, 2014.

Table 13
2022 Monitoring Program
Twin Creeks Environmental Centre - 2021 Annual Monitoring Report

Monitoring Locations	Parameters	Frequency
Leachate		
PS1, PS3, PS5, PS7*, MH3S, MH4, MH5, MH6, MH7, MH8, MH9, MH10, MH11, MH12, MH16, MH17, MH18, OW22A-10, OW51A-15, OW53-10, Sump, LW1, LW2, LW3, LW4, LW5, LW6	Leachate Levels	May and November
PS1, PS3, PS5, PS7*	Leachate Levels	Daily
PS1, PS3, PS5, PS7*, South Fill Area (MH18), West Central Fill Area (Sump), Central Fill Area (Composite of MH3, MH4, MH5, MH6, MH7, MH9, MH11)	PLIL-GW, SLIL-GW, PLIL-SW, SLIL-SW, LS	May
Equalization Tank	BOD_5, DOC, phosphorus (total), TKN, BTEX, pH	Quarterly
	PLIL-SW, SLIL-SW, LS	May and November
Treated Leachate Effluent		
Treatment Plant Effluent	Discharge Rates, COD, pH, turbidity	Daily
	Chloride, $CBOD_5$, BOD_5, DOC, BTEX, ammonia, pH	Weekly
	PLIL-GW, SLIL-GW, PLIL-SW, SLIL-SW, LS	Monthly
	PCB, organochlorines	May and November
Treated Leachate Temporary Storage Cells : Cells 1 and 2	Discharge Rates	Daily
Cell 1 Inlet, Cells 1 and 2	Chloride, $CBOD_5$, BOD_5, DOC, BTEX, ammonia, pH	Weekly
Cells 1 and 2	DO, pH, alkalinity, DOC	Weekly
Cells 1 and 2	PLIL-GW, SLIL-GW, PLIL-SW, SLIL-SW, LS	Monthly
Cell 1	Biomonitoring	May and November
Secondary Drainage Layer		
PS2, PS4, PS6, PS8*	Groundwater Levels	Monthly
Active Aquitard		
OW16-6, OW17-4, OW40D-4, OW54A-4, OW56-4, OW57-4, OW58-6, OW59-6, OW60-4, **OW61-4, OW62-5**, OW67-4, OW68-5, OW69-5, OW70B-5, OW71A-5[†], OW72-6, OW73-6, **OW75-3, OW76-5, OW77-4, OW78-4**, OW79-5, OW80-3, OW81-5, OW82(new), OW83(new), OW84(new), **OW85-5,** P1, P2, P3	Groundwater Levels	May and November
OW16-6, OW17-4, OW54A-4, OW56-4, OW57-4, OW58-6, OW59-6, **OW61-4, OW62-5**, OW67-4, OW68-5, OW69-5, OW70B-5, OW71A-5*, OW72-6, OW73-6, **OW75-3, OW76-5, OW77-4, OW78-4**	PLIL-GW, SLIL-GW	May and November
OW40D-4, OW60-4, OW79-5, OW80-3, OW81-5, OW82(new), OW83(new), OW84(new), **OW85-5**	PLIL-GW, SLIL-GW	May
OW16-6, **OW61-4, OW62-5, OW75-3, OW78-4**	Volatiles	May and November
OW17-4, OW40D-4, OW54A-4, OW56-4, OW57-4, OW58-6, OW59-6, OW60-4, OW67-4, OW68-5, OW69-5, OW70B-5, OW71A-5*, OW72-6, OW73-6, **OW76-5, OW77-4**, OW79-5, OW80-3, OW81-5, OW82(new), OW83(new), OW84(new), **OW85-5**	Volatiles	May
Interstadial Silt and Sand		
OW16-7, OW40A-7, OW46-7, OW47-6, OW54-10, OW57-15, OW58-17, OW60-8, **OW61-6, OW62-7**, OW67-11, OW72-10, OW73-9, **OW75-7, OW78-6**, OW79-7, OW80-6, OW81-7, OW82(new), OW83(new), OW84(new), **OW85-8**	Groundwater Levels	May and November
OW46-7, OW47-6, OW54-10, OW57-15, OW58-17, OW67-11, OW72-10, OW73-9	PLIL-GW, SLIL-GW	May and November
OW16-7, **OW61-6, OW62-7, OW75-7, OW78-6**	PLIL-GW, SLIL-GW, volatiles	May and November
OW40A-7 OW60-8, OW79-7, OW80-6, OW81-7, OW82(new), OW83(new), OW84(new), **OW85-8**	PLIL-GW, SLIL-GW	May
OW40A-7, OW46-7, OW47-6, OW54-10, OW57-15, OW58-17, OW60-8, OW67-11, OW72-10, OW73-9, OW79-7, OW80-6, OW81-7, OW82(new), OW83(new), OW84(new), **OW85-8**	Volatiles	May
Interface Aquifer		
OW17-30, OW19-29, OW39A-26, OW40A-28, OW49-29, OW60-25, **OW61-26, OW62-30**, OW79-26, OW80-27, OW81-27, OW82(new), OW83(new), OW84(new)	Groundwater Levels	May and November
OW19-29, OW39A-26, OW49-29, OW79-26, OW80-27, OW81-27, OW82(new), OW83(new), OW84(new), Cemetery Well	PLIL-GW, SLIL-GW	May
OW19-29, OW39A-26, OW49-29, OW79-26, OW80-27, OW81-27, OW82(new), OW83(new), OW84(new), Cemetery Well	Volatiles	Biennial - May 2022
Background Station		
SS10, SS16	Flow Rates	Quarterly after 10 mm precipitation events. Greater than 1 month intervals between sampling.
	PLIL-SW, SLIL-SW, nitrite	
	LS-SW	Spring Precipitation Event
	Biomonitoring	Spring Precipitation Event
Sedimentation Ponds (Discharge Points)		
SP1, SP2, SP3, SP4	Flow Rates	Quarterly after 10 mm precipitation events. Greater than 1 month intervals between sampling.
	PLIL-SW, SLIL-SW, nitrite	
	LS-SW, volatiles, semi-volatiles	Quarterly after 10 mm precipitation events. Greater than 1 month intervals between sampling.
	Biomonitoring	Spring Precipitation Event
Western Site Boundary Compliance Point		
SS1	Flow Rates	Quarterly after 10 mm precipitation events. Greater than 1 month intervals between sampling.
	PLIL-SW, SLIL-SW, nitrite	
	LS-SW, volatiles, semi-volatiles	Quarterly after 10 mm precipitation events. Greater than 1 month intervals between sampling.
	Biomonitoring	Spring Precipitation Event
Poplar Tree Plantation Land Application Area		
SS17A, SS17B, SS18A, SS18B	Flow Rates	Quarterly after 10 mm precipitation events. Greater than 1 month intervals between sampling.
	PLIL-SW, SLIL-SW, nitrite	
	LS-SW, volatiles, semi-volatiles	Quarterly after 10 mm precipitation events. Greater than 1 month intervals between sampling.
	Biomonitoring	Spring Precipitation Event
Compost Facility (if constructed)		
SS19	PLIL-SW, SLIL-SW, nitrite, BOD_5, TSS, Total Coliform, Fecal Coliform, E. Coli	Prior to water use
Landfill Gas Monitoring		
Landfill Cap	Inspections	Monthly (April to November)
GP1A, GP2, GP3, GP4, GP5, GP6, GP7, GP8, GP9(new), GP10(new)	Methane Gas	January, February, March, April, July, November, December

Notes:

1) PLIL-GW indicates: chloride, nitrate, boron.

2) SLIL-GW indicates: alkalinity, sulphate, calcium, magnesium, potassium, sodium, barium, cadmium, iron, lead, DOC, TDS, ammonia (total), TKN, pH, conductivity. Field parameters of pH, conductivity, temperature, turbidity.

3) PLIL-SW indicates: chloride, ammonia (total and unionized), phenols, boron, nickel, chromium (total), zinc.

4) SLIL-SW indicates: alkalinity, sulphate, calcium, magnesium, potassium, sodium, total phosphorus, iron, nitrate, TKN, TDS, pH, conductivity. Field parameters of temperature, pH, conductivity, turbidity, DO.

5) LS indicates: arsenic, barium, cadmium, copper, lead, manganese, mercury, nitrite, TSS, volatiles, semi-volatiles, BOD_5, COD.

6) LS-SW indicates: arsenic, barium, cadmium, copper, lead, mercury, nitrite, TSS, BOD_5, COD.

7) Volatiles should include the following at a minimum: benzene, 1,4-dichlorobenzene, dichloromethane, toluene, ethylbenzene, xylenes, and vinyl chloride.

8) Semi-volatiles should include the following at a minimum: 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, hexachlorobenzene, diethylphthalate, dimethylphthalate, di-n-butyl phthalate, phenol, benzo(a)pyrene, 2,4,6-trichlorophenol, 2,4-dichlorophenol, pentachlorophenol.

9) Organochlorines include herbicide and pesticide scan.

10) Biomonitoring indicates toxicity testing for Rainbow Trout and Daphnia Magna.

11) Biennial indicates every second year.

12) QA/QC includes one (1) blind duplicate for each 15 samples or once per event, whichever is greater.

13) Surface water samples shall be collected in a downstream to upstream sequence.

14) OW84(new) denotes monitoring wells to be installed per EMP dated December 20, 2007.

15) Spring denotes: April, May, and June.

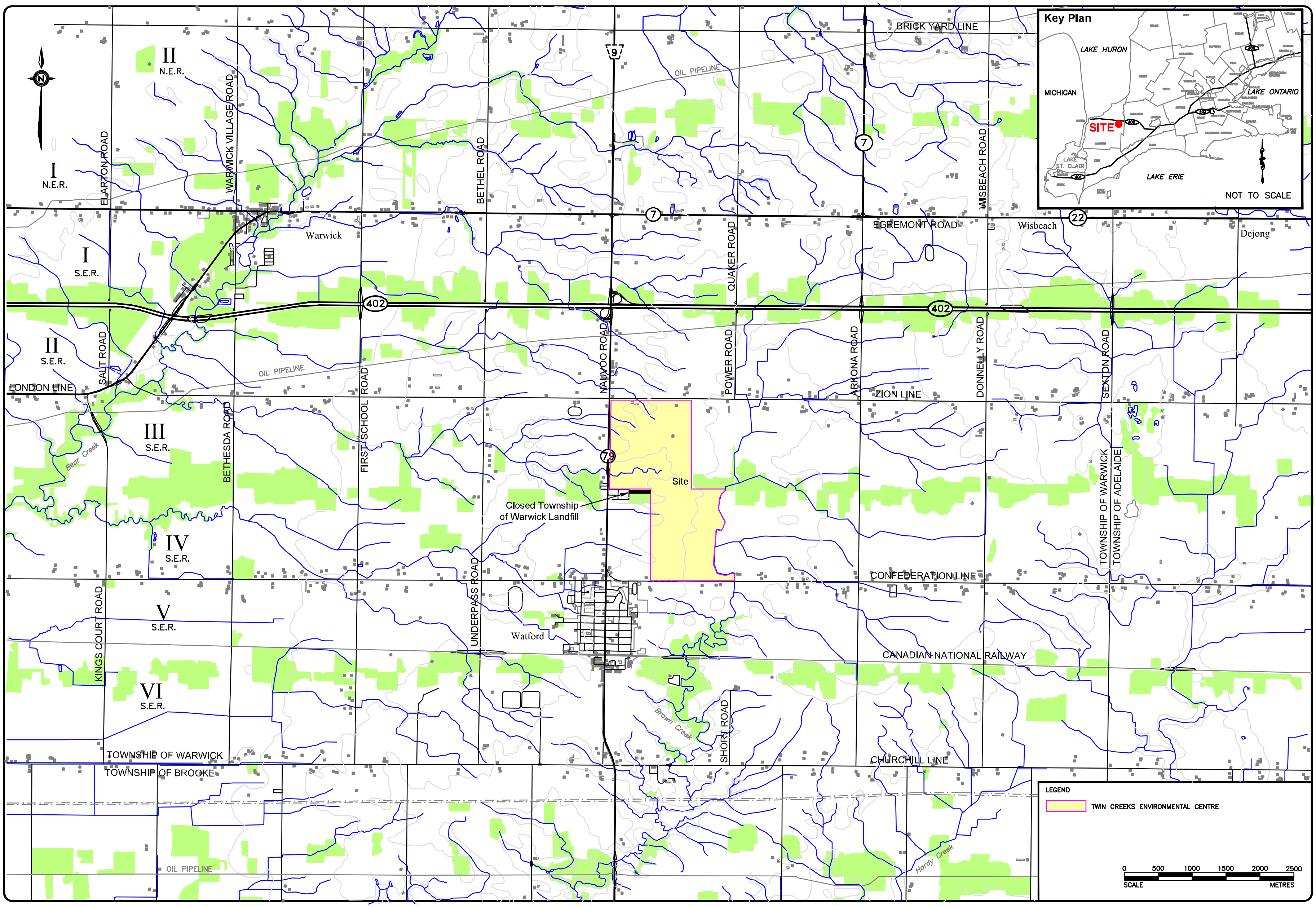
16) † indicates that OW71A-5 is not required as part of the monitoring program, however, obtained data is interpolated for the monitoring well OW67-4, which used to show dry conditions.

17) Since the Poplar Plantation is not required to be utilized until a few months prior to the initiation of the treatment plant as operational, monitoring per the EMP and ECA, as well as the Waste and Sewage ECA's that is completed to evaluate the vigour of the Poplar Plantation, is not required. It is recognized that once the Poplar Plantation is initialized, then the required monitoring to evaluate the Poplar Plantation would be reinitiated.

18) Monitoring stations that are currently idle until 2 months prior to the leachate treatment plant being operational, include the following: 1) Surface water stations **SS17A, SS17B, SS18A, SS18B**; and 2) Groundwater monitoring locations **OW61, OW62, OW75, OW76, OW77, OW78, AND OW85.**

19) * PS7, and PS8 not yet constructed.

FIGURES



MAP SOURCE:
FIGURE PROVIDED BY GENIVAR INC., FIGURE 1, FILE REF NO. 111-53111-00-F1-LM 12CM Q4, DATED FEBRUARY 2013.

WASTE MANAGEMENT

SITE LOCATION MAP

2021 COMPLIANCE MONITORING PROGRAM

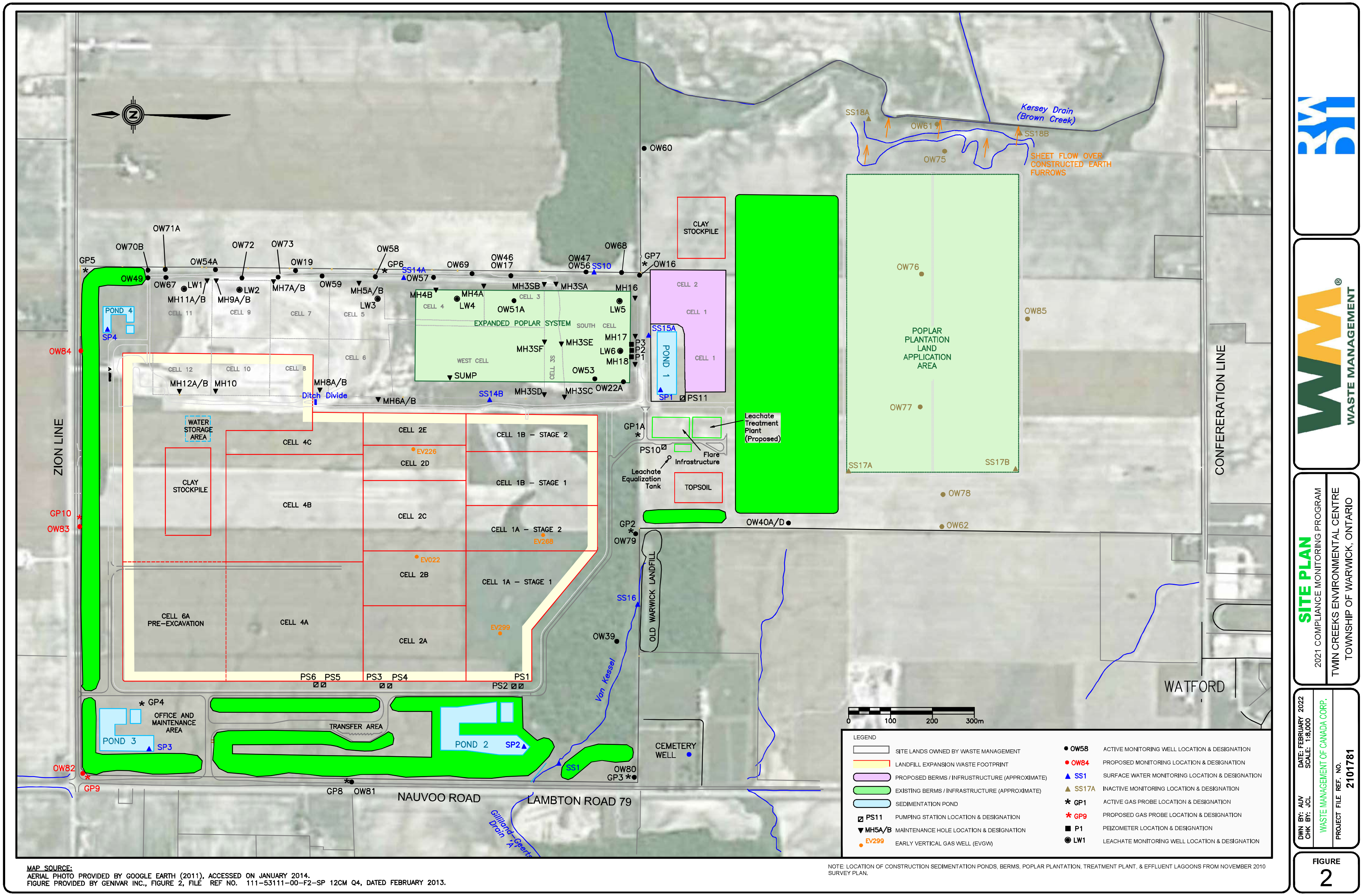
TWIN CREEKS ENVIRONMENTAL CENTRE
TOWNSHIP OF WARWICK, ONTARIO

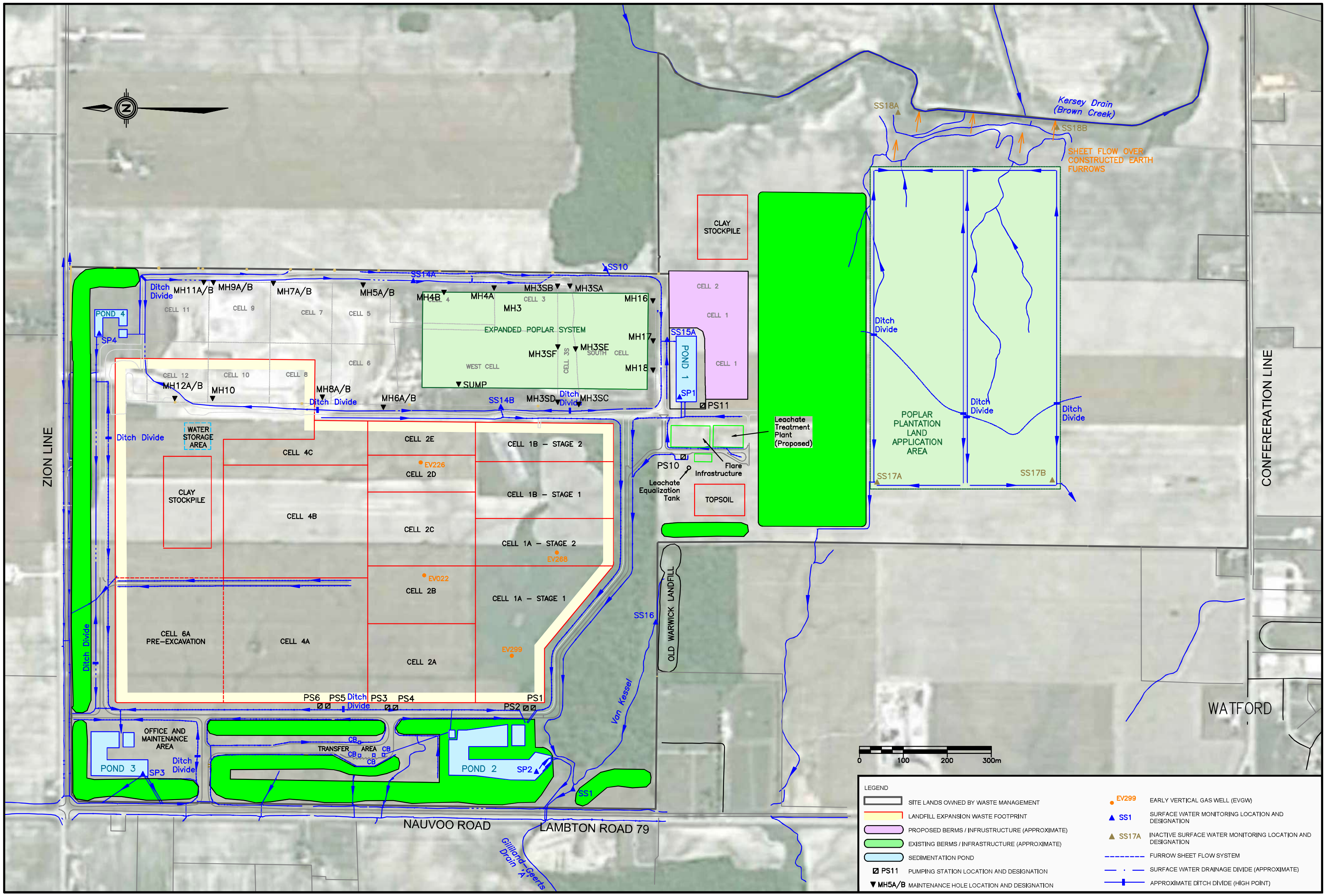
DWN BY: AJV
CHK BY: PEJ
DATE: MAY 2021
SCALE: 1:50,000

WASTE MANAGEMENT OF CANADA CORP.

PROJECT FILE REF. NO.
2101781

FIGURE
1


ZION LINE
CONFERERATION LINE
NAUVOO ROAD
LAMBTON ROAD 79
WATFORD
Kersey Drain (Brown Creek)
SHEET FLOW OVER CONSTRUCTED EARTH FURROWS
POPLAR PLANTATION LAND APPLICATION AREA
CLAY STOCKPILE
EXPANDED POPLAR SYSTEM
POND 1
POND 2
POND 3
POND 4
WATER STORAGE AREA
CELL 6A PRE-EXCAVATION
CELL 4A
CELL 4B
CELL 4C
CELL 2A
CELL 2B
CELL 2C
CELL 2D
CELL 2E
CELL 1A – STAGE 1
CELL 1A – STAGE 2
CELL 1B – STAGE 1
CELL 1B – STAGE 2
Leachate Treatment Plant (Proposed)
Flare Infrastructure
Leachate Equalization Tank
TOPSOIL
OLD WARWICK LANDFILL
Van Kessel
Gilliland-Geerts Drain 'A'
OFFICE AND MAINTENANCE AREA
TRANSFER AREA
CEMETERY WELL
Ditch Divide
0 100 200 300m
LEGEND
SITE LANDS OWNED BY WASTE MANAGEMENT
LANDFILL EXPANSION WASTE FOOTPRINT
PROPOSED BERMS / INFRUSTRUCTURE (APPROXIMATE)
EXISTING BERMS / INFRASTRUCTURE (APPROXIMATE)
SEDIMENTATION POND
PS11 PUMPING STATION LOCATION & DESIGNATION
MH5A/B MAINTENANCE HOLE LOCATION & DESIGNATION
EV299 EARLY VERTICAL GAS WELL (EVGW)
OW58 ACTIVE MONITORING WELL LOCATION & DESIGNATION
OW84 PROPOSED MONITORING LOCATION & DESIGNATION
SS1 SURFACE WATER MONITORING LOCATION & DESIGNATION
SS17A INACTIVE MONITORING LOCATION & DESIGNATION
GP1 ACTIVE GAS PROBE LOCATION & DESIGNATION
GP9 PROPOSED GAS PROBE LOCATION & DESIGNATION
P1 PEIZOMETER LOCATION & DESIGNATION
LW1 LEACHATE MONITORING WELL LOCATION & DESIGNATION
RWDI
WM WASTE MANAGEMENT
SITE PLAN
2021 COMPLIANCE MONITORING PROGRAM
TWIN CREEKS ENVIRONMENTAL CENTRE
TOWNSHIP OF WARWICK, ONTARIO
DATE: FEBRUARY 2022
SCALE: 1:8,000
DWN BY: AJV
CHK BY: JCL
WASTE MANAGEMENT OF CANADA CORP.
PROJECT FILE REF. NO.
2101781
FIGURE
2
MAP SOURCE:
AERIAL PHOTO PROVIDED BY GOOGLE EARTH (2011), ACCESSED ON JANUARY 2014.
FIGURE PROVIDED BY GENIVAR INC., FIGURE 2, FILE REF NO. 111-53111-00-F2-SP 12CM Q4, DATED FEBRUARY 2013.
NOTE: LOCATION OF CONSTRUCTION SEDIMENTATION PONDS, BERMS, POPLAR PLANTATION, TREATMENT PLANT, & EFFLUENT LAGOONS FROM NOVEMBER 2010 SURVEY PLAN.



MAP SOURCE:
AERIAL PHOTO PROVIDED BY GOOGLE EARTH (2011), ACCESSED ON JANUARY 2014.
FIGURE PROVIDED BY GENIVAR INC., FIGURE 3, FILE REF NO. 111-53111-00-F3-SP 12CM Q4, DATED JANUARY 2013.

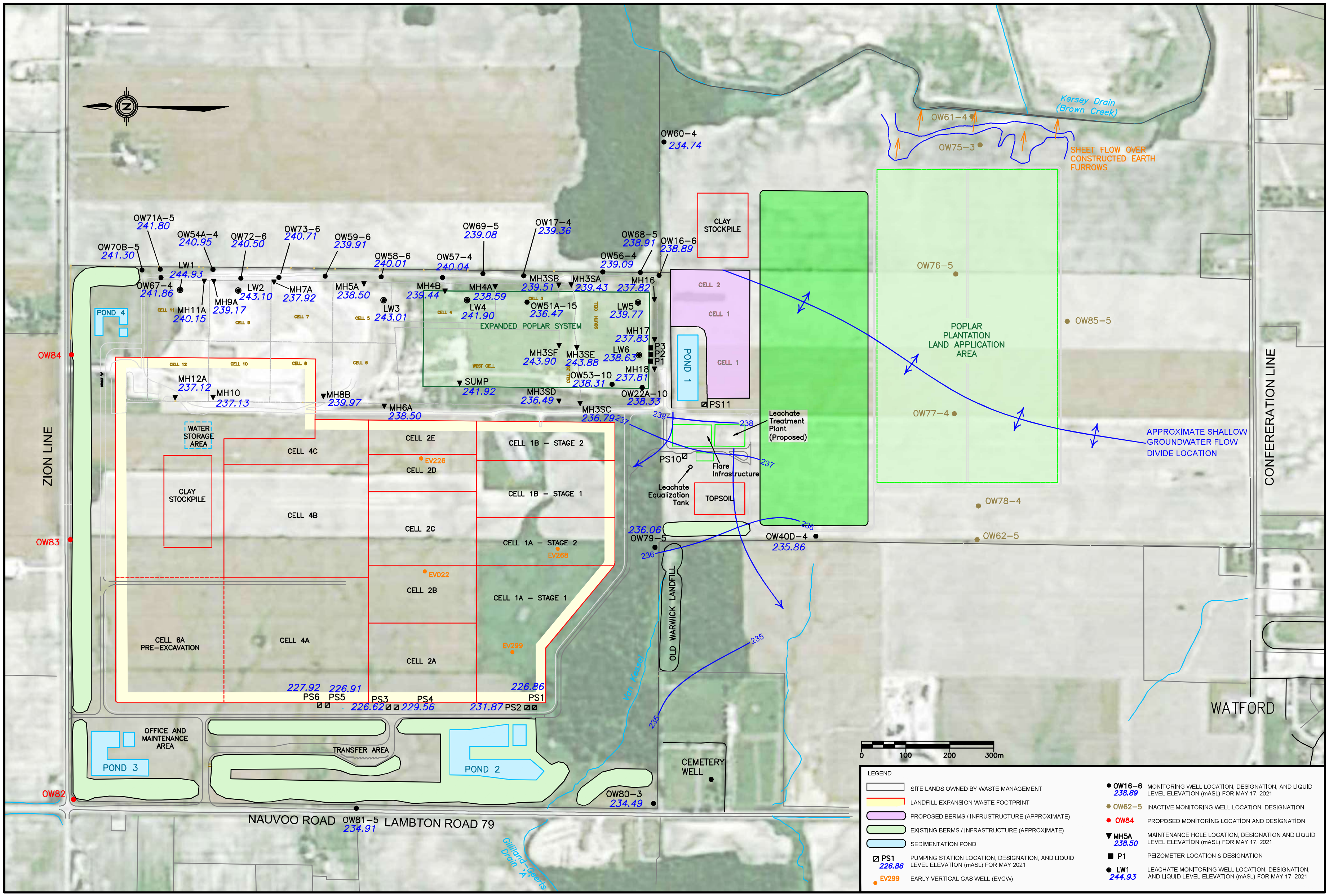
NOTE:
LOCATION OF CONSTRUCTION SEDIMENTATION PONDS, BERMS, POPLAR PLANTATION, TREATMENT PLANT, & EFFLUENT LAGOONS FROM NOVEMBER 2010 SURVEY PLAN.

WASTE MANAGEMENT

SURFACE WATER SYSTEM
2021 COMPLIANCE MONITORING PROGRAM
TWIN CREEKS ENVIRONMENTAL CENTRE
TOWNSHIP OF WARWICK, ONTARIO

DWN BY: AJV
CHK BY: JCL
DATE: FEBRUARY 2022
SCALE: 1:8,000
WASTE MANAGEMENT OF CANADA CORP.
PROJECT FILE REF. NO. 2101781

FIGURE
3



MAP SOURCE:
AERIAL PHOTO PROVIDED BY GOOGLE EARTH (2011), ACCESSED ON JANUARY 2014.
FIGURE PROVIDED BY GENIVAR INC., FIGURE 3, FILE REF NO. 111–53111–00–F4–GW 12CM Q4, DATED FEBUARY 2013.

NOTE:
LOCATION OF CONSTRUCTION SEDIMENTATION PONDS, BERMS, POPLAR PLANTATION, TREATMENT PLANT, & EFFLUENT LAGOONS FROM DECEMBER 2010 SURVEY PLAN.

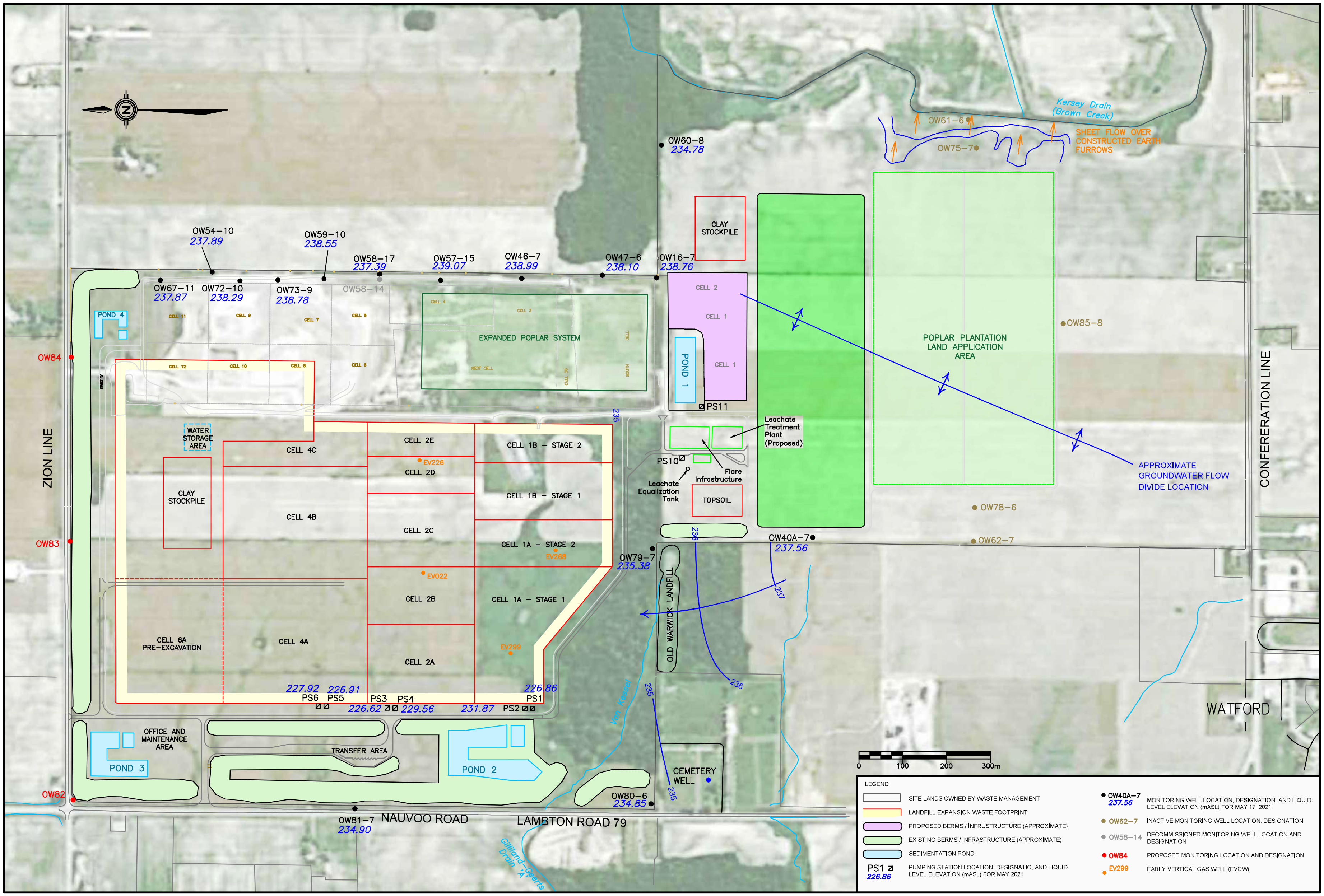
RWDI

WM WASTE MANAGEMENT

LEACHATE & SHALLOW GROUNDWATER ELEVATIONS
2021 COMPLIANCE MONITORING PROGRAM
TWIN CREEKS ENVIRONMENTAL CENTRE
TOWNSHIP OF WARWICK, ONTARIO

DWN BY: AJV
CHK BY: JCL
DATE: FEBRUARY 2022
SCALE: 1:8,000
WASTE MANAGEMENT OF CANADA CORP.
PROJECT FILE REF. NO. 2101781

FIGURE
4



NOTE:
LOCATION OF CONSTRUCTION SEDIMENTATION PONDS, BERMS, POPLAR PLANTATION, TREATMENT PLANT, & EFFLUENT LAGOONS FROM DECEMBER 2010 SURVEY PLAN.

MAP SOURCE:
AERIAL PHOTO PROVIDED BY GOOGLE EARTH (2011), ACCESSED ON JANUARY 2014.
FIGURE PROVIDED BY GENIVAR INC., FIGURE 3, FILE REF NO. 111-53111-00-F5-GW 12CM Q4, DATED FEBUARY 2013.

WASTE MANAGEMENT

INTERSTADIAL SILT AND SAND GROUNDWATER ELEVATIONS

2021 COMPLIANCE MONITORING PROGRAM

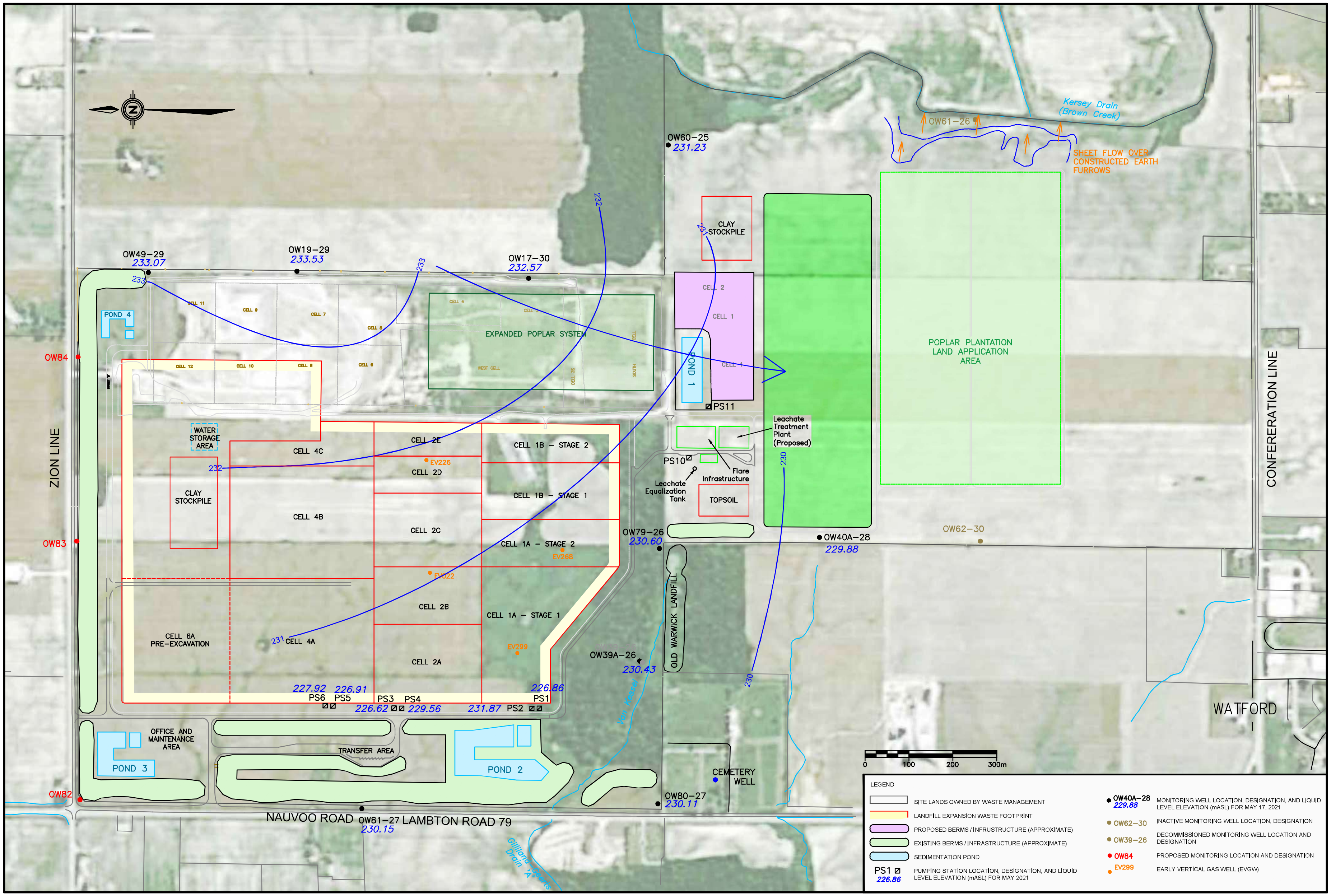
TWIN CREEKS ENVIRONMENTAL CENTRE
TOWNSHIP OF WARWICK, ONTARIO

DWN BY: AJV
CHK BY: JCL
DATE: FEBRUARY 2022
SCALE: 1:8,000

WASTE MANAGEMENT OF CANADA CORP.

PROJECT FILE REF. NO. **2101781**

FIGURE
5



MAP SOURCE:
AERIAL PHOTO PROVIDED BY GOOGLE EARTH (2011), ACCESSED ON JANUARY 2014.
FIGURE PROVIDED BY GENIVAR INC., FIGURE 3, FILE REF NO. 111–53111–00–F6–GW 12CM Q4, DATED FEBUARY 2013.

NOTE:
LOCATION OF CONSTRUCTION SEDIMENTATION PONDS, BERMS, POPLAR PLANTATION, TREATMENT PLANT, & EFFLUENT LAGOONS FROM DECEMBER 2010 SURVEY PLAN.

RWDI

WM WASTE MANAGEMENT

INTERFACE AQUIFER GROUNDWATER ELEVATIONS
2021 COMPLIANCE MONITORING PROGRAM
TWIN CREEKS ENVIRONMENTAL CENTRE
TOWNSHIP OF WARWICK, ONTARIO

DWN BY: AJV
CHK BY: JCL
DATE: FEBRUARY 2022
SCALE: 1:8,000
WASTE MANAGEMENT OF CANADA CORP.
PROJECT FILE REF. NO. 2101781

FIGURE
6

Table C-9
Historical Precipitation Data Summary
Twin Creeks Environmental Centre

Year	Climatological Station Precipitation Total (mm/a)	On-site Precipitation Total (mm/a)
30-Year Normal (1961-1990)	711.9	-
30-Year Normal (1971-2000)	935.5	-
30-Year Normal (1981-2010)	959.2	-
1995	868.7	-
1996, 1997	Complete annual data not available	-
1998	788.8	-
1999	805.1	-
2000	1,140.6	-
2001	867.2	-
2002	682.6	472.0
2003	982.8	726.7
2004	954.8	729.2
2005	898.3	577.0
2006	1,245.8	853.3
2007	804.4	699.8
2008	1,241.8	852.2
2009	1,001.8	729.1
2010	927.1	676.7
2011	1255.0	812.3
2012	860.2	592.7
2013	1,194.4	911.4
2014	895.6	829.5
2015	828.0	724.0
2016	1,012.8	816.5
2017	979.2	843.3
2018	1,169.6	951.3
2019	1007.6	808.6
2020	966.6	725.4
2021	1028.4	870.6

Notes

1) Dash (-) denotes climatologial station not operational

2) On-site precipiitation data collected from the automated RWDI Envision climatological station since 2019 instead of manual rain gauge readings, as in years prior.

Table I-1
Precipitation Event Surface Water Quality - Field Chemical Results
Twin Creeks Environmental Centre

Station Number	Location	pH	Conductivity	Temperature	Turbidity	Dissolved Oxygen	Estimated Flow Rate
		(pH units)	(µS/cm)	(°C)	(NTU)	(mg/L)	(L/s)
First Quarter							
March 26, 2021 (Routine monitoring for March 25, 2021 precipitation event)							
SS1	Downstream of landfill 60m east of Lambton Road 79	7.5	530	7.7	>1000	10.0	Flooded
SS10	Off-Site Flow into East Ditch Line - Background surface water quality	7.7	270	6.4	652	10.2	1
SS16	On-Site Flow from Township land to the south – Background surface water quality	7.4	288	7.9	97.9	8.8	28
SP1	Southeast Sedimentation Pond	7.7	636	9.8	466	9.3	136
SP2	Southwest Sedimentation Pond	7.7	722	8.8	588	9.8	111
SP3	Northwest Sedimentation Pond	7.8	596	8.9	88.2	9.8	<1
SP4	Northeast Sedimentation Pond	7.6	461	9.3	103	9.6	32
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	7.8	561	6.8	52.7	9.6	30
SS14B	On-Site Flow into West Ditch Line, Background of Poplar System	7.8	912	6.3	318	10.5	14
SS15A	On-Site Flow into Sedimentation Pond 1, intersecting point of East and West Ditch Line South of the Poplar System	7.5	636	7.4	658	9.2	36
April 9, 2021 (Verification monitoring for March 26, 2021 precipitation event)							
SS1	Downstream of landfill 60m east of Lambton Road 79	7.5	716	14.9	200	9.24	5
SP2	Southwest Sedimentation Pond	7.9	868	18.6	26.9	8.75	No Flow
Second Quarter							
June 3, 2021 (Routine monitoring for June 2, 2021 precipitation event)							
SS1	Downstream of landfill 60m east of Lambton Road 79	7.6	766	17.0	53.2	8.9	3
SS10	Off-Site Flow into East Ditch Line - Background surface water quality	Ins	Ins	Ins	Ins	Ins	Ins
SS16	On-Site Flow from Township land to the south – Background surface water quality	Ins	Ins	Ins	Ins	Ins	Ins
SP1	Southeast Sedimentation Pond	Ins	Ins	Ins	Ins	Ins	Ins
SP2	Southwest Sedimentation Pond	Ins	Ins	Ins	Ins	Ins	Ins
SP3	Northwest Sedimentation Pond	10.2	679	26.1	3.74	11.5	13
SP4	Northeast Sedimentation Pond	9.8	421	25.1	26.5	12.2	5
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
SS14B	On-Site Flow into West Ditch Line, Background of Poplar System	7.6	888	21.5	69.2	8.2	1
SS15A	On-Site Flow into Sedimentation Pond 1, intersecting point of East and West Ditch Line South of the Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
June 26, 2021 (Routine monitoring for June 25, 2021 precipitation event)							
SS10	Off-Site Flow into East Ditch Line - Background surface water quality	Ins	Ins	Ins	Ins	Ins	Ins
SP1	Southeast Sedimentation Pond	Ins	Ins	Ins	Ins	Ins	Ins
SP2	Downstream of landfill 60m east of Lambton Road 79	8.0	1096	20.8	19.3	6.22	14
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
SS15A	On-Site Flow into Sedimentation Pond 1, intersecting point of East and West Ditch Line South of the Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
July 9, 2021 (Verification monitoring for June 3, 2021 precipitation event after July 8, 2021 precipitation event)							
SP2	Southwest Sedimentation Pond	8.0	959	19.9	5.09	7.28	16
Third Quarter							
July 9, 2021 (Routine monitoring for July 8, 2021 precipitation event)							
SS1	Downstream of landfill 60m east of Lambton Road 79	7.6	781	17.5	50.8	9.16	2
SS10	Off-Site Flow into East Ditch Line - Background surface water quality	7.6	716	20.6	96.1	6.71	<1
SS16	On-Site Flow from Township land to the south – Background surface water quality	Ins	Ins	Ins	Ins	Ins	Ins
SP1	Southeast Sedimentation Pond	8.0	663	18.8	85.0	7.89	1
SP2	Southwest Sedimentation Pond	Unable to collect sample until after July 25, 2021 (1 month after Q2 routine sample)					
SP3	Northwest Sedimentation Pond	9.4	854	23.3	2.73	12.1	35
SP4	Northeast Sedimentation Pond	8.6	542	21.9	15.7	9.37	2
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
SS14B	On-Site Flow into West Ditch Line, Background of Poplar System	8.5	770	20.9	222	10.5	1
SS15A	On-Site Flow into Sedimentation Pond 1, intersecting point of East and West Ditch Line South of the Poplar System	7.7	617	20.6	56.5	7.82	<1
July 30, 2021 (Routine monitoring for July 29, 2021 precipitation event)							

Table I-1
Precipitation Event Surface Water Quality - Field Chemical Results
Twin Creeks Environmental Centre

Station Number	Location	pH	Conductivity	Temperature	Turbidity	Dissolved Oxygen	Estimated Flow Rate
		(pH units)	(µS/cm)	(°C)	(NTU)	(mg/L)	(L/s)
SP2	Southwest Sedimentation Pond	7.3	861	22.2	141	7.60	23
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
July 30, 2021 (Verification monitoring for July 9, 2021 precipitation event after July 29, 2021 precipitation event)							
SS1	Downstream of landfill 60m east of Lambton Road 79	7.9	590	21.3	69.0	8.70	9
September 8, 2021 (Storm event monitoring for September 7, 2021 precipitation event)							
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
SS14B	On-Site Flow into West Ditch Line, Background of Poplar System	8.1	728	21.8	83.7	8.75	<1
SS15A	On-Site Flow into Sedimentation Pond 1, intersecting point of East and West Ditch Line South of the Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
September 23, 2021 (Routine monitoring for September 22, 2021 precipitation event)							
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	7.9	547	15.7	20.2	9.11	3
September 23, 2021 (Storm event monitoring for September 22, 2021 precipitation event)							
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	7.9	547	15.7	20.2	9.11	3
SS14B	On-Site Flow into West Ditch Line, Background of Poplar System	8.2	978	15.8	>1000	9.68	1
SS15A	On-Site Flow into Sedimentation Pond 1, intersecting point of East and West Ditch Line South of the Poplar System	7.8	693	14.6	74.1	8.39	5
Fourth Quarter							
October 4, 2021 (Routine monitoring for October 3, 2021 precipitation event)							
SS1	Downstream of landfill 60m east of Lambton Road 79	7.4	684	20.4	11.9	8.74	20
SS10	Off-Site Flow into East Ditch Line - Background surface water quality	Ins	Ins	Ins	Ins	Ins	Ins
SS16	On-Site Flow from Township land to the south – Background surface water quality	Ins	Ins	Ins	Ins	Ins	Ins
SP1	Southeast Sedimentation Pond	8.2	696	22.4	28.7	9.21	15
SP2	Southwest Sedimentation Pond	8.9	607	23.9	27.4	9.76	11
SP3	Northwest Sedimentation Pond	8.6	534	23.7	45.8	9.17	288
SP4	Northeast Sedimentation Pond	8.2	500	24.2	34.6	8.55	4
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
SS14B	On-Site Flow into West Ditch Line, Background of Poplar System	Ins	Ins	Ins	Ins	Ins	Ins
SS15A	On-Site Flow into Sedimentation Pond 1, intersecting point of East and West Ditch Line South of the Poplar System	7.7	744	21.3	21.8	7.26	6
October 15, 2021 (Verification monitoring for October 4, 2021 precipitation event)							
SS1	Downstream of landfill 60m east of Lambton Road 79	8.1	725	19.5	83.7	8.30	45
SP2	Southwest Sedimentation Pond	8.4	844	19.7	143	8.71	120
SP3	Northwest Sedimentation Pond	8.0	685	19.6	15.4	8.07	42
October 26, 2021 (Routine monitoring for October 25, 2021 precipitation event)							
SS14A	On-Site Flow into East Ditch Line, Upstream of Poplar System	7.6	760	7.3	19.6	10.0	1
SS14B	On-Site Flow into West Ditch Line, Background of Poplar System	8.2	1141	7.8	42.4	11.4	3

Notes:
1) Ins denotes insufficient volume to sample.
2) µS/cm denotes microsiemens per centimetre.
3) °C denotes degrees Celsius.
4) NTU denotes nephelometric turbidity unit.
5) mg/L denotes milligrams per litre.
6) L/s denotes litres per second.
7) Estimated Flow Rate = Average flow rate (m/s) x channel width (m) x channel depth (m) x 1000 L/m3
8) NR denotes not recorded

F

PTTW & Riparian Property Owners Survey

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December 15, 2023

Mr. Sean Morrison, District Manager
Ministry of the Environment, Conservation and Parks - Sarnia District Office
1094 London Road
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T: 519.336.4030
E: Sean.Morrison@ontario.ca

Re: Condition 4.2 – Work Plan to Investigate the Potential Impacts of the Water Taking Twin Creeks Environmental Centre – Permit To Take Water No. 4682-BLJRYJ
RWDI Reference No. 2303459.5000

Dear Mr. Morrison,

On behalf of Waste Management of Canada Corporation (WM), RWDI AIR Inc. (RWDI) is pleased to provide to the Ministry of the Environment, Conservation and Parks (MECP) the findings of the Work Plan to satisfy the requirements of Condition 4.2 of the Permit To Take Water (System No. 4682-BLJRYJ), dated November 8, 2021 (PTTW). The Work Plan is included as **Appendix A**, and was approved by the MECP on January 16, 2023, as included in **Appendix B**.

The purpose of the Work Plan was the complete the following studies along the length of Gilliland-Geerts Drain between Nauvoo Road and Underpass Road.

1) An Ecological Study to evaluate the potential impacts of the water taking on the downstream ecosystem.
2) A survey of downstream riparian property owners.

ECOLOGICAL STUDY

The Ecological Study were completed by Natural Resource Solutions Inc. from Waterloo, ON. Their findings are included as **Appendix C**.

In summary, the Ecological Study indicated that water from the on-site Sedimentation Ponds was primarily used to control dust within the PTTW during the summer season. 2022 represented a relatively dry year in comparison to the 30-Year Normal, and therefore water taking had the potential to elicit more pronounced impacts on downstream ecosystems. However, no ecological impacts were observed in 2022. Completing an impact assessment for a comparatively dry year provides additional confidence that water taking during future years can proceed without causing any negative impacts to the ecological functions within the Gilliland-Geerts Drain.

The conclusion of this Ecological Study is that there is no evidence that water taking within the TCEC is causing any impacts or changes to the ecosystem within or adjacent to the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road.

SURVEY OF DOWNSTREAM RIPARIAN PROPERTY OWNERS

The Survey of Downstream Riparian Property Owners Was completed by RWDI from Guelph ON. Their findings are included as **Appendix D**.

In summary the survey indicated that there is no water taking from the Gilliland-Geerts Drain. Therefore, in accordance with the Work Plan an assessment of potential impacts on riparian water users was not required to be completed. Also, as responses were not received from 5 owners (representing 6 properties) an assessment of potential impacts on riparian water users was not required to be completed for the properties they owned.

CONCLUSION

We trust that the findings of the Work Plan are sufficient to satisfy the requirements of Condition 4.2 of the Permit To Take Water (System No. 4682-BLJRYJ), dated November 8, 2021. Please contact us with any questions that you may have.

Respectfully submitted by:

RWDI AIR Inc.

Khalid Hussein, P.Eng.
Project Manager

Brent J. Langille, B.Sc., P.Geo.
Senior Technical Director | Principal

KAMH/BJL/kta

Attach.

APPENDICES

APPENDIX A

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March 25, 2022

Mr. Sean Morrison, District Manager
Ministry of the Environment, Conservation and Parks - Sarnia District Office
1094 London Road
Sarnia Ontario N7S 1P1
519.336.4030
E: sean.morrison@ontario.ca

Re: Permit To Take Water No. 4682-BLJRYJ - Condition 4.2
Work Plan to Investigate the Potential Impacts of the Water Taking
Waste Management of Canada - Twin Creeks Environmental Centre
RWDI Reference No. 2202861.06

Dear Mr. Morrison,

On behalf of Waste Management of Canada Corporation (WM), RWDI AIR Inc. (RWDI) is pleased to provide to the Ministry of the Environment, Conservation and Parks (MECP) the following Work Plan to Investigate the Potential Impacts of the Water Taking (Work Plan) to satisfy the requirements of Condition 4.2 of the Permit To Take Water (System No. 4682-BLJRYJ), dated November 8, 2021 (PTTW).

The purpose of this Work Plan is to outline the studies that WM will complete to satisfy Condition 4.2, which states: "*Within 180 days of the issuance of this Permit, the Permit Holder shall submit to the District Manager, a Plan (the "Plan") to investigate the potential impacts of the Water Taking. The Plan shall include two components:*

a. An Ecological Study which includes an inventory of the ecosystem in the immediate vicinity of the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road, and an assessment of potential impacts of the water taking on that ecosystem; and

b. A survey of downstream riparian property owners along the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road to determine the extent of any surface water uses by those property owners and assess any impacts of the water taking on those uses.

The Plan shall include timelines for completing the outlined work. Upon acceptance of the Plan by the District Manager, the Permit Holder shall complete the action items outlined with the Plan within the prescribed timelines."

Ecological Study

The tasks and subtasks of the Ecological Study to address Condition 4.2 a. are outlined below.

- Complete an inventory of the ecosystem in the immediate vicinity of the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road as outlined below.
  - Background data review pertaining to the biological resources.
  - Desktop Species at Risk (SAR), Species of Conservation Concern (SCC), and Significant Wildlife Habitat screening.
  - Targeted field surveys to collect baseline information on the ecological function and character of natural habitats within approximately 50m of the Gilliland-Geerts Drain where access to private property is granted. Surveys will include:
    - ecological Land Classification (ELC) and 3-season vegetation inventory;
    - breeding bird surveys;
    - anuran call surveys;
    - general area searches for insects, reptiles, and mammals;
    - aquatic habitat assessments; and
    - fish community assessments
  - Analysis of natural feature significance based on the results of the above-noted surveys and background information review
  - Evaluation of the sensitivity of vegetation communities and wildlife habitats to hydrological change

- Complete an assessment of potential impacts of the water taking on the ecosystem according to the results of the natural feature significance analysis and the hydrological sensitivity evaluation.

WM will retain Natural Resource Solutions Inc. from Waterloo, ON to complete the Ecological Study including the ecosystem inventory and impact assessment.

Survey of Downstream Riparian Property Owners

A survey of downstream riparian property owners along the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road will be completed. The purpose of this survey will be to determine the extent of any surface water uses by those property owners and assess any impacts of the water taking on those uses.

The tasks and subtasks of the survey of downstream riparian property owners to address Condition 4.2 b. are outlined below.

- Complete a Riparian Property Owners Water Use Survey (Survey) which will include the following tasks.
    - Identify the properties adjacent to the Gilliland-Geerts Drain. These 11 properties are displayed on **Figure 1** (attached).
    - Determine the property ownership for these 11 properties.
    - Contact the property owners and conduct the Survey. The Survey will ask the following questions.
        - Does the owner use or take water from the drain?
        - What are the uses of the water taken from the drain?
        - Is any infrastructure installed to take water?
        - How often is the water used (e.g. Daily, Monthly, Seasonally, Yearly)?
        - What quantity of water is used? Provide pumping rate if applicable (e.g. Gal/min or L/min)?

- Complete an assessment of potential impacts of the water taking on riparian water users.
    - Note: If the Survey identifies that no water is being taken, then the assessment of potential impacts on riparian water users will not be completed. If responses are not received from Owner(s) the assessment of potential impacts will not consider related properties.

WM will retain RWDI AIR Inc. from Guelph, ON to complete the Riparian Property Owners Water Use Survey and impact assessment.

TIMELINE

The timeline for completing the outlined work noted below.

- If this workplan is approved by December 31, 2022:
    - the Ecological Study and assessment of potential impacts will be conducted during the spring and summer of 2023;
    - the Riparian Property Owners Water User Survey and impact assessment will be conducted during the summer of 2023; and
    - the findings will be presented to the MECP Sarnia District Office by December 31, 2023.

CONCLUSION

We trust that this Work Plan is sufficient to satisfy the requirements of Condition 4.2 of the Permit To Take Water (System No. 4682-BLJRYJ), dated November 8, 2021. On behalf of WM, RWDI looks forward to receiving approval from the MECP Sarnia District Office to proceed with the Ecological Study and Riparian Property Owners Water Use Survey. It is understood that the Township of Warwick may have comments on the Workplan which may affect the scheduling of the proposed studies noted herein.

Please contact us with any questions or comments that you may have. We appreciate the MECP's time and consideration on this Work Plan such that it can be implemented within the timelines noted herein. Upon written approval by the MECP of this Work Plan, WM will initiate the undertaking as detailed above.

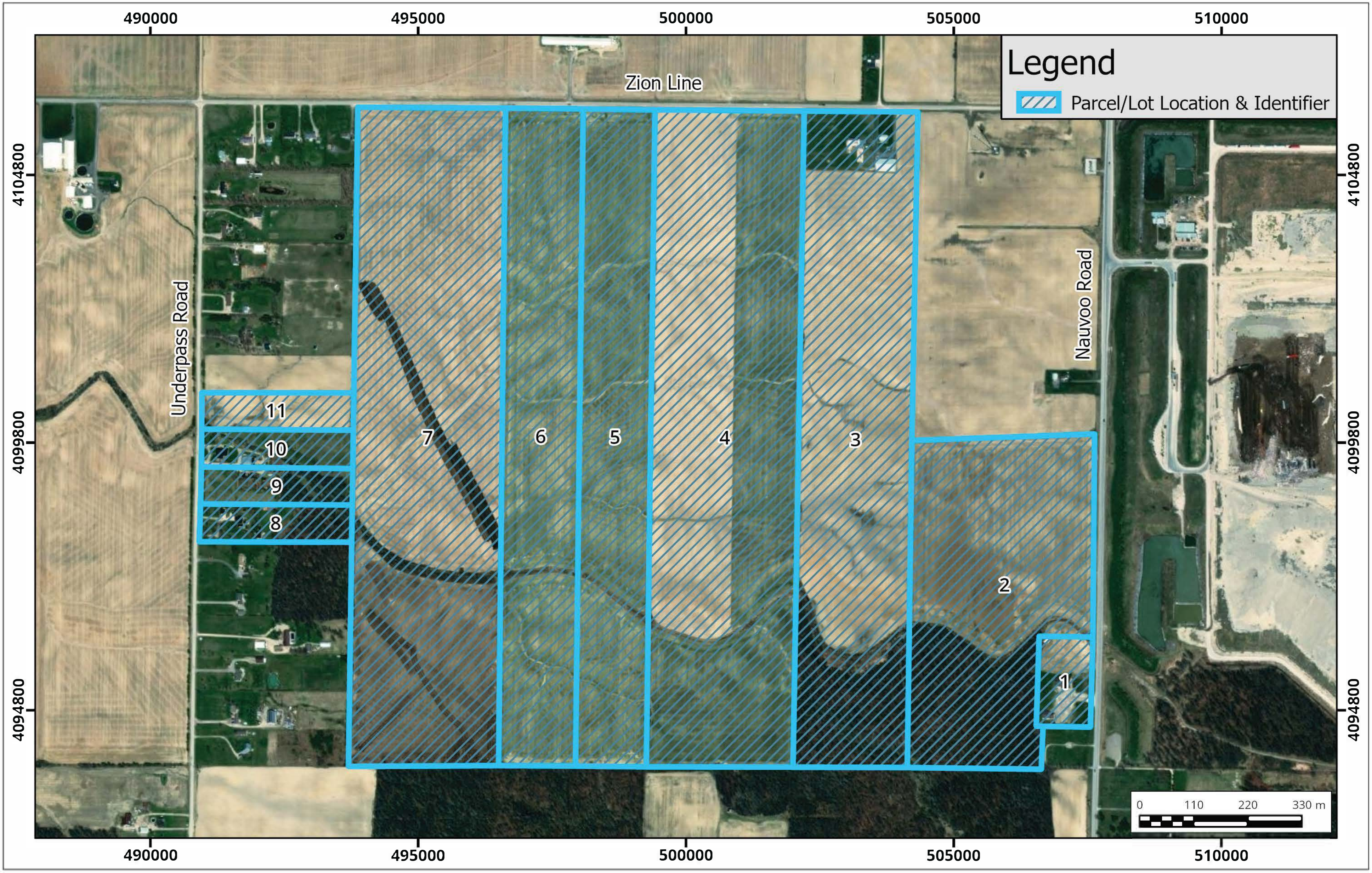
Respectfully submitted by:

RWDI AIR Inc.

Khalid Hussein, P.Eng.
Project Manager

Brent J. Langille, B.Sc., P.Geo.
Technical Director | Principal

FIGURE



Downstream Riparian Properties
Permit to Take Water 4682-BLJRYJ Condition 4.2 Work Plan

Notes:
1. Basemap provided by esri, accessed January, 2022.

True North

Drawn by: AUV	Figure: 1
Approx. Scale:	1:10,892
Date Revised:	Jan 18, 2022

Map Projection: NAD 1983 UTM Zone 17N
Waste Management of Canada Corp. - Twin Creeks Environmental Centre, Township of Warwick, Ontario

Project #: 2101781

APPENDIX B

Ministry of the Environment, Conservation and Parks

Southwest Region

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Ontario

January 16, 2023

John McDonald, Senior District Manager
Waste Management of Canada Corporation
Twin Creeks Environmental Centre
5768 Nauvoo Rd Watford
Warwick Township, County of Lambton
N0M 2S0

Dear Mr. McDonald,

Re: Permit to Take Water No. 4682-BLJRYJ – Condition 4.2 Work Plan

The Ministry of the Environment, Conversation and Parks (MECP) has reviewed the Work Plan to Investigate the Potential Impacts of the Water Taking, dated March 25, 2022, submitted by Brent J. Langille, of RWDI on behalf of Waste Management of Canada Corporation as required under Condition 4.2 of Permit to Take Water No. 4682-BLJRYJ. The MECP has also reviewed the comments and responses to Walpole Island First Nation (WIFN) and Warwick Township's Technical Review Team (TRT).

The MECP is satisfied with the workplan as presented. WIFN and the TRT have requested additional detail with respect to the workplan and received RWDI response in return (August 30, 2022 responses). The MECP is satisfied with the responses provided by RWDI. In the absence of follow up communication from stakeholders, the MECP is of the opinion that Condition 4.2 has been met and that the workplan can proceed as amended by RWDI responses to stakeholder comments.

If you have any questions regarding the above, please feel free to contact Provincial Officer Michael Harris at 226-932-2720.

Yours truly,

Sean Morrison
District Manager
Sarnia/Windsor District

APPENDIX C

Twin Creeks Environmental Centre PTTW No. 4682-BLJRYJ

Ecological Study

Prepared for:

WM Canada Corporation
5768 Nauvoo Road
Watford, ON
N0M 2S0

Project No. 2538B | December 2023

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Twin Creeks Environmental Centre PTTW No. 4682-BLJRYJ

Ecological Study

Project Team

Desta Frey	Terrestrial & Aquatic Biologist, Project Manager & Report Author
Elaine Gosnell	Senior Terrestrial & Wetland Biologist, Report Reviewer
Katharina Richter	Senior Terrestrial & Wetland Biologist, Project Advisor
Nathan Grant	Terrestrial & Aquatic Biologist
Monica Varga	GIS Analyst

Report submitted on December 12, 2023

Desta Frey
Project Manager
Terrestrial & Aquatic Biologist

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1.0 Introduction

Natural Resource Solutions Inc. (NRSI) was retained by WM Canada Corporation (WM) to complete an Ecological Study required as a condition of Permit to Take Water (PTTW) No. 4682-BLJRYJ, issued for water taking within the Twin Creeks Environmental Centre (TCEC). The TCEC is a regional landfill facility that provides disposal services for the province of Ontario and is approved to receive municipal, industrial, commercial, and institutional solid non-hazardous wastes generated, including non-hazardous contaminated soil. The TCEC is located at 5768 Nauvoo Road in the Township of Warwick, within the County of Lambton. The TCEC lies to the north of the community of Watford and is generally bounded by Confederation Line to the south, Nauvoo Road to the west, Zion Line to the north, and agricultural lands to the east.

PTTW No. 4682-BLJRYJ was issued to WM Canada Corporation by the Ministry of the Environment, Conservation and Parks (MECP) on November 8, 2021. Condition 4.2.a of the permit states that an investigation of potential impacts of the water-taking is necessary and must include "*An ecological study which includes an inventory of the ecosystem in the immediate vicinity of the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road, and an assessment of potential impacts of the water taking on that ecosystem."*

The study area for this Ecological Study is defined as the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road, in addition to the lands within approximately 300m (which allows the assessment of potential impacts on all aquatic and terrestrial features with the potential to be impacted by water taking activities). The study area is shown on Map 1.

In 2022, NRSI biologists completed comprehensive, three-season field surveys within the study area to inform the ecological components of the ongoing TCEC Landfill Optimization Project Environmental Assessment (EA). The EA is being carried out in accordance with the requirements of the *Ontario Environmental Assessment Act* (OEAA, R.S.O. 1990) and a Terms of Reference (ToR) approved by the MECP on December 13, 2022. This PTTW Ecological Study report draws on that study and describes the existing ecological conditions within and adjacent to the Gilliland-Geerts Drain, and provides an analysis of natural feature significance based on the results of field surveys and a review of available background information. An evaluation of the sensitivity of nearby vegetation communities and species, fish and wildlife habitats, and important ecosystem functions is also described and was used to assess potential impacts to sensitive features and species from water taking within the TCEC.

2.0 General Study Context

In early 2007, a Notice of Approval to Proceed with the Undertaking was issued regarding the OEAA approval of the Warwick Landfill Expansion (renamed Twin Creeks Landfill and subsequently to Twin Creeks Environmental Centre). The current TCEC consists of an older existing landfill and the area approved for expansion.

On behalf of WM, RWDI prepared the 2022 Fourth Quarter and Annual Monitoring Report, Volumes 1 and 2: Compliance Monitoring and Operations Program for the TCEC (RWDI 2023). Referred to herein as the '2022 Annual Report', this document summarizes the results of compliance monitoring for the 2022 calendar year and presents the most recent information available related to water takings and surface water management within the TCEC at the time of writing. The 2022 Annual Report addresses requirements set out in the terms and conditions of regulatory permits (the PTTW) and Environmental Compliance Approvals (ECAs) specific to waste, sewage, and air for the landfill site, gas flare systems, and stormwater management (SWM) facilities for the January 1 to December 31, 2022 reporting period. NRSI biologists have interpreted and summarized relevant information from the 2022 Annual Report in relation to water taking volumes and methods, surface water drainage characteristics, and the hydrogeological conditions within the study area. In addition to the 2022 Annual Report (RWDI 2023a), the following documents were also reviewed to inform this Ecological Study:

- PTTW No. 4682-BLJRYJ issued by the MECP on November 8, 2021, referred to herein as the 'Permit Document' and inclusive of the terms and conditions of the PTTW; and
- Development & Operations Plans: Warwick Landfill Expansion Volume 1 of 3 (Henderson Paddon & Associates 2008), referred to herein as the 'D&O Plan'.

2.1 Surface Water Systems

Under existing conditions, the total drainage area that flows through the TCEC is estimated to be approximately 318ha, which is slightly larger than the landfill property itself (i.e., lands owned by WM), which is 301ha (RWDI 2023). Most lands within the TCEC total drainage area drain westward towards the St. Clair River and are within the Bear Creek Headwaters watershed (RWDI 2023b). The remaining total drainage area drains south towards the Sydenham River and are within the Brown Creek watershed. The division between the Bear Creek and Brown Creek watersheds is shown on Figure 8-2 of the D&O Plan (Henderson Paddon & Associates 2008), a copy of which has been provided in Appendix I.

Areas contributing to the Brown Creek watershed are mostly located in the southeastern portion of the TCEC, with an additional minor contribution from a small area draining the northeastern edge of the landfill property (Appendix I). Surface runoff originating in these areas sheetflows overland and either infiltrates or is conveyed by the on-site ditch network emptying to the Kersey Drain (Brown Creek). Surface water within the remaining lands (generally the north and eastern portions of the TCEC) ultimately drains to the Bear Creek watershed. In these areas, runoff is managed through a network of ditches and swales, a temporary water storage area, and four Sedimentation Ponds. Detailed mapping of all components of the surface water system within the TCEC is shown on Figure 3 of the 2022 Annual Report (RWDI 2023), a copy of which is also provided in Appendix I. The Gilliland-Geerts Drain (i.e., the focal feature of this Ecological Study) is part of the Bear Creek watershed; the subsequent sections will therefore exclusively discuss the drainage systems that are relevant to the study area of this report. The Bear Creek Headwaters watershed falls within the jurisdiction of the St. Clair Region Conservation Authority (SCRCA) and has a total area of approximately 37,900ha (SCRCA 2018).

Sedimentation Ponds 1 through 4 were constructed in 2009 and primarily manage runoff originating from the operational areas of the TCEC. Surface water collected within the Sedimentation Ponds has been used by the TCEC for industrial purposes since they were constructed (see additional details in Section 2.2 below and RWDI 2023). Ponds 1, 2, and 3 are hydrologically connected to the Gilliland-Geerts Drain subwatershed, while Pond 4 ultimately discharges to a northern tributary of Bear Creek (north of Zion Line) via the tiled Laird Drain (RWDI 2023, OMAFRA 2023). Of the total TCEC drainage area that flows to the Bear Creek watershed, the majority drains to the Gilliland-Geerts Drain (Henderson Paddon & Associates 2008). The remaining areas drain to hydrologically separate Bear Creek tributaries to the north (Laird Drain) or south (Brown-Jarriott Drain) and therefore do not contribute to conditions within the Gilliland-Geerts Drain. Surface water runoff in the areas that contribute to the Gilliland-Geerts Drain is managed in large part by Sedimentation Ponds 1, 2, and 3; surface water is also conveyed overland through on- and off-site ditches and enters the Gilliland-Geerts Drain subwatershed via one of two routes (also see Appendix I):

- Through the feature previously known as the Van Kessel Drain, which discharges to a municipal drainage tile and catch basin that ultimately outlets to the Sedimentation Pond 2 drainage ditch and then under Nauvoo Road before flowing into the main stem of the Gilliland-Geerts Drain; or

- Through an existing headwater drainage feature (HDF) previously referred to as 'Gilliland-Geerts Drain Branch' but updated recently on the interactive mapping tool 'AgMaps' (OMAFRA 2023) to reflect the feature's mostly naturalized condition. For the purposes of this Ecological Study report, this feature will be referred to as HDF 1.

Sedimentation Ponds 1 through 4, the Van Kessel Drain, HDF 1, and the Gilliland-Geerts Drain are shown on Map 1; where applicable, Department of Fisheries and Oceans (DFO) drain classifications are also shown on Map 1 for the stream network within the study area (OMAFRA 2023). It is noted here (with additional discussion provided in Section 4.3.1 below) that although the DFO has classified the portion of the Gilliland-Geerts Drain (between the TCEC and approximately 1.2km downstream) as a 'Class E drain with permanent flows and a warmwater thermal regime'. Based on the results of investigations completed to inform the Warwick Landfill Expansion EA (Gartner Lee Ltd. 2004), and confirmed through subsequent observation of the system in the intervening years by RWDI, this designation is incorrect. Surface water flows within the Gilliland-Geerts Drain are ephemeral, with visible flows only occurring after snowmelt or prolonged periods of precipitation (Gartner Lee Ltd. 2004, Henderson Paddon & Associates 2008, RWDI 2023). The Gilliland-Geerts Drain is also a highly-modified system that has been historically channelized in sections and was originally constructed to receive flows from the extensive tile drain network within adjacent agricultural fields. A constructed pond feature of anthropogenic origin is also present within the Gilliland-Geerts Drain near Underpass Road, and is visible on aerial imagery dating back to at least 2003 (as reviewed on Google Earth). This online pond-like feature has subsequently caused water to back-up within the Gilliland-Geerts Drain on adjacent properties to the south and east of Underpass Road.

2.2 Water Taking Activities

In Ontario, a PTTW may be required when a person plans to take ≥50,000 L/day from any surface or groundwater source in the environment. The PTTW program ensures that water resources in the province are protected and used sustainable, and that water taking activities in Ontario are managed in accordance with the Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement (OMNR 2005). Water taking is governed by Ontario Regulation (O. Reg.) 387/04 (Water Taking and Transfer) under the *Ontario Water Resources Act* (R.S.O. 1990).

PTTW No. 4682-BLJRYJ was issued to WM in part for the removal of surface water from the four Sedimentation Ponds within the TCEC for industrial purposes; it cancels and replaces an earlier PTTW issued in January 2012. The necessity for water-taking at the TCEC generally commenced in 2008 with the initiation of landfill expansion activities, and a PTTW has been in place since that time. The current PTTW covers water-taking from surface and groundwater sources at several locations within the TCEC, as outlined in Table A of the Permit Document.

Surface water runoff from the landfill is collected in the four Sedimentation Ponds, and then taken as needed for the purposes of on-site dust control and road cleaning during landfill operations (RWDI 2023). The PTTW also covers dewatering of groundwater from the Secondary Drainage Layer (SDL) (denoted as dug wells PS2, PS4, PS6, and PS8 in Table A of the Permit Document). Maximum daily water taking limits authorized by PTTW No. 4682-BLJRYJ across the TCEC, inclusive of both surface and groundwater sources, is a total of 42,068,160 L/day.

In 2022, surface water was taken from Ponds 1, 2, 3, and 4, with total litres taken within the calendar year ranging between 279,000 L (Pond 1) to 7,570,750 L (Pond 2) (RWDI 2023). Groundwater was also taken from pumping station PS6 for use as recompacted clayey liner soil conditioning (RWDI 2023). Maximum value limits set out in the Permit Document for litres taken per minute and day, hours taken per day, and days taken per year were never exceeded during the 2022 calendar year; all water-taking remained in compliance with the PTTW limits for the site (RWDI 2023).

The hydrology of the Gilliland-Geerts Drain is driven almost entirely by surficial processes, and does not receive any meaningful input from groundwater sources originating within the TCEC (Henderson Paddon & Associates 2008). As a result, this Ecological Study focuses on potential ecosystem impacts related to changes in surface water flows during water taking activities. Details on the hydrogeological setting and groundwater conditions are presented in Section 4.1 for informational purposes but do not require further consideration under the scope of this study.

3.0 Methods

To provide a fulsome characterization of the existing conditions of the terrestrial and aquatic environments within and adjacent to the Gilliland-Geerts Drain, results of available ecological background information have been combined with the results of seasonal field surveys completed by NRSI biologists in 2022.

3.1 Background Information Review

Information on natural heritage features, vegetation, wildlife, Species at Risk (SAR), Species of Conservation Concern (SCC), and Significant Wildlife Habitat (SWH) from within at least 1km (and up to 10km in the case of wildlife atlas data) of the study area was collected and reviewed. The background sources included the following:

- Natural Heritage Information Centre (NHIC) database (MNRF 2023a);
- Species at Risk (SAR) listings at the federal and provincial levels (MECP 2023a, Government of Canada 2023);
- Township of Warwick Official Plan (2021);
- County of Lambton Official Plan (2020);
- St. Clair Region Conservation Authority (SCRCA) regulations mapping (SCRCA 2023);
- Bear Creek Headwaters Subwatershed Report Card 2018 (SCRCA 2018);
- Warwick Landfill Expansion Environmental Assessment: Natural Environment and Resources Baseline Report (Gartner Lee Ltd. 2004).
- Aquatic Resource Area data (MNRF 2023b);
- Department of Fisheries and Oceans (DFO) Aquatic Species at Risk Mapping (DFO 2023);
- Ontario Breeding Bird Atlas (BSC et al. 2006);
- Ontario Reptile and Amphibian Atlas (Ontario Nature 2019);
- Ontario Mammal Atlas (Dobbyn 1994);
- Ontario Butterfly Atlas (Macnaughton et al. 2023);
- Ontario Odonata Atlas Database (OOAD 2023); and
- Research-grade observations from community-based wildlife databases including eBird (2023) and iNaturalist (2023).

Requests for available background information were submitted by NRSI biologists to the MECP, Ministry of Natural Resources and Forestry (MNRF), and SCRCA on February 22, 2021. A response was received from the MECP on March 15, 2021 (Zarkovich, pers. comm. 2021), and from the SCRCA on February 25, 2021 (Hodgkiss, pers. comm. 2021). A response to the information request was not received from the MNRF.

Wildlife lists were prepared to summarize the species observed and reported from the vicinity of the study area. Information on species from the 10km x 10km square overlapping the study area was compiled (square #17MH25). Species lists incorporated data from these background sources and were then updated based on 2022 field survey results.

3.1.1 Significant Species Screening

SAR are those listed under Ontario Regulation (O. Reg. 230/08) to the *Endangered Species Act* (ESA, 2007), referred to as the Species at Risk in Ontario List (MECP 2023a). These include species identified by the Committee on the Status of Species at Risk in Ontario (COSSARO) as provincially Endangered, Threatened, or Special Concern. Species listed as Endangered or Threatened are protected under the ESA, which includes protection to their habitats.

SCC are defined as:

- Species designated provincially as Special Concern;
- Species that have been assigned a conservation status (S-Rank) of S1 to S3 or SH by NHIC; and
- Species that are designated federally as Threatened or Endangered by the Committee for the Status of Endangered Wildlife in Canada (COSEWIC) but not provincially by the COSSARO. These species may be protected by the federal *Species at Risk Act* (SARA) if they are listed as Threatened or Endangered on Schedule 1 of the SARA.

To assess if potential impacts to SAR or SCC would require analysis as part of this Ecological Study, the habitat requirements for SAR and SCC with records from the vicinity of the study area were compared with the habitats available within and adjacent to the Gilliland-Geerts Drain. The full results of the Significant Species Screening are provided in Appendix II.

3.1.2 Significant Wildlife Habitat Screening

A screening exercise was also conducted to determine the presence of any Significant Wildlife Habitat (SWH) types within the study area. The Significant Wildlife Habitat Technical Guide (SWHTG) outlines the types of habitats that the MNRF considers significant in Ontario, as well as criteria to identify these habitats for Ecoregion 7E (OMNR 2000, MNRF 2015). The SWHTG groups SWH into four broad categories: seasonal concentration areas, rare vegetation communities and specialized wildlife habitat, habitats of SCC, and animal movement corridors.

Potential SWH types were screened based on NRSI biologists' knowledge of the natural heritage features within the study area and using the discrete significance criteria established by the MNRF (2015). The full results of the SWH Screening are provided in Appendix III.

3.2 Field Surveys

NRSI biologists conducted comprehensive field surveys within the study area and surrounding lands to characterize the form and function of natural heritage features. The scope of field surveys was determined through the ToR process for the ecological component of the ongoing TCEC Landfill Optimization Project EA and considered the results of the significant species and SWH screenings described above.

Terrestrial and aquatic surveys within the study area were conducted between April 7 and December 12, 2022; the date and weather conditions during each field survey is outlined in Table 1. Surveys were undertaken in accordance with provincial and local guidance documents, and the protocols followed during each survey are summarized in the following sections. Monitoring stations and survey areas are shown on Map 2. Where direct property access was not available, NRSI biologists completed investigations from the property boundary or road right-of-way (ROW).

Table 1. Summary of 2022 Field Surveys

Survey Type	Date (2022)	Start and End Time (24h)	Temp. (°C)	Wind Speed (Beaufort Scale)	Cloud (%)	Precipitation	Observer(s)
Terrestrial Surveys							
General Site Reconnaissance, Habitat Assessment, & Daytime Anuran Call Surveys	April 5	1130h – 1430h	5-12	1	60-100	None	K. Richter, H. Fotherby
	April 7	1000h – 1545h	8	3	70	None	D. Frey, N. Grant
	April 22	1000h – 1330h	6	2	30	None	D. Frey, T. Brenton
Evening Anuran Call Surveys	April 12	2040h – 2310h	8-13	1-5	10-75	None	J. Pedersen, S. Hoffstetter, S. Burgin, A. Timmerman
	May 12	2110h – 0000h	13-18.5	0-3	10	None	J. Pedersen, C. Kemp, J. Lance, E. Krauss
	June 13	2135h – 0000h	18-23	0-3	100	None-Light Rain	D. Frey, J. Dertinger, J. Pedersen, J. Birtch
Breeding Bird Surveys	June 3	0645h – 0930h	9-16	0-2	0	None	N. Miller
	June 28	0600h – 0810h	6-15	2-3	0	None	K. Hoo, M. Sanderson
Ecological Land Classification and Vascular Flora Inventories	May 17	1315h – 1615h	12-16	0-4	30-70	None	K. Richter, J. Weber
	August 25	0935h – 1800h	23	1	10	None	K. Richter, T. Sieg
	October 3	1050h – 1800h	9	1	10	None	K. Richter, J. Weber
Bat Habitat Assessment	December 12	0900h – 1445h	-1	2-3	100	None	J. Birtch, T. Brenton
Aquatic Surveys							
Aquatic Habitat Assessment & Fish Community Survey	October 25	1200h – 1500h	21	1-2	60	None	S. Catry, J. Nene

3.3 Terrestrial Field Surveys

3.3.1 Vegetation Surveys

Natural vegetation communities within the study area were mapped using the Ecological Land Classification (ELC) System for Southern Ontario (Lee et al. 1998). Details on the vegetation communities were recorded, including species composition, dominance, and uncommon species or features.

A three-season vascular flora inventory was completed within each vegetation community. A comprehensive area search was undertaken and all observed plant species were recorded during spring (May 17, 2022), summer (August 25, 2022), and fall (October 3, 2022) surveys. Any rare species or vegetation communities were identified and their location(s) were recorded.

3.3.2 Breeding Bird Surveys

NRSI biologists completed two early morning breeding bird surveys, consisting of 10-minute point counts at three stations within the study area (Map 2). Area searches were also used to document bird species as biologists travelled between monitoring stations. The first survey was completed on June 3, 2022, and the second survey was completed on June 28, 2022. Surveys were conducted in accordance with Ontario Breeding Bird Atlas (OBBA 2021) and Ontario Forest Bird Monitoring Program (Cadman et al. 1998) methodology.

3.3.3 Herpetofauna Surveys

Anurans

NRSI biologists completed three evening anuran (frog and toad) call surveys, consisting of 3-minute point counts at four stations within the study area where candidate amphibian breeding habitat was identified during initial site reconnaissance visits (Map 2). Surveys were completed on April 12, May 12, and June 13, 2022 when ambient evening air temperatures were a minimum of 8°C, 13°C, and 18°C, respectively. Surveys were conducted at least half an hour after sunset and in accordance with the methodology outlined in the Marsh Monitoring Program protocol (BSC 2009).

NRSI biologists also completed three daytime anuran call surveys, in conjunction with other field work, to determine the presence of the SCC Western Chorus Frog (*Pseudacris triseriata* pop. 2). Surveys were completed during the species breeding season on April 5, April 7, and April 22, 2022 when ambient air temperature was at least 5°C. Daytime anuran call surveys were conducted between 1000h and 1800h and followed the methodologies outlined in the Survey

Protocol for 2020 Western Chorus Frog Long-Term Monitoring Program (Blazing Star Environmental 2020).

Reptiles

Initial site visits involved a habitat assessment completed prior to the spring reptile emergence period to determine if suitable habitat for significant snake and turtle species is present. NRSI biologists undertook the habitat assessment on April 5 and 7, 2022 during initial site reconnaissance visits. Natural features were reviewed and available habitats were compared with those preferred by the target species, specifically the SAR Eastern Hog-nosed Snake (*Heterodon platirhinos*) and the SCC Snapping Turtle (*Chelydra serpentina*).

The results of the initial habitat assessment indicated that no candidate habitat for Snapping Turtle is present within the study area. However, summer foraging and thermoregulation habitat for Eastern Hog-nosed Snake may be present. In keeping with the methods outlined in the Survey Protocol for Ontario's Species at Risk Snakes (MNRF 2016), no further targeted surveys were undertaken for Eastern Hog-nosed Snake due to its cryptic nature and the difficulty of detecting individuals within suitable habitats. Eastern Hog-nosed Snake has been assumed present within the study area, and an analysis of candidate habitat is provided in Section 4.2.5.

Reptile area searches were also carried out in tandem with all other 2022 surveys conducted by NRSI biologists during suitable weather conditions within the reptile active season (April to October). During peak reptile activity periods (e.g., spring emergence, nesting), searches were expanded to include driving surveys that documented any reptiles on roadways in the area adjacent to the study area. These area searches and driving surveys informed the general abundance and diversity of reptile species in the study area.

3.3.4 Insect Surveys

Insect area searches focusing on butterflies, dragonflies, and damselflies were carried out in tandem with 2022 breeding bird surveys in June, and vascular flora inventories in August. NRSI biologists conducted these area searches during suitable weather conditions to determine the presence of one SCC butterfly and one SCC damselfly: Monarch (*Danaus plexippus*) and its larval food plants (Milkweed, *Asclepias* spp.), and Blue-tipped Dancer (*Argia tibialis*).

3.3.5 Bat Habitat Assessments

Bat habitat assessments were completed by NRSI biologists during leaf-off conditions. Plot-based bat habitat assessments were conducted on December 12, 2022 in the forested ecosites located within the study area (Map 2). The results of the habitat assessments were used to analyze the presence of suitable roosting habitat (e.g., cavity trees, leaf clusters) that may be used by SAR bats, as well as Bat Maternity Colony SWH. Surveys were conducted in accordance with the Survey Protocol for Species at Risk Bats within Treed Habitats (MNRF 2017), as well as recent guidance from the MECP including the Survey Protocol for Maternity Roost Surveys (Forests/Woodlands) (MECP 2022a) and the Bat Survey Standards Note (MECP 2022b).

Plots with a fixed radius of 12.6 m (equating to an area of 0.05 ha) were randomly selected within each contiguous forested ecosite. A minimum of 10 plots for ecosites ≤10 ha were surveyed, and for larger ecosites an additional plot per hectare was added up to a maximum of 35 plots (MECP 2022a). The number of standing live or dead trees with cracks, crevices, hollows, cavities, and/or loose or naturally exfoliating bark that could provide suitable roosting habitat for bats, was documented within each plot. The presence of leaf clusters with suitable roosting habitat for Tri-colored Bat (*Perimyotis subflavus*) was also documented. All trees within plots, regardless of size, were assessed for bat habitat. Information on candidate roost trees was documented and included the location, tree species, diameter at breast height (DBH), decay class (Watt and Caceres 1999), and the number, height, and type (e.g., cavity, crevice, sloughing bark, leaf cluster) of suitable roost sites.

3.3.6 General Wildlife Observations

In addition to the targeted surveys described above, all wildlife species observed were recorded during field surveys. Any features that may be indicative of SWH or habitat for SAR were assessed in detail, photographed, and georeferenced. General assessments of habitat connectivity and ecological linkage areas were also completed during surveys. When time permitted following the completion of scheduled field work, NRSI biologists completed driving surveys on Nauvoo Road, Zion Line, Confederation Line, and Underpass Road. During driving surveys, all wildlife observations (live sightings, sign, and road mortalities) were documented.

3.4 Aquatic Surveys

3.4.1 Aquatic Habitat Assessments

NRSI biologists undertook detailed aquatic habitat assessments within the Gilliland-Geerts Drain and HDF 1 on October 25, 2022 to characterize the existing conditions of these features within the study area, as shown on Map 2. Detailed assessments were completed for three aquatic habitat areas; general observations were also recorded at an additional roadside survey location where the Gilliland-Geerts Drain crosses Underpass Road (Map 2).

Aquatic habitat characterization followed a modified version of the standard Ontario Stream Assessment Protocol (OSAP) methodology (Stanfield 2017). The following information was recorded during the surveys:

- General characteristics and channel morphology (e.g., bankfull and wetted widths, bank height, riffle/pool characteristics);
- Substrate composition;
- Flow conditions and water depths;
- In-stream and riparian vegetation;
- Location and type of fish habitat available, if present (e.g., refuge areas, nesting sites, areas, and types of food supply including overhanging vegetation, woody debris);
- Adjacent land use and slopes;
- Indications of groundwater discharge; and
- In situ water quality measurements (e.g., water temperature, conductivity, pH, and turbidity).

3.4.2 Fish Community Surveys

NRSI biologists completed fish community surveys simultaneously with aquatic habitat assessments on October 25, 2022. Fish community sampling was undertaken with an electrofishing backpack unit in accordance with single-pass screening electrofishing methodology described in Section 3, Module 1 of OSAP (Stanfield 2017). This protocol is designed to provide a comprehensive fish species list for a site, characterize the fish community, and provide a qualitative assessment of species abundance. Surveys were conducted under the authority of a License to Collect Fish for Scientific Purposes (License No. 1100316) issued to NRSI on March 23, 2022 by the MNRF Aylmer District Office.

Fish community composition was sampled at three electrofishing monitoring stations located in the same aquatic habitat areas described above. A Smith-Root electrofishing backpack (Model LR-24B), dip nets, and an aerated portable container were used. NRSI biologists began sampling downstream within each watercourse and moved upstream, against the flow. Different types of habitats (e.g., riffles, pools, and runs) were targeted within the watercourse to fully assess the fish community present. All fish collected were identified to species, enumerated, and released alive outside of the sampling area shortly after capture within the watercourse. Water quality conditions, electrofishing backpack settings, and the total number of shocking seconds are summarized for each electrofishing monitoring station in Table 2.

Table 2. Electrofishing Backpack Settings, Shocking Seconds, and Water Quality During 2022 Fish Community Surveys

	Gilliland-Geerts Drain		HDF 1
	EMS-01	**EMS-02**	**EMS-03**
Approx. Reach Length (m)	400	690	600
Voltage (V)	200	150-200	150-200
Pulsating Frequency (Hz)	90	90	90
Amperes (A)	4.0-5.2	3.0-4.7	DNR
Shocking Seconds	274	DNR	232
Air Temp. (˚C)	21.0	22.0	20.0
Water Quality Measurements			
Water Temp. (˚C)	13.6	14.4	13.0
pH	7.64	7.37	7.28
Conductivity (mS)	1.01	2.02	0.71
Total Dissolved Solids (ppt)	0.50	1.01	0.75

4.0 Existing Conditions

4.1 Soils and Groundwater Systems

The study area is located on the Lambton Clay Plain, which is relatively flat with localized undulating topography (Chapman and Putnam 1984). The land generally drains to the southwest towards northern Lake Erie. The soils of the Lambton Clay Plain exhibit moderate drainage compared to similar but slower-draining clay plains in Southern Ontario. Soils within the study area are predominantly beveled till plains and clay plains, and consist largely of silt and Whittlesey clay (Chapman and Putnam 1984, SCRCA 2018). Local stratigraphy within the TCEC is subdivided into four main units described as follows in the 2022 Annual Report (RWDI 2023) and D&O Plan (Henderson Paddon & Associates 2008):

- Southern Till, ranging in thickness from approximately 1.6m to 12.5m and consisting of silty clay to clayey silt with trace amounts of disseminated sand and gravel;
- Interstadial deposits, consisting of two distinct deposits that are discontinuous under the site: an upper deposit of silt and clay (up to 5.2m thick) and a lower deposit of silt and sand (4.0m to 10.7m below ground surface);
- Rannoch Till, with an approximately thickness of 21.4m and consisting of a gritty-to-moderately stoney clayey silt to silt till with some textural variations; and
- Basal sand overlying bedrock, where occasional, discontinuous layers of sand and gravel between the Rannoch Till and the underlying black, bituminous shale bedrock of the Kettle Point Formation are present. Bedrock ranges from approximately 23.4m to 30.8m below ground surface.

Groundwater in the vicinity of the TCEC is influenced by local topography and drainage systems, the presence of the landfill, the low permeability of the overburden, and the bedrock. The overburden units in the above-noted stratigraphic sequence constitute an aquitard (i.e., a low-permeability formation that can store groundwater but slows its transmission from one aquifer to another) (Henderson Paddon & Associates 2008). Groundwater movement through the overburden occurs slowly and generally in a downward direction. On the west side of the topographic division between the Bear Creek and Brown Creek watersheds (see Appendix I), lateral groundwater movement occurs through the shallow overburden occurs from topographic highs to lows. Groundwater flow is generally in a southwest or northwest direction and is influenced by soil fractures and anthropogenic features (e.g., agricultural drains and ditches). Depth of the water table varies from near ground surface (particularly during spring freshet conditions or following major precipitation events) to 6.3m below ground (Henderson Paddon & Associates 2008). In the extensively tile-drained agricultural fields beyond the landfill, tile systems maintain the groundwater elevation to approximately 1m below ground surface (Henderson Paddon & Associates 2008).

The overburden (aquitard) is underlain by the regional aquifer that consists of the upper fractured portion of the bedrock and overlying basal sand form the local bedrock aquifer (which is also termed the 'interface aquifer) (Henderson Paddon & Associates 2008, RWDI 2023). Groundwater flow within the regional aquifer is generally towards the west. The study area does not overlap with any Significant Groundwater Recharge Areas or Wellhead Protection Areas (MECP 2023b).

For a detailed description of surface water systems that influence the hydrology of the study area, the reader is referred to Section 2.1.

4.2 Terrestrial Ecosystems

4.2.1 Vegetation

Vegetation Communities

Lands within the study area are dominated by agricultural fields growing row crops, including wheat, corn, and soybeans. Rural residential properties are present along Underpass Road in the west; cemetery lands and a commercial property (thrift shop) front on Nauvoo Road in the east. Natural vegetation communities within the study area are a combination of deciduous forests, swamp and upland thickets, and marshes. Most natural vegetation communities within the study area have been historically disturbed by anthropogenic activity to some extent. Despite this historical influence and fragmentation due to agricultural activities, areas with important ecological and hydrological functions remain; within the study area, these include interior woodland habitat, locally important wetlands and surface water drainage features, wildlife movement and linkage opportunities, and habitats of significant species.

Vegetation communities in the study area are described in Table 3 where site access permitted a thorough examination of plant species and community characteristics; these communities have been assigned a refined ELC code. All communities, including those that were characterized at a courser level from the roadside or property boundaries, are shown on Map 3.

Vascular Flora

According to available data from background information sources and this study, 321 species of vascular flora are reported from the vicinity of the study area (Gartner Lee Ltd. 2004, MNRF 2023a, iNaturalist 2023). In total, 208 species were observed by NRSI biologists during botanical inventories completed in 2022. A list of all plant species reported from the study area is included in Appendix IV.

Of the NRSI-observed species, 14 are listed as regionally rare in Lambton County (Oldham 2017). A list of these significant plant species, and the vegetation communities they were observed in, is presented in Table 4. Based on available records and the results of 2022 field surveys, three plant SAR and four plant SCC are reported from the vicinity of the study area (Gartner Lee Ltd. 2004, iNaturalist 2023, MNRF 2023a). The results of the Final Significant Species Screening are provided in Appendix II. No plant SAR or SCC were observed by NRSI biologists during comprehensive, three-season vascular flora inventories within the study area in 2022.

Table 3. Vegetation Community Descriptions.

ELC Ecosite Type	ELC Description	Environmental Characteristics
Forest		
FOD6-5	Fresh - Moist Sugar Maple - Hardwood Deciduous Forest Type	Two Fresh - Moist Sugar Maple - Hardwood Deciduous Forest (FOD6-5) communities are present within the study area. These communities are in the woodlots to the west of the TCEC and are characterized by canopies of Sugar Maple (*Acer saccharum*), American Beech, Shagbark Hickory, and Black Maple (*Acer nigrum*), and subcanopies of Sugar Maple, Bitternut Hickory (*Carya cordiformis*) and Eastern Hop-hornbeam (*Ostrya virginiana*). These communities contain understories of Green Ash (*Fraxinus pennsylvanica*), Bitternut Hickory and Sugar Maple. The ground layers in these features are dominated by Spotted Geranium, Sedge species (*Carex* spp.), and Yellow Trout-lily (*Erythronium americanum*). The northern of the two FOD6-5 communities contains Willow Mineral Thicket Swamp (SWT2-2) and Mineral Cultural Meadow (CUM1) inclusions along its northwestern boundary, adjacent to the Gilliland-Geerts Drain. Sandbar Willow (*Salix interior*), Heart-leaved Willow (*Salix eriocephala*), Gray Dogwood (*Cornus racemosa*), and Pale Dogwood (*Cornus obliqua*) comprise the SWT2-2 inclusion. The CUM1 inclusion contains a sparse understorey of Hawthorn species (*Crataegus* sp.) and Staghorn Sumac (*Rhus typhina*) and a groundcover dominated by Tall Goldenrod (*Solidago altissima*), Kentucky Bluegrass (*Poa pratensis*), and Reed Canary Grass (*Phalaris arundinacea*). The FOD6-5 communities are relatively undisturbed: both are bisected by an older farm access laneway that does not appear to be in regular use.
FOD9-4	Fresh - Moist Shagbark Hickory Deciduous Forest Type	Two Fresh - Moist Shagbark Hickory Deciduous Forest (FOD9-4) communities are present within the study area. Both FOD9-4 communities within the study area are generally similar in species composition and characteristics. The community immediately west Nauvoo Road has a canopy dominated by Shagbark Hickory and American Elm, and a subcanopy dominated by Shagbark Hickory, American Elm, and Bitternut Hickory. The understorey of this community is dominated by Bitternut Hickory and Common Buckthorn. The ground layer is comprised of Spotted Geranium, Yellow Trout-lily, and Sedge species. The community immediately east of Underpass Road has a canopy comprised of Shagbark Hickory, Red Oak (*Quercus rubra*) and American Basswood, and a subcanopy of Eastern Hop-hornbeam and Shagbark Hickory. The understorey of this community is dominated by Common Buckthorn and the ground layer contains a mix of Spotted Geranium, Running Strawberry Bush (*Euonymus obovatus*) and Green Ash.

ELC Ecosite Type	ELC Description	Environmental Characteristics
Wetland		
MAM2-10	Forb Mineral Meadow Marsh Type	A single Forb Mineral Meadow Marsh (MAM2-10) community with a Silky Dogwood Mineral Thicket Swamp (SWT2-8) inclusion is present in the study area, within the woodlot immediately west of Nauvoo Road. These communities correspond to the flow path of HDF 2 (Map 3). The MAM2-10 community contains dense ground cover of hydrophytic forbs and graminoids dominated by Panicled Aster, Fringed Sedge (*Carex crinita*), and multiple other Sedge species. The SWT2-8 inclusion is dominated by Pale Dogwood with a similar herbaceous groundcover of Panicled Aster, Fringed Sedge, and Spotted Jewelweed (*Impatiens capensis*).
SWT2-5	Red-osier Dogwood Mineral Thicket Swamp Type	A single Red-osier Dogwood Mineral Thicket Swamp (SWT2-5) community is present in the study area within the woodlot immediately west of Nauvoo Road and corresponding to immediate riparian zone of HDF 1. This community is dominated by Red-osier Dogwood (*Cornus sericea*), with an herbaceous groundcover comprised of Fringed Sedge, Panicled Aster and a mix of other hydrophytic herbs and forbs.
Cultural		
CUT1	Mineral Cultural Thicket Ecosite	A single Mineral Cultural Thicket (CUT1) community is present within the study area. This community comprises the riparian corridor of the Gilliland-Geerts Drain in the western portion of the study area. The CUT1 community is characterized by a sparse canopy of Hawthorn species and Common Buckthorn, a sub-canopy of Common Buckthorn and Willow species (*Salix* spp.) and a ground layer of Fringed Loosestrife and Green Ash seedlings.

Table 4. Vascular Flora Observed by NRSI Biologists in 2022 and Listed as Rare in Lambton County (per Oldham 2017).

Scientific Name	Common Name	SRank[1]	Location Observed
Agrimonia parviflora	Swamp Agrimony	S4	FOD9-4
Carex bromoides	Brome-like Sedge	S5	SWT2-5
Carex digitalis	Slender Woodland Sedge	S4S5	FOD9-4
Carex lurida	Sallow Sedge	S4S5	MAM2-10, SWT2-5
Carex pseudocyperus	Cyperus-like Sedge	S5	MAM2-10
Claytonia caroliniana	Carolina Spring Beauty	S5	SWT2-5
Dryopteris cristata	Crested Wood Fern	S5	FOD6-5
Dryopteris marginalis	Marginal Wood Fern	S5	FOD6-5, FOD9-4

Scientific Name	Common Name	SRank[1]	Location Observed
Epilobium coloratum	Purple-veined Willowherb	S5	MAM2-10
Geum aleppicum	Yellow Avens	S5	FOD9-4
Lobelia cardinalis	Cardinal Flower	S5	SWT2-5
Mimulus ringens	Square-stemmed Monkeyflower	S5	SWT2-5
Solidago flexicaulis	Zigzag Goldenrod	S5	FOD6-5, FOD9-4
Viola rostrata	Long-spurred Violet	S5	FOD6-5

[1] Provincial Rank (SRank): S2 – imperiled; S3 – vulnerable; S4 – apparently secure; S5 – secure.

4.2.2 Designated Natural Areas

Significant Woodlands

Within the study area, two treed vegetation communities have been designated as Significant Woodland in the Township of Warwick Official Plan Schedule “C” Natural Heritage (Township of Warwick 2021), as shown on Map 1. The western Significant Woodland unit (approximately 3.4ha) is primarily comprised of a Fresh - Moist Shagbark Hickory Deciduous Forest (FOD9-4), but is also mapped on official plan schedules as including the Mineral Cultural Thicket (CUT1) along the Gilliland-Geerts Drain (Township of Warwick 2021, Map 1). The eastern Significant Woodland unit (approximately 25.4ha) is dominated by Fresh - Moist Sugar Maple - Hardwood Deciduous Forest (FOD6-5), but also includes a Fresh - Moist Shagbark Hickory Deciduous Forest (FOD9-4) community. A Forb Mineral Meadow Marsh (MAM2-10) that transitions to a Red-osier Dogwood Mineral Thicket Swamp (SWT2-5) is present within the Significant Woodland, associated with the riparian area of the surface water feature HDF 1 (Maps 1 and 3).

Section 8.4.2 of the Lambton County Official Plan (2020) states:

“*Significant woodlands include any forested area that:*

a) is 2 hectares or greater in size,
b) has woodland interior habitat (100 metres from all edges),
c) is the largest woodland patch by landform or soil type,
d) is the largest woodland patch occurring on a particular valleyland, or
e) is 0.5 hectares or greater in size and
  i) is located within 30 metres of another natural heritage feature specifically identified in the Map 2 feature inventory;
  ii) provides linkage (a “stepping stone”) between (is in a line between and within 120 metres of) two or more significant woodlands that are separated by more than 120 metres of each other;
  iii) is located on or within 30 metres of a surface water feature,
  iv) is located above a highly vulnerable aquifer or significant groundwater recharge area;
  v) has unique woodland diversity – i.e., contains target communities for Ecodistrict 7E-2 that help to conserve the biodiversity of the Great Lakes region of Ontario as identified by The Great Lakes Conservation Blueprint (Henson et al. 2005);
  vi) has uncommon characteristics such as unique species composition; a rare vegetation community (NHIC provincial ranking of S1, S2, or S3); rare, uncommon, or restricted woodland plant species habitat; older woodlands, or larger tree size structure; or
  vii) has high socio-economic, cultural, historic, or educational value as identified in a local official plan.”

The two Significant Woodlands overlapping with the study area are considered significant due to their size, the presence of woodland interior habitat (but only in the eastern unit) and key hydrologic features, their ecological linkage functions and potential to support a variety of significant plant and wildlife species, and the relative scarcity of forested areas in Lambton County.

Wetlands

Within the study area, wetland communities are present primarily in association with the riparian corridor of the surface water feature HDF 1 (Map 3). A narrow Forb Mineral Meadow Marsh (MAM2-10) originates immediately west of Nauvoo Road (outside and south of the study area), and transitions to a Red-osier Dogwood Mineral Thicket Swamp (SWT2-5). Together, these riparian wetland communities measure approximately 3.6ha and are almost entirely contained within the eastern-most deciduous forest unit. An additional small band (approximately 0.16ha) of Willow Mineral Thicket Swamp (SWT2-2) is also present at the northwestern interface edge of the same deciduous forest, south of the Gilliland-Geerts Drain (Map 3).

No wetlands identified as Provincially Significant Wetland (PSW) are present in the study area. The nearest PSW is the Warwick Conservation Area PSW, which is located more than 5 km northwest of the TCEC. The Warwick Conservation Area PSW is also upstream of any watercourses connected to the study area.

The Lambton County Official Plan (2020) defines a PSW as "*a natural feature evaluated by the Ministry of Natural Resources and Forestry using the Ontario Wetland Evaluation System and officially designated as a wetland of provincial significance*." A Locally Significant Wetland (LSW) is defined as "*a natural feature classified and listed as an "other" wetland by the Ministry of Natural Resources and Forestry through the Ontario Wetland Evaluation System, meaning it has not yet been evaluated to determine its level of significance or has been evaluated and determined to be a wetland that is not of provincial significance*." No PSW, non-PSW, or unevaluated wetland features are currently mapped by the MNRF within the study area (MNRF 2023a). SCRCA interactive regulations mapping (SCRCA 2023) and municipal official plan schedules (Township of Warwick 2021, Lambton County 2020) also do not currently show any wetlands within the study area.

Wetland vegetation communities are present within the study area (as documented by NRSI biologists), but as they are unevaluated and unmapped by MNRF, they are not designated as PSW or LSW within official plans. However, all wetlands (regardless of mapping or status) are regulated by the SCRCA through Ontario Regulation (O. Reg.) 171/06, "Development, Interference with Wetlands and Alterations to Shorelines and Watercourses under the provincial *Conservation Authorities Act*, R.S.O. 1990.

Wetland features within the study area provide important ecological and hydrological functions and will be considered as part of the impact analysis portion of this Ecological Study. Important ecological functions documented by NRSI biologists during 2022 field surveys are summarized in the sections below.

4.2.3 Wildlife and Wildlife Habitat

Birds

According to available data from background information sources and this study, 126 bird species are reported from the vicinity of the study area (Gartner Lee Ltd. 2004, BSC et al. 2006, MNRF 2023a, eBird 2023, iNaturalist 2023). In total, 41 bird species were observed by NRSI biologists during field surveys in 2022. Most observed species are common in southern Ontario and have stable populations. A list of all bird species reported from the study area is included in Appendix V.

In total, 37 bird species were observed exhibiting evidence of breeding within the study area. Possible or probable evidence of breeding was indicated by observations including (but not limited to) singing males, courtship displays, or the presence of the species within a permanent territory. Confirmed breeding evidence was indicated by observations such as adults carrying food or occupying a nest, nests with eggs or young, or the presence of fledged young. American Robin (*Turdus migratorius*) is the only species confirmed to be breeding immediately within the study area, as evidence by the observation of an adult carrying food on June 28, 2022 at BMB-01 (Map 2). However, an active Eastern Wood-Pewee (*Contopus virens*) nest was also observed (indicating evidence of confirmed breeding) immediately south of the study area but within the deciduous woodland adjacent to Nauvoo Road; the entire woodland is therefore considered confirmed breeding habitat for this SCC.

Based on available records and the results of 2022 field surveys, six bird SAR and eight bird SCC are reported from the vicinity of the study area (Gartner Lee Ltd. 2004, BSC et al. 2006, MNRF 2023a, eBird 2023). The results of the Final Significant Species Screening are provided in Appendix II. During 2022 field surveys, NRSI biologists observed no bird SAR within the study area, but did observe three bird SCC: Eastern Wood-Pewee, Tufted Titmouse

(*Baeolophus bicolor*), and Canada Warbler (*Cardellina canadensis*). Confirmed and candidate habitats of bird SCC are shown on Map 4, and species observations are described as follows:

- During breeding bird surveys on June 3, and June 28, 2022, adult male Eastern Wood-Pewees were heard singing (indicating evidence of possible breeding) from deciduous woodlands within the study area, including BMB-01 and BMB-02. The species was observed occupying a permanent territory (indicating evidence of probable breeding) at BMB-03, and an occupied nest was observed in the portion of the woodland south of BMB-03 but outside the study area. The deciduous woodland nearest to Nauvoo Road is considered confirmed breeding habitat for Eastern Wood-Pewee, and the species is potentially breeding within the smaller deciduous woodland nearest to Underpass Road;
- A single adult male Tufted Titmouse was heard singing (indicating evidence of possible breeding) from the deciduous woodland west of Nauvoo Road on May 17, 2022. The woodland where the singing male was heard provides suitable breeding habitat for the species. Although Tufted Titmouse was not subsequently detected during breeding bird surveys, nesting can begin in May and the species may potentially breed in the study area; and
- A single adult male Canada Warbler was heard singing (indicating evidence of possible breeding) from the deciduous woodland immediately east of Underpass Road, during breeding bird surveys on June 3, 2022. The woodland in this location is smaller than the forested tracts usually preferred by the species, however the habitat in this woodland, as well as elsewhere within the study area, are suitable for Canada Warbler. The species is potentially breeding within the deciduous woodland near Underpass Road.

Herpetofauna

According to available data from background information sources and this study, 11 herpetofauna species (reptiles and amphibians) are reported from the vicinity of the study area (Gartner Lee Ltd. 2004, Ontario Nature 2019, iNaturalist 2023). In total, six herpetofauna species were observed by NRSI biologists within the study area during field surveys in 2022. Most observed species are common in southern Ontario and have stable populations. A list of all herpetofauna species reported from the study area is included in Appendix VI.

Anurans (Frogs and Toads)

During evening anuran call surveys, NRSI biologists detected American Toad (*Anaxyrus americanus*), Gray Treefrog (*Dryophytes versicolor*), Western Chorus Frog - Great Lakes / St. Lawrence - Canadian Shield population (*Pseudacris triseriata* pop. 2), Spring Peeper (*Pseudacris crucifer*) and Wood Frog (*Lithobates sylvaticus*) calling within the study area. Of American Toad, Gray Treefrog, Spring Peeper and Wood Frog, only a few individuals were heard; the maximum number of individuals recorded at these survey stations during any single survey was seven (Spring Peeper at ANR-01 on April 12, 2022).

Daytime and evening anuran call surveys detected full choruses of Western Chorus Frog at several locations throughout the study area. This calling level is recorded when calls are numerous and overlapping, individuals cannot be distinguished. Seasonal standing water in several vegetation communities was confirmed to support breeding populations of Western Chorus Frog (i.e., call code level 3, full chorus) in 2022. Locations where Western Chorus Frog was confirmed breeding are shown on Map 4; vernal pools within the following vegetation communities provide breeding habitat for the species:

- The Cultural Thicket (CUT1) in the western extent of the study area;
- The Red-osier Dogwood Mineral Thicket Swamp (SWT2-5) and Silky Dogwood Mineral Thicket Swamp (SWT2-8) inclusion associated with the riparian corridor of HDF 1; and
- The Willow Mineral Thicket Swamp (SWT2-2) inclusion immediately south of the Gilliland-Geerts Drain in the eastern portion of the study area.

Reptiles

Suitable overwintering and nesting habitats for turtles (with a focus on Snapping Turtle) were determined to be absent from the study area. During 2022 field surveys, NRSI biologists encountered a single reptile species: Eastern Gartersnake (*Thamnophis sirtalis sirtalis*).

While no individuals were observed, suitable summer foraging and thermoregulation habitat for Eastern Hog-nosed Snake was identified during habitat assessments in the woodlands within the study area. In keeping with the recommendations outlined in the Survey Protocol for Ontario’s Species at Risk Snakes (MNRF 2016), Eastern Hog-nosed Snake is assumed present within the study area for the purpose of this assessment.

Based on available records and the results of 2022 field surveys, one reptile SAR, one reptile SCC, and one amphibian SCC are reported from the vicinity of the study area (Gartner Lee Ltd. 2004, Ontario Nature 2019, MECP 2021, iNaturalist 2023). The results of the Final Significant Species Screening are provided in Appendix II.

During 2022 field surveys, NRSI biologists observed one amphibian SCC, Western Chorus Frog, and identified candidate habitat for one reptile SAR, Eastern Hog-nosed Snake. Confirmed breeding habitat for Western Chorus Frog is present in the study area, as described above. Candidate summer foraging and thermoregulation habitat for Eastern Hog-nosed Snake is identified in all forested habitats within study area (Map 5).

Mammals

According to available data from background information sources and this study, 47 mammal species are reported from the vicinity of the study area (Dobbyn 1994, Gartner Lee Ltd. 2004, iNaturalist 2023). In total, seven mammal species were observed by NRSI biologists during field surveys in 2022. All observed species are common in southern Ontario and have stable populations. A list of all mammal species reported from the study area is included in Appendix VII.

Mammal species observed most frequently by NRSI biologists within the study area in 2022 included White-tailed Deer (*Odocoileus virginianus*), Eastern Gray Squirrel (*Sciurus carolinensis*), Coyote (*Canis latrans*), and Northern Raccoon (*Procyon lotor*).

Based on available records and the results of 2022 field surveys, five mammal SAR and one mammal SCC are reported from the vicinity of the study area (Gartner Lee Ltd. 2004, Dobbyn 1994, Humphrey and Fotherby 2019, iNaturalist 2023). The results of the Final Significant Species Screening are provided in Appendix II.

<u>Bats</u>

During 2022 field surveys, NRSI biologists identified candidate habitat for four SAR bat species, including Eastern Small-footed Myotis (*Myotis leibii*), Little Brown Myotis (*Myotis lucifungus*), Northern Myotis (*Myotis septentrionalis*), and Tri-colored Bat. During the plot-based bat habitat assessments of the woodland in the eastern portion of the study area, NRSI biologists documented candidate roost trees that may be used Little Brown Myotis, Northern Myotis, Tri-colored Bat, and non-SAR bats. The density of candidate roost trees in the woodland for Little

Brown Myotis and Northern Myotis (candidate roost tree DBH >0 cm) was 2.4 candidate roost trees/ha; for non-SAR bats (candidate roost tree DBH >25 cm) the density was 2.1 candidate roost trees/ha. Candidate roost trees for Tri-colored Bat include those with hanging live or dead leaf clusters and are most likely to be oaks (*Quercus* spp.) or maples (*Acer* spp.). Suitable leaf clusters for Tri-colored Bat are anticipated to be present within all deciduous woodlands in the study area. No suitable roosting habitat for Eastern Small-footed Myotis was observed. However, all four SAR bats may forage and travel within the study area along the edges of, and/or within, any of the deciduous woodlands.

Insects

According to available data from background information sources, 11 butterfly species and 12 odonata (dragonfly and damselfly) species are reported from the vicinity of the study area (Macnaughton et al. 2023, OOAD 2023, iNaturalist 2023). NRSI biologists observed butterfly species during 2022 field surveys: Cabbage White (*Pieris rapae*) and Eastern Comma (*Polygonia comma*). No odonata species were observed. Appendix VIII and IX provide full lists of all butterfly, dragonfly, and damselfly species with records from within the study area.

Based on available records and the results of 2022 field surveys, one damselfly SCC, Blue-tipped Dancer (*Argia tibialis*), is reported from the vicinity of the study area (OOAD 2023). As summarized in the Significant Species Screening (Appendix II), suitable habitat for this species may be present along the Gilliland-Geerts Drain; however, Blue-tipped Dancer was not observed by NRSI biologists during 2022 field surveys.

4.2.4 Significant Wildlife Habitat

Based on background information review, desktop analyses, and the results of 2022 field surveys, several confirmed and candidate SWH types are present within the study area. The results of the Final SWH Screening are provided in Appendix III, and confirmed and candidate SWH types are shown on Map 4. The following sections summarize the characteristics and significance of the SWH types documented within the study area.

Confirmed Significant Wildlife Habitat

'Confirmed' SWH means that the habitat has been subject to detailed study and assessed as significant based on meeting discrete significance criteria established by the MNRF for Ecoregion 7E where the study area is located (OMNR 2000, MNRF 2015). To be confirmed as SWH, a habitat not only needs to meet the established criteria, but also qualify as providing important ecological function(s) on a landscape scale and be considered in the context of the abundance and availability of alternative habitats that may provide similar functions.

Terrestrial Crayfish Habitat

Ontario has two species of burrowing crayfish, the Digger Crayfish (*Fallicambarus fodiens*) and the Meadow Crayfish (*Cambarus diogenes*). These crayfish live in wetlands, creek beds, ditches, and in dry areas where they can burrow below the water table. These species are found only in southwestern Ontario and are uncommon throughout their range. They often live in small patches of high-quality habitat. Terrestrial crayfish are threatened by habitat loss and competition with non-native crayfish. Crayfish are included in the definition of 'fish' according to Section 34 of the federal *Fisheries Act* (1985).

The criteria for confirming terrestrial crayfish habitat includes documenting the presence of one or more individuals of either species or their chimneys (burrows) in suitable marsh meadow or swamp habitats as described in the Ecoregion 7E Criteria Schedule (MNRF 2015). NRSI biologists observed terrestrial crayfish chimneys in the study area during 2022 field surveys. Chimneys were observed within the Forb Mineral Meadow Marsh (MAM2-10) community corresponding to the upstream extent of HDF 1; a grouping of 10 chimneys was observed on May 17, 2022, and suitable habitat for terrestrial crayfish may be present elsewhere within the riparian corridor of HDF 1 (i.e., within Red-osier Dogwood Mineral Thicket Swamp). Suitable habitats appear limited at the landscape scale, and the listed vegetation communities are therefore considered SWH for terrestrial crayfish. The MNRF defines the habitat as the suitable wetland ELC Ecosite Area.

Habitats of Special Concern / Rare Wildlife Species

Important habitats of species designated as SCC are considered SWH. NRSI biologists observed several SCC during 2022 field surveys. Of these species, two were confirmed as having important breeding habitat within the study area: Western Chorus Frog and Eastern Wood-Pewee. For both species, the MNRF defines the habitat as the area of the finest ELC scale that protects the habitat form and function as delineated through detailed field studies. The designated area also needs to cover an important life stage component for the species, which in this case for Western Chorus Frog and Eastern Wood-Pewee, is their breeding habitat.

Western Chorus Frog (Great Lakes / St. Lawrence – Canadian Shield population) is an SCC species designated as Threatened on Schedule 1 of the federal *Species at Risk Act (SARA)*. This species occupies lowland habitats with open or discontinuous canopies where depressions support the formation of seasonal wetlands (Environment Canada 2015a). The study area is located approximately 1 km north of the Carolinian faunal province where Western Chorus Frog has a provincial S-Rank of S4 (apparently secure) and is not designated as Threatened on Schedule 1 of the federal *SARA*. Despite the relatively close proximity of the study area to the non-SCC population of Western Chorus Frog, habitats where the species was confirmed to be breeding are considered significant for the purpose of this assessment due to the generally limited availability of suitable breeding habitat at the landscape scale.

A few individual Western Chorus Frogs were heard calling in several locations throughout the study area by NRSI biologists during spring surveys in 2022. However, only suitable wetland features supporting breeding populations, as evidenced by a full chorus (Call Code 3), are designated as confirmed SWH for the species. Western Chorus Frog breeding populations were confirmed in a total of three vegetation communities, as shown on Map 4 and listed in Section 4.2.3.

Eastern Wood-Pewee is an SCC species designated as Special Concern under Ontario Regulation (O. Reg.) 230/08 of the ESA. Eastern Wood-Pewee breeds in intermediate-aged mature deciduous and mixed forest communities, and prefers forest stands with little understory vegetation (COSSARO 2013). An active Eastern Wood-Pewee nest was observed (indicating evidence of confirmed breeding) immediately south of the study area but within the deciduous woodland adjacent to Nauvoo Road; the entire woodland is therefore considered confirmed breeding habitat for the species. As shown on Map 4, Eastern Wood-Pewee is also considered to have candidate breeding habitat in several other deciduous forest communities within and nearby the study area.

Candidate Significant Wildlife Habitat

'Candidate' SWH means that suitable habitat has been detected, but additional studies or analyses are necessary to determine significance and the confirmed presence or absence of the ecological functions of the SWH type. In some cases, a SWH may meet some or all of the discrete significance criteria established by the MNRF for Ecoregion 7E (OMNR 2000, MNRF 2015) but remain designated as candidate due to unknown factors or data gaps that prevent a confident determination of presence or absence.

Bat Maternity Colonies

Candidate Bat Maternity Colony SWH is typically identified in mature deciduous or mixed forested habitats when the density of large-diameter (>25 cm DBH) candidate roost trees exceeds a threshold of 10/ha. This SWH type is confirmed when studies document the presence of maternity colonies consisting of >10 Big Brown Bats (*Eptesicus fuscus*) or >5 Silver-haired Bats (*Lasionycteris noctivagans*) (MNRF 2015).

Based on the results of the bat habitat assessments completed on lands where direct site access was available, none of the surveyed vegetation communities met the density target of at least 10 candidate roost trees >25 cm DBH per ha (see Map 2 for survey locations and Section 4.2.3 for roost tree densities). However, since direct site access was not available for all forested habitats within the study area, remaining deciduous forests are considered candidate for this SWH type as shown on Map 4.

Snake Hibernaculum

In southern Ontario, snakes overwinter in subterranean habitats where areas below the frost line can be accessed. Reptile hibernacula can be accessed via features such as old mammal burrows, rock fissures, old wells, crumbling foundations or stone walls, rock piles or slopes, and bridge abutments. Wetlands can also be important overwintering habitat. Congregations of snakes emerge from hibernacula in the early spring and are typically found basking near the feature for a period following emergence.

Sites for hibernation possess specific habitat parameters (e.g., temperature, humidity) and are frequently used annually, often by many of the same individuals of a local population. Other critical life processes (e.g., mating) often take place near hibernacula. The feature in which the hibernacula is located plus a 30m buffer is the SWH.

This SWH type is confirmed when studies document the presence of a hibernaculum feature confirmed to be used by a minimum of five individuals of the same snake species, or individuals of two or more snake species (MNRF 2015). Wildlife surveys within the study area in 2022 did not uncover any potential hibernacula features (e.g., rock piles, wells, crumbling foundations), and only a few observations of Eastern Gartersnake were documented. However, the absence of snake hibernaculum SWH cannot be ruled out without extensive surveys, which were not undertaken as part of this study. Although absence cannot be ruled out completely, it is considered very unlikely that hibernacula are present within the study area. Candidate Snake Hibernaculum SWH is identified for the majority of ecosites (and forested and swamp ecosites in particular) within the study area. This SWH type is not shown on Map 4 due to the potential for snake hibernaculum to occur in any southern Ontario ecosite other than very wet ones and the associated logistical constraints of demonstrating this on a map.

Habitats of Special Concern / Rare Wildlife Species

In addition to the confirmed breeding habtiats of Western Chorus Frog and Eastern Wood-Pewee, two additional bird SCC were also observed and are considered to have candidate habitats within the study area: Canada Warbler and Tufted Titmouse.

Canada Warbler is an SCC species designated as Special Concern under Ontario Regulation (O. Reg.) 230/08 of the ESA. Canada Warbler prefers to breed in large tracts of forest or thicket swamps, riparian woodlands, brushy ravines, and other mature forests with gaps in the canopy (Environment Canada 2015b). During 2022 breeding bird surveys in early June, a single adult male was heard singing (indicating evidence of possible breeding) from the deciduous woodlot immediately east of Underpass Road, in the western portion of the study area (Map 4**)**. The woodland in this location is smaller than the forested tracts usually preferred by the species, however the habitat in this woodland, as well as elsewhere within the study area, may be suitable for Canada Warbler. The species is considered to be potentially breeding within the deciduous woodlot near Underpass Road.

Tufted Titmouse is an SCC species with a provincial S-Rank of S3 (Vulnerable) (MECP 2023a). Tufted Titmouse prefers to nest in deciduous or mixed deciduous woodlands in areas with a dense canopy and a diversity of tree species (Cornell Lab of Ornithology 2019). During 2022 field surveys, a single adult male was heard singing (indicating evidence of possible breeding) from the deciduous woodland near Nauvoo Road. The woodland where the singing male was heard provides suitable breeding habitat for the species. Although the observation of Tufted Titmouse occurred relatively early in the breeding season (on May 17, 2022) and the species was not subsequently detected during breeding bird surveys, nesting can begin in May and the species is considered to be potentially breeding in the study area (Map 4).

4.2.5 Habitat of Endangered and Threatened Species

Field surveys completed by NRSI biologists in 2022 identified potential habitat for five SAR listed as Endangered or Threatened in O. Reg. 230/08: Species at Risk in Ontario List of the provincial ESA. Species include four SAR bats and one SAR snake.

The MECP categorizes SAR habitat into three categories as follows:

- Category 1: highly sensitive habitats with low tolerance to alteration;
- Category 2: moderately sensitive habitats with moderate tolerance to alteration; and
- Category 3: habitats with high tolerance to alteration.

The following sections discuss the preferred habitats of SAR with the potential to occur within the study area.

Species at Risk Bats

Eastern Small-footed Myotis, Little Brown Myotis, Northern Myotis, and Tri-colored Bat are all listed as Endangered provincially and are afforded general habitat protection under the ESA (2007). The latter three species are also listed as Endangered on Schedule 1 of the federal SARA. Category 1 (highly sensitive) habitats for these species include maternity colony, male, and/or dispersal/migratory day-roosts. Foraging habitats are considered Category 2 (moderately sensitive), and travel corridors or flyways are considered Category 3 (minimally sensitive).

Eastern Small-footed Myotis primarily roosts in open, sunny, rocky habitats, including cracks and crevices in cliffs and boulders, in talus slopes, beneath stones on rock barrens and in rock outcrops containing crevices (Humphrey 2017). Roosting habitat for this species is not present within the study area. Little Brown Myotis and Northern Myotis typically roost in tree cavities, hollows, under loose bark, and in buildings (OMNR 2000; MNRF 2017). Tri-colored Bat roosts in clusters of live or dead tree foliage in or below the canopy; oak species are often preferred to other tree species, although maple species are also used.

Candidate roosting habitat (Category 1) is potentially present for Little Brown Myotis, Northern Myotis, and Tri-colored Bat within all deciduous forest ecosites in the study area (Map 5). Based on the results of plot-based habitat assessments completed in the woodland in the eastern portion of the study area, candidate roost tree density for Little Brown Myotis and Northern Myotis (candidate roost tree DBH >0 cm) was just 2.4 candidate roost trees/ha. This density is lower than the 10 candidate roost trees/ha density that characterizes high quality, preferred maternity roosting habitat for bats (MNRF 2017); however, the woodland still has the potential to provide Category 1 roosting habitat for these species. Trees with suitable leaf clusters (Category 1 roosting habitat for Tri-colored Bat) are anticipated to be present throughout all deciduous forest ecosites in the study area (Map 5). The availability, location, and density of leaf clusters within a woodland can change on an annual basis.

Foraging (Category 2) and/or movement corridor (Category 3) habitat for Eastern Small-footed Myotis, Little Brown Myotis, Northern Myotis, and Tri-colored Bat may also be present within all deciduous forest ecosites within the study area. All four species forage within or along the edges of forested vegetation communities, and may also forage over waterbodies such as the Sedimentation Ponds within the TCEC. Forest edges and clearings may also be used as flyways by SAR bats travelling between roosting and foraging habitats.

In summary, candidate habitat for SAR bats within the study area includes roosting (Category 1), foraging (Category 2), and flyway (Category 3) habitats.

Eastern Hog-nosed Snake

Eastern Hog-nosed Snake is listed as Threatened both provincially and federally (MECP 2023a, Government of Canada 2023), and receives general habitat protection under the ESA. Category 1 (highly sensitive) habitats for these species include oviposition (i.e., nesting) and overwintering sites. Summer foraging and thermoregulation habitats are considered Category 2 (moderately sensitive), and movement corridors are considered Category 3 (minimally sensitive).

In Ontario, Eastern Hog-nosed Snake uses a wide range of habitats, including open pine, deciduous and mixed forest, oak savanna, open meadow, and sandy shoreline (Kraus 2011). Regardless of habitat type, individuals show a preference for areas with sandy, well-drained soils (Rowell 2012). In southwestern Ontario, the species is often associated with areas underlain by glacial till or fluvial sand deposits. The species generally avoids areas with moist and poorly drained soil, but is often found in areas of dry habitat located near water or areas where their preferred amphibian prey, American and Fowler's (*Anaxyrus fowleri*) Toads, are abundant (Rouse 2006, Rowell 2012). Riparian corridors associated with watercourses and drains are also suitable for movement corridor habitat for the species.

Due to the cryptic nature of this species, when it is determined that habitat for Eastern Hog-nosed Snake is present, it is assumed that the species is present as best practice. Eastern Hog-nosed Snakes prefer open habitats, such as open woods, brushland or forest edges, with well-drained loose or sandy soils, well-drained substrates and uses rocks, logs, stumps, etc. as shelter (Kraus 2011). Loose sandy soils, which are necessary for oviposition and overwintering habitats, are not present in the study area; substrates generally have a high clay content. Suitable oviposition and overwintering habitat (Category 1) for Eastern Hog-nosed Snake is therefore not present. The deciduous forest communities within the study area have the potential to provide suitable summer foraging and thermoregulation habitat (Category 2). Field studies in 2022 identified the presence of abundant cover in the form of woody debris, leaf litter and vegetation from previous growing seasons, and gaps in the forest canopy provide suitable sun exposure and thermoregulation habitat for the species. American Toad, the primary prey species of Eastern Hog-nosed Snake, were also observed during anuran call surveys. The Gilliland-Geerts Drain may provide a travel corridor (Category 3) for individuals moving from sandy overwintering and nesting habitats that could be present along Bear Creek approximately 7 km to the east.

In summary, candidate habitat for Eastern Hog-nosed Snake within the study area includes summer foraging and thermoregulation (Category 2), and movement corridor (Category 3) habitats.

4.3 Aquatic Ecosystems

4.3.1 Aquatic Features

As described in Section 2.1, the study area generally drains westward towards the St. Clair River and is within the Bear Creek Headwaters subwatershed. Bear Creek originates more than 10 km north of the study area, and flows southwest. Surface water features within the study area are tributaries that join the main stem of Bear Creek approximately 5 km west of Underpass Road. These tributaries are the Gilliland-Geerts Drain and HDF 1 (Map 1).

The Gilliland-Geerts Drain is a constructed, open, municipal drain that has been historically modified to receive flow from tile drains. Information available from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) indicates that tile drain systems have been installed in most agricultural fields within the study area (OMAFRA 2023). HDF 1 is an open feature that is mostly naturalized, except for some historical and recent alterations downstream near its confluence with the Gilliland-Geerts Drain: a catchbasin near the edge of the agricultural field was observed during field surveys, and was presumably installed to redirect flows under the agricultural field via a tile drain.

The DFO has mapped and classified municipal drains into categories (Classes A, B, C, D, E, F or Unrated) based on flow regime and fish species present; drain classifications are available through the interactive mapping tool ‘AgMaps’ (OMAFRA 2023) and were reviewed as part of this study. As shown on Map 1, portions of the Gilliland-Geerts Drain are mapped as E- and F-class drains within the study area; closed/tiled drains are also present (OMAFRA 2023). E-class drains are characterized by permanent flows and warmwater thermal regimes, with potential presence of sensitive fish species; F-class drains are characterized by intermittent flows, are typically dry for three or more months each year, and provide seasonal and/or indirect fish habitat (Kavanaugh et al. 2017). However, as noted in Section 2.1, surface water flows within the Gilliland-Geerts Drain are ephemeral, with visible flows only occurring after snowmelt or prolonged periods of precipitation (RWDI 2023, Henderson Paddon & Associates 2008). The E-class designation of the drain by DFO is therefore considered incorrect with regards to the permanence of flow within the feature. The presence of the online pond-like feature near Underpass Road, which causes water to back up within the Gilliland-Geerts Drain, may create the appearance of permanent flows; however, this artificial condition is not representative of the feature or its overall landscape functions. The following sections provide additional details on the existing conditions of the Gilliland-Geerts Drain and HDF 1.

Gilliland-Geerts Drain

The Gilliland-Geerts Drain begins downstream of Nauvoo Road and is fed by surface runoff originating within the TCEC. Prior to the construction of the on-site Sedimentation Ponds in 2009, surface runoff was conveyed to a pre-existing and now decommissioned SWM pond and through the subsequent downstream agricultural fields via the Vankessel Drain. Currently, water that contributes flow to the Gilliland-Geerts Drain comes from the Sedimentation Ponds, the modified Vankessel Drain, and HDF 1 (see Section 2.1 and Map 1). The Gilliland Geerts Drain flows generally to the west-northwest through agricultural lands, along deciduous forest communities and residential properties, and has been classified by the DFO as an E-class drain for most of the reach between Nauvoo Road and Underpass Road as shown on Map 1 (OMAFRA 2023). Beginning approximately 700 m east of Underpass Road, the Gilliland-Geerts Drain has been classified by the DFO as an F-class drain (OMAFRA 2023).

The portions of the drain where aquatic habitat assessments and fish community sampling were completed on October 25, 2022 correspond to the portions designated by DFO as E-class drains (AHA-01 and AHA-02 on Map 2). In the week prior to surveys, approximately 40mm of rain was recorded from Environment Canada's Strathroy-Mullifarry climatological station (located approximately 18km east of the TCEC) (Environment Canada 2023). During surveys, shallow, flowing water (<0.5L/s) was present within the Gilliland-Geerts Drain, with a maximum recorded depth of 16cm. Electrofishing was completed within intermittent small pools where sufficient water depth was present. In these pools, NRSI biologists documented a small number of fish (between 18 and 53 individuals during more than four minutes of direct shocking) belonging to two species: Fathead Minnow (*Pimephales promelas*) and Green Sunfish (*Lepomis cyanellus*).

The channel of the Gilliland-Geerts Drain has been historically straightened and is characterized by a low gradient. Limited evidence of riffle and pool habitat was observed within the drain. Instream habitat and cover consists of woody debris, aquatic vegetation, and cobble and boulder deposits associated with culverts and crossings. Emergent vegetation was observed throughout the drain, dominated by cattails (*Typha* spp.) and Common Reed (*Phragmites australis*), with willows (*Salix* spp.) and dogwoods (*Cornus* spp.) growing within the main channel and dominating much of the banks. The wetted width at the time of survey ranged from 0.28 to 1.5 m, while the bankfull width ranged from 2.2 to 4.1 m. Substrates throughout the Gilliland-Geerts Drain were consistent, and were dominated primarily by clay overlain by deposits of silt, cobble, muck, and detritus.

The extent of frequent flood and natural vegetation ranged from 0 to 10 m on either side of the channel and were generally contained within the historically-modified banks of the drain. The banks of the drain were densely vegetated by deciduous shrubs with an understory of herbaceous plants. The extent of natural vegetation was limited to 0 to 10 m in areas adjacent to agricultural fields, but exceeded 30 m along the southern bank adjacent to the woodland. Shading was generally poor (20%) throughout much of the assessed reach, but the deciduous forest provided good shade relief (80%) where the drain runs adjacent to the feature. Various inputs from tile drains were observed throughout the lower reaches of the drain, including a large perched culvert conveying flows from HDF 1 (discussed further in the next section).

Common indicators of groundwater seepage can include rust-staining or oil-like sheens from iron-oxidizing bacteria, or the presence of specific plant species such as Watercress

(*Nasturtium officinale*) or Skunk Cabbage (*Symplocarpus foetidus*). NRSI biologists did not observe any groundwater indicators within the Gilliland-Geerts Drain during field surveys, which is consistent with features that have flow regimes driven mainly by surface water runoff.

HDF 1

HDF 1 originates from a series of drainage features conveying surface runoff from the southern portions of the TCEC and agricultural fields east of Nauvoo Road (Map 1). Surface runoff appears to collect in a depressional area immediately east of Nauvoo Road before flowing through a culvert under the road and northwest into the woodland feature before joining the main stem of the Gilliland-Geerts Drain. During the October 25, 2022 survey, water flow was absent, however areas of standing water indicated that HDF 1 Branch had conveyed flows recently. NRSI biologists sampled the intermittent standing water in various locations with electrofishing, and did not document any fish species.

Within its upper reaches, HDF 1 exhibited shallow standing water (<10 cm), disorganized drainage patterns, and did not have a defined channel within the meadow marsh areas near Nauvoo Road. As the drain entered the deciduous woodland, the feature periodically developed defined bed and banks. Water depths remained shallow, although the limited establishment of vegetation within these locations indicates the presence of intermittent flows throughout the growing season. At the western edge of the woodland, the feature emptied into a small catchbasin. The flow path proceeded underground through a tile drain in the agricultural field to the perched culvert outlet into the main stem of the Gilliland-Geerts Drain. A newly-dug, dry channel was observed along the western edge of the woodland, which likely conveys seasonal overflow from the catchbasin north to the Gilliland-Geerts Drain. The perched culvert outlet, >150 m of tile drained-length, and the catchbasin inlet at the edge of the woodland are significant barriers to the upstream migration of fish from the main stem of Gilliland-Geerts Drain. Together with the absence of fish during electrofishing surveys and the intermittent flow regime, HDF 1 provides indirect fish habitat only.

The channel of HDF 1 is characterized by a low gradient with a combination of straightened and meandering channel. In-stream vegetation consisted of a large patch of Common Reed near Nauvoo Road and other forbs within the meadow marsh area in the upstream reaches. Abundant woody debris was observed throughout the feature where it passed through the woodland, and deciduous trees and shrubs were rooted in the channel. Limited aquatic vegetation was observed within the feature, except for patches throughout where Watercress and jewelweeds (*Impatiens* spp.) were abundant. The wetted width at the time of survey ranged from 0.5 to 3.0 m where it was feasible to measure, while the bankfull width ranged from 0.8 to 3.0 m where the channel was defined. Substrates throughout HDF 1 were consistent, and dominated primarily by clay overlain by deposits of silt, cobble, muck, and detritus.

The extent of frequent flood ranged from 0 to 10 m on either side of the downstream, more defined reaches, and from 20 to 30 m on either side in the upstream areas where flows were diffuse through meadow marsh and thicket areas. The riparian corridor is densely vegetated by deciduous trees and shrubs with an understory of herbaceous plants. The extent of natural vegetation was limited to 0 to 10 m in areas adjacent to agricultural fields, but exceeded 30 m along the banks adjacent to the woodland. Shading was moderate to good quality (60-80%) throughout most of the feature.

4.3.2 Aquatic Species

According to available data from background information sources and this study, 14 fish species and four freshwater mussels are reported from the vicinity of the study area (Gartner Lee Ltd. 2004, MNRF 2023a, b, DFO 2023, iNaturalist 2023). In total, two fish species were observed by NRSI biologists during field surveys in 2022 throughout the Gilliland-Geerts Drain, Fathead Minnow and Green Sunfish. Both observed species are common in southern Ontario and have stable populations. Appendix X and XI provide full lists of all fish and mussel species with records from within the study area.

Based on available records, three mussel SAR are reported from the vicinity of the study area (iNaturalist 2023). Suitable habitat for mussels is not present within the Gilliland-Geerts Drain due to intermittent flow conditions that are incompatible with mussel survival. No fish SAR or SCC are reported by the DFO within the study area (DFO 2023). The results of the Final Significant Species Screening are provided in Appendix II.

4.3.3 Fish Habitat Summary and Significance

Gilliland-Geerts Drain provides seasonal, direct fish habitat of marginal quality due to its historically-straightened channel form, limited abundance of in-stream habitat features, and the overall poor quality shade relief throughout the assessed reaches. Only a small number of two common fish species were documented in the Gilliland-Geerts Drain, suggesting low fish community diversity consistent with intermittent systems. A direct comparison of 2022 fish community sampling data with baseline monitoring completed by Gartner Lee Ltd. in 1998 is not possible, as electrofishing surveys informing the Warwick Landfill Expansion EA were only completed in the northern tributary of Bear Creek (Laird Drain) and not within the Gilliland-Geerts Drain (Gartner Lee Ltd. 2004).

HDF 1 was determined to provide indirect fish habitat only. This feature functions to provide water flows, allochthonous inputs (nutrients and minerals), sediments, and potential seasonal benthic invertebrate production to downstream reaches that contain direct fish habitat.

5.0 Impact Assessment

Condition 4.2.a of PTTW No. 4682-BLJRYJ requires both an inventory of the ecosystem in the vicinity of the Gilliland-Geerts Drain (between Nauvoo Road and Underpass Road), and an assessment of potential impacts of the water taking on that ecosystem. Section 4.0 summarizes the existing terrestrial and aquatic conditions within approximately 300m of the Gilliland-Geerts Drain based on a combination of background information review and the results of field surveys completed by NRSI biologists in 2022. To present the results of a fulsome ecological inventory, this report includes details on all natural features, species, and habitats whether or not they are sensitive to hydrological change. For the purposes of this impact assessment, only the ecosystem components that are known to be sensitive to hydrological change are considered.

To determine which ecosystem components may be subject to potential impacts from water taking, NRSI biologists and ecohydrologists have used a combination of professional judgement and available resources, including the Toronto and Region Conservation Authority's (TRCA) Water Balance for Protection of Natural Features (TRCA 2012) and Wetland Water Balance Risk Evaluation (TRCA 2017) documents. The latter Risk Evaluation framework provides a list of hydrologically-sensitive flora and fauna, and assigns a rank of 'low', 'medium' or 'high' sensitivity to each listed species. This impact assessment considers the hydrological requirements for carrying out the life cycle of species documented within the study area, and compares these details with the information from reports prepared by others (e.g., RWDI, Henderson Paddon & Associates) describing hydrological systems to determine if ecological impacts from water taking within the TCEC are likely to occur.

5.1 Ecohydrology Context

Surface water systems within the study area are described in detail in Section 2.1. This section specifies that the hydrology of the Gilliland-Geerts Drain is driven almost entirely by surficial processes, and does not receive any meaningful input from groundwater sources originating within the TCEC. During field surveys, NRSI biologists did not document any common indicators of groundwater within the Gilliland-Geerts Drain (e.g., no rust-staining or oil-like sheens from iron-oxidizing bacteria, no plant species such as Watercress or Skunk Cabbage). Throughout the study area, the drain is historically channelized, and has been modified by downcutting to contain the frequent flood limits. These alterations have created conditions whereby the low-flow channel is entirely downslope of adjacent lands (Figure 1). Based on these conditions, the Gilliland-Geerts Drain does not contribute surface water to riparian vegetation communities. None of the documented wetland communities next to the drain (i.e., the Willow Mineral Thicket Swamp [SWT2-2] inclusion) are supported by water originating from the drain, as they are perched above the drain corridor.

Surface water from adjacent lands eventually collects in the drain and is subsequently carried downstream and out of the study area. Therefore, changes to flow within the Gilliland-Geerts Drain have the potential to impact aquatic habitats within the drain itself, but not any adjacent wetlands or the hydrological function of adjacent terrestrial habitats. For example, vernal pools within the study area that were documented to support amphibian breeding habitat for Western Chorus Frog (shown on Map 4) are perched above the Gilliland-Geerts Drain. The formation of these pools is therefore reliant on highly localized catchment areas and upgradient hydrological processes that are unrelated to the drain itself.

Within the portion of the study area that overlaps with HDF 1, several terrestrial and wetland ecosystem components rely on surface water. These include:

- Wetland vegetation communities within the woodland immediately west of Nauvoo Road, including the Forb Mineral Meadow Marsh (MAM2-10), its Silky Dogwood Mineral Thicket Swamp (SWT2-8) inclusion, and the Red-osier Dogwood Mineral Thicket Swamp (SWT2-5) that comprise the riparian corridor of HDF 1 (Map 3);

- Vernal pools within the above-noted wetland vegetation communities that are confirmed breeding habitat for the SCC Western Chorus Frog (Map 4); and

- Confirmed Terrestrial Crayfish SWH within the wetland communities online with HDF 1 (Map 4).

Although HDF 1 originates within the southern portion of the TCEC and a part of its catchment (approximately 18.1ha) is located on-site, it is considered unlikely these listed ecosystem components directly receive surface water from the TCEC. Due to the distance (>500m) between the TCEC and these vegetation communities and habitats, and the relatively flat topography in the vicinity, the listed ecosystem components are instead expected to be supported by localized surface runoff from their own catchments as well as shallow groundwater or saturated soils. In addition, runoff from the catchment feeding HDF 1 is not managed as part of the TCEC's SWM system, but instead flows overland through on-site and off-site ditches. During landfill operations, water is taken only from the four Sedimentation Ponds that intercept runoff from the northern portion of the TCEC. Therefore, none of the above-noted ecosystem components are vulnerable to impacts resulting from water taking activities within the TCEC.

Figure 1. The low-flow channel of the Gilliland-Geerts Drain contained within 1-2m high banks and located downslope of adjacent terrestrial habitats. Photograph taken in the approximate centre of the study area, facing west towards Underpass Road (April 7, 2022).

5.2 Water Taking Impact Analysis

Aquatic habitat within the Gilliland-Geerts Drain was assessed by NRSI biologists as being of marginal quality but supportive of seasonal, direct fish habitat. Ephemeral flows occur during spring freshet-like conditions and following major rain events at any time of year (RWDI 2023, Henderson Paddon & Associates 2008). The intermittent nature of the drain is supported by the results of electrofishing surveys in 2022, where NRSI biologists documented only a relatively small number of fish belonging to two tolerant species (Fathead Minnow and Green Sunfish). Conditions resembling permanent flows may be artificially introduced by the online and constructed pond-like feature near Underpass Road that causes water to back up within the western portion of the Gilliland-Geerts Drain. Tile drains within the agricultural fields adjacent to the drain may also intercept shallow groundwater within the overburden (particularly during periods of the year when the water table is high) and direct additional volumes to the drain (Henderson Paddon & Associates 2008). However, neither of these factors are related to, or changed by, surface water taking within the TCEC.

As described in Section 2.1, runoff from only a portion of the Gilliland-Geerts Drain study area catchment (i.e., the catchment relevant to the portion of the drain between Nauvoo Road and Underpass Road) is detained and managed by TCEC Sedimentation Ponds 1, 2, and 3. Otherwise, runoff from the remaining portions of the TCEC is conveyed overland through on-site and off-site ditches; a portion of this uncontrolled runoff contributes to the study area catchment (e.g., via the Vankessel Drain and HDF 1), while the remainder is directed to other Bear Creek tributaries to the north (Laird Drain) or South (Brown-Jarriott Drain).

Given that water from the Sedimentation Ponds is used for dust control and road cleaning within the TCEC, it is a reasonable assumption that most water taking occurs during the dry, summer months (generally late June through August). This also correlates to the portion of the year when flows within the Gilliland-Geerts Drain would typically be low or absent (even if water taking was not occurring), based on its intermittent flow regime and reliance on surface water inputs. Data from the TCEC's climatological station indicate that 2022 represented a comparatively dry year overall in relation to the 30-Year Normal (1991-2020) (RWDI 2023). Dust control measures during a dry year would presumably result in the need to take more water than during other years with more precipitation. In drier years, water taking may also have more pronounced impacts on downstream ecosystems. Using 2022 data to inform this impact assessment therefore allows a conservative approach.

Aquatic habitats and fish communities within the Gilliland-Geerts Drain are not likely to be impacted by water taking within the TCEC, regardless of the volumes taken. Intermittent surface water-driven systems are subjected to regular fluctuations in water levels, flow rates, and volumes even in areas that are not downstream of areas managed with detention ponds. The degree to which these fluctuations change specifically due to water taking is not expected to be significantly different from that in a more naturalized (and uncontrolled) intermittent system. Both fish species documented within the Gilliland-Geerts Drain during 2022 field surveys, Fathead Minnow and Green Sunfish, have similar environmental requirements and life histories, and are both considered tolerant to hydrological change (Holm et al. 2010, TRCA 2017, NatureServe 2023). Fathead Minnow and Green Sunfish prefer warmwater thermal regimes and are characteristic residents of temporary streams, pools and ditches. Both species tolerate a wide range of water temperatures, low oxygen, and highly turbid conditions that often occur in intermittent systems (Holm et al. 2010, NatureServe 2023). Spawning occurs in the spring and summer, generally May to August (Holm et al. 2010). While the spawning period for the fish community within the Gilliland-Geerts Drain corresponds to the time of year when water taking within the TCEC occurs most frequently, eggs are typically deposited in shallow but permanent water like the online constructed pond-like feature near Underpass Road and the backwater conditions that are subsequently created immediately upstream. Water taking within the TCEC is not likely to impact the availability of spawning habitat or the reproductive success of either Fathead Minnow or Green Sunfish. The persistence of fish within the upstream portions of the study area (i.e., those nearest to the TCEC) during October 2022 fish community sampling indicates that sufficient refuge areas are available to support aquatic life during periods of the year when surface flows are reduced or absent. Individuals from these refuge areas then re-colonize previously-dry portions of the drain during wetter seasons. Fathead Minnow and Green Sunfish are well-adapted to the habitats provided by these periodically dry features.

Terrestrial species confirmed or with the potential to occur within the study area may use the Gilliland-Geerts Drain as a travel corridor or stopover habitat throughout the year. Species include SCC such as Western Chorus Frog, Blue-tipped Dancer, and Snapping Turtle, the SAR Eastern Hog-nosed Snake, and many other common non-SAR/SCC mammals, reptiles, amphibians, insects, and birds. The presence of water within the drain may be important to the travel corridor and stopover habitat function (particularly for amphibian species). However, since the Gilliland-Geerts Drain is typically dry for periods of the year even without water taking activities, species using the feature are already subject to (and adapted to) fluctuations in water levels and seasonally dry periods. Water taking within the TCEC is therefore not anticipated to impact the travel corridor or stopover habitat function of the drain.

6.0 Summary and Conclusion

This Ecological Study has been prepared to address Condition 4.2.a of PTTW No. 4682-BLJRYJ, issued to WM for water taking within the TCEC. The study area is defined as the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road, in addition to the lands within approximately 300m (Map 1). In 2022, NRSI biologists completed comprehensive, three-season terrestrial and aquatic field surveys within the study area to inform the ongoing TCEC Landfill Optimization Project EA. The results of field surveys have been combined with available background information to provide an inventory and description of all existing ecosystem components within the study area, whether or not they are sensitive to hydrological change. Information prepared by RWDI and others related to water taking volumes, surface water drainage characteristics, and hydrogeological conditions were interpreted and used to inform an assessment of potential impacts of the water on the ecosystem within the study area.

Surface water features within the study area include the Gilliland-Geerts Drain and HDF 1, with are both ephemeral features with intermittent flow regimes. Natural vegetation communities within the study area are a combination of deciduous forests, swamp and upland thickets, and marshes. Based on the results of field surveys and a review of available background information, habitat for a variety of plant and wildlife species are present in the study area, including confirmed and candidate SWH types, potential habitat for SAR, and seasonal habitat for fish. Of these ecosystem components, only aquatic habitats required consideration as part of the impact assessment, as no terrestrial species or habitats were determined to be vulnerable to impacts resulting from water taking within the TCEC.

Direct but seasonal fish habitat of marginal quality is present within the Gilliland-Geerts Drain. NRSI biologists documented two tolerant fish species, Fathead Minnow and Green Sunfish during 2022 field surveys. Both species are typical residents in intermittent streams and are well-adapted to regular changes in hydrological conditions. The conclusions of the impact assessment indicate that no negative impacts to terrestrial or aquatic ecosystems within the study area are likely to occur as a result of water taking within the TCEC.

Water from the on-site Sedimentation Ponds was primarily used to control dust within the PTTW during the summer season. 2022 represented a relatively dry year in comparison to the 30-Year Normal, and therefore water taking had the potential to elicit more pronounced impacts on downstream ecosystems. However, no ecological impacts were observed in 2022. Completing an impact assessment for a comparatively dry year provides additional confidence that water taking during future years can proceed without causing any negative impacts to the ecological functions within the Gilliland-Geerts Drain.

The conclusion of this Ecological Study is that there is no evidence that water taking within the TCEC is causing any impacts or changes to the ecosystem within or adjacent to the Gilliland-Geerts Drain between Nauvoo Road and Underpass Road.

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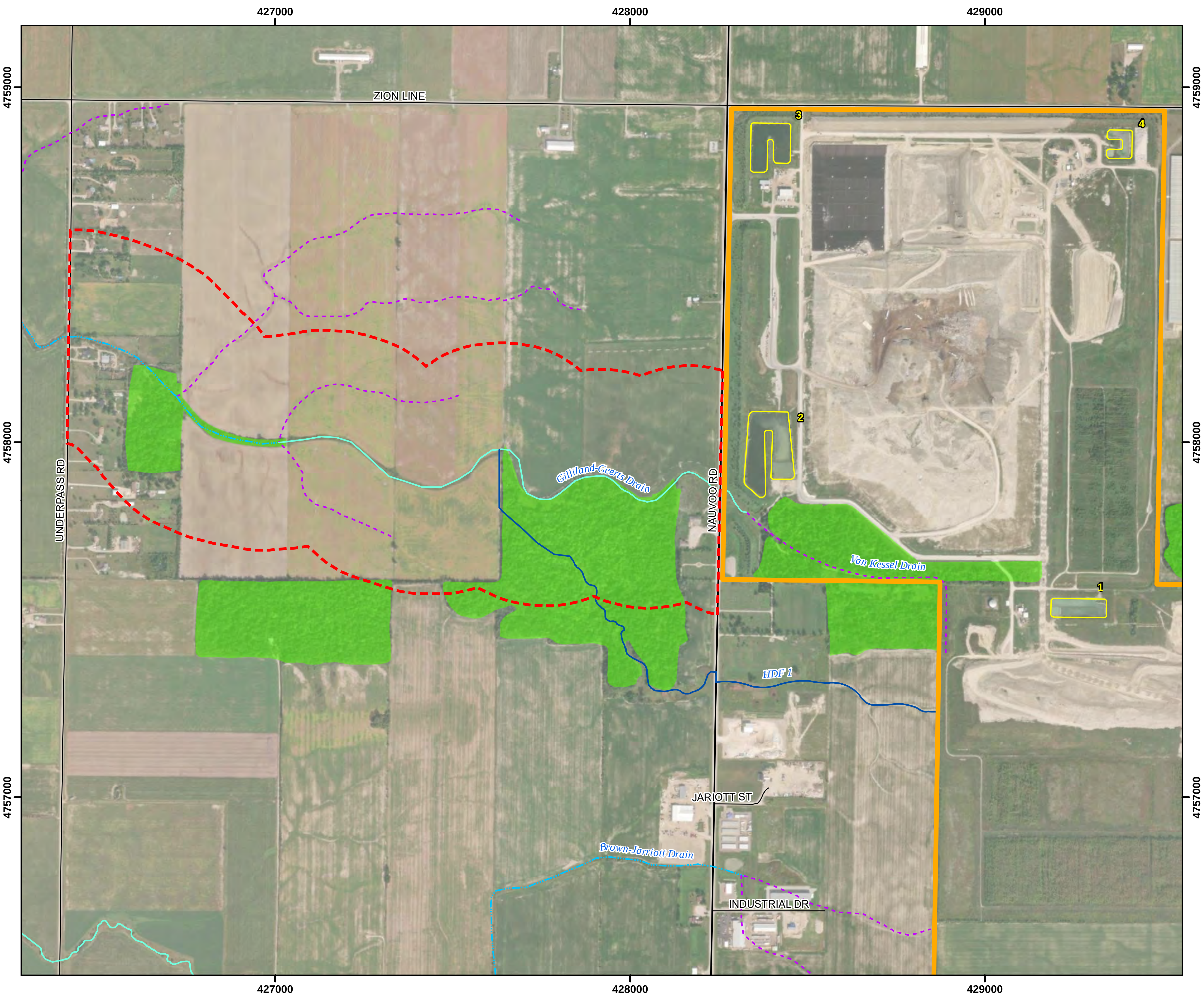
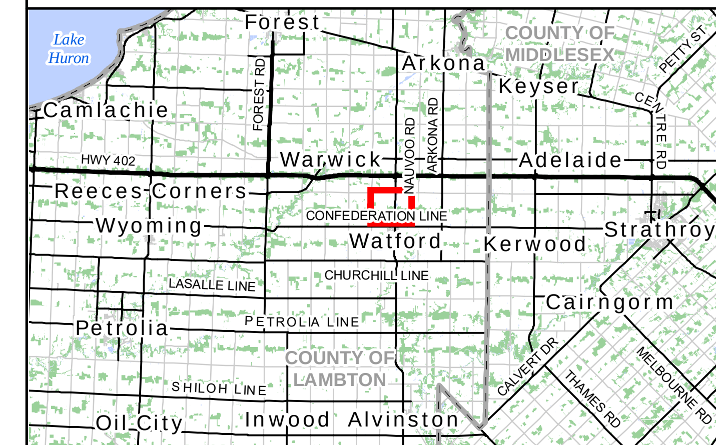
Maps

Map 1

TCEC PTTW Ecological Study

Study Area





Legend

- Twin Creeks Environmental Centre (TCEC)
- Study Area
- Primary Road
- Secondary Road
- Sedimentation Pond
- Significant Woodland (Township of Warwick Official Plan 2021)

Stream Network:

- Headwater Drainage Feature

Department of Fisheries and Oceans (DFO) Drain Classification (OMAFRA 2023)

- Closed/Tiled
- Class E - Permanent Flows, Warmwater Thermal Regime
- Class F - Intermittent Flows

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Project: 2538 Date: November 30, 2023	NAD83 - UTM Zone 17 Size: 11x17" **1:10,500**

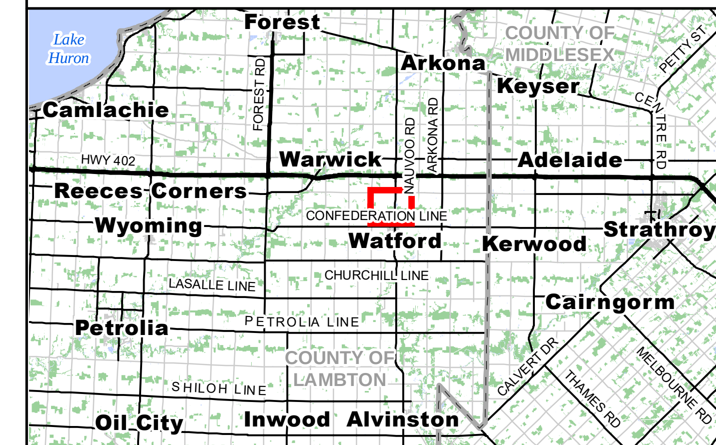
0 200 400 600 Meters

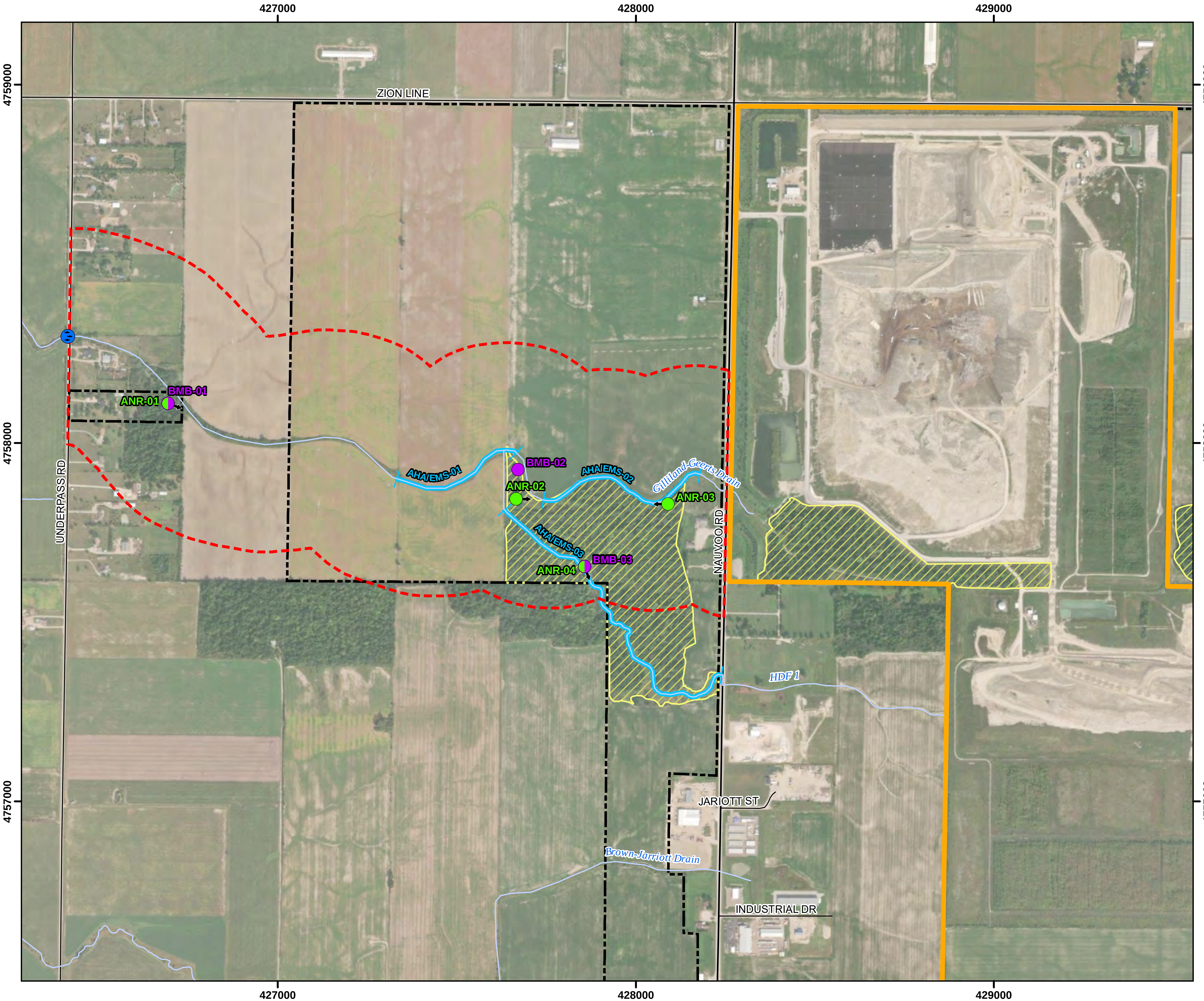
N

Map 2

TCEC PTTW Ecological Study

Monitoring Locations





Legend

- Twin Creeks Environmental Centre (TCEC)
- Study Area
- Property Access (permission to enter private property was granted by landowners for the purposes of 2022 ecological field surveys)
- Bat Habitat Assessment
- Primary Road
- Secondary Road
- Surface Water Feature
- Annuran Call Station (ANR)
- Breeding Bird Station (BMB)
- Aquatic Habitat Area (AHA) and Electrofishing Monitoring Station (EMS)
- Roadside Aquatic Assessment Location

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Project: 2538
Date: November 30, 2023

NAD83 - UTM Zone 17
Size: 11x17"
1:10,500

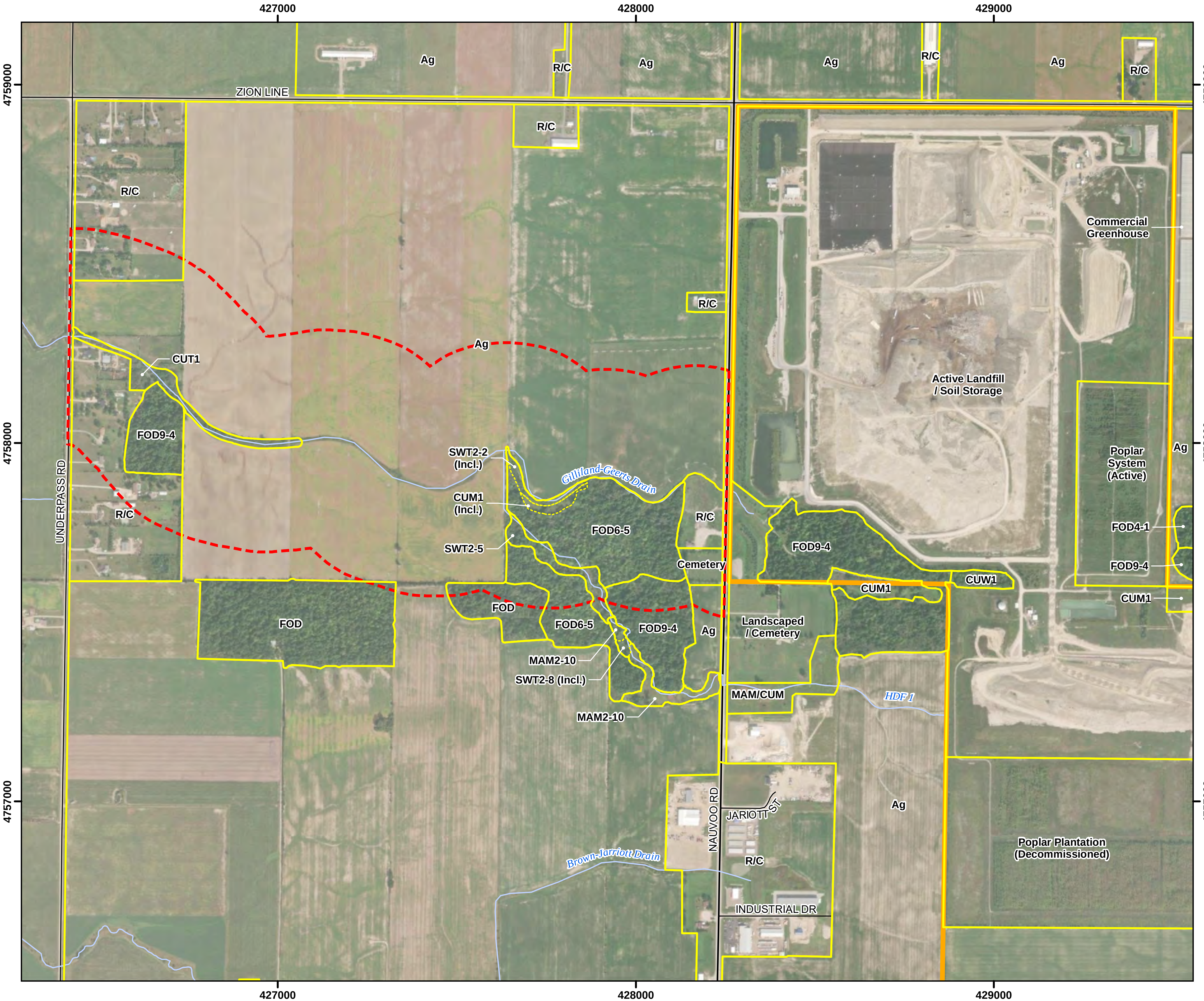
0 200 400 600 Meters

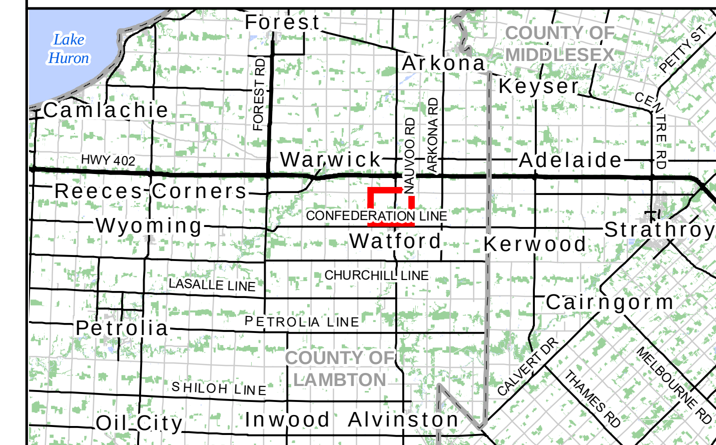
N

Map 3

TCEC PTTW Ecological Study

Vegetation Communities





Legend

- Twin Creeks Environmental Centre (TCEC)
- Study Area
- Primary Road
- Secondary Road
- Surface Water Feature
- Ecological Land Classification (ELC)
- ELC Inclusion
- (Ag) Agriculture
- (CUM1) Mineral Cultural Meadow Ecosite
- (CUT1) Mineral Cultural Thicket Ecosite
- (CUW1) Mineral Cultural Woodland Ecosite
- (FOD) Deciduous Forest
- (FOD4-1) Dry - Fresh Beech Deciduous Forest Type
- (FOD6-5) Fresh - Moist Sugar Maple - Hardwood Deciduous Forest Type
- (FOD9-4) Fresh - Moist Shagbark Hickory Deciduous Forest Type
- (MAM) Meadow Marsh
- (MAM2-10) Forb Mineral Meadow Marsh Type
- (R/C) Residential / Commercial
- (SWT2-2) Willow Mineral Thicket Swamp Type
- (SWT2-5) Red-osier Dogwood Mineral Thicket Swamp Type
- (SWT2-8) Silky Dogwood Mineral Thicket Swamp Type

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

Project: 2538
Date: November 30, 2023

NAD83 - UTM Zone 17
Size: 11x17"
1:10,500

0 200 400 600 Meters

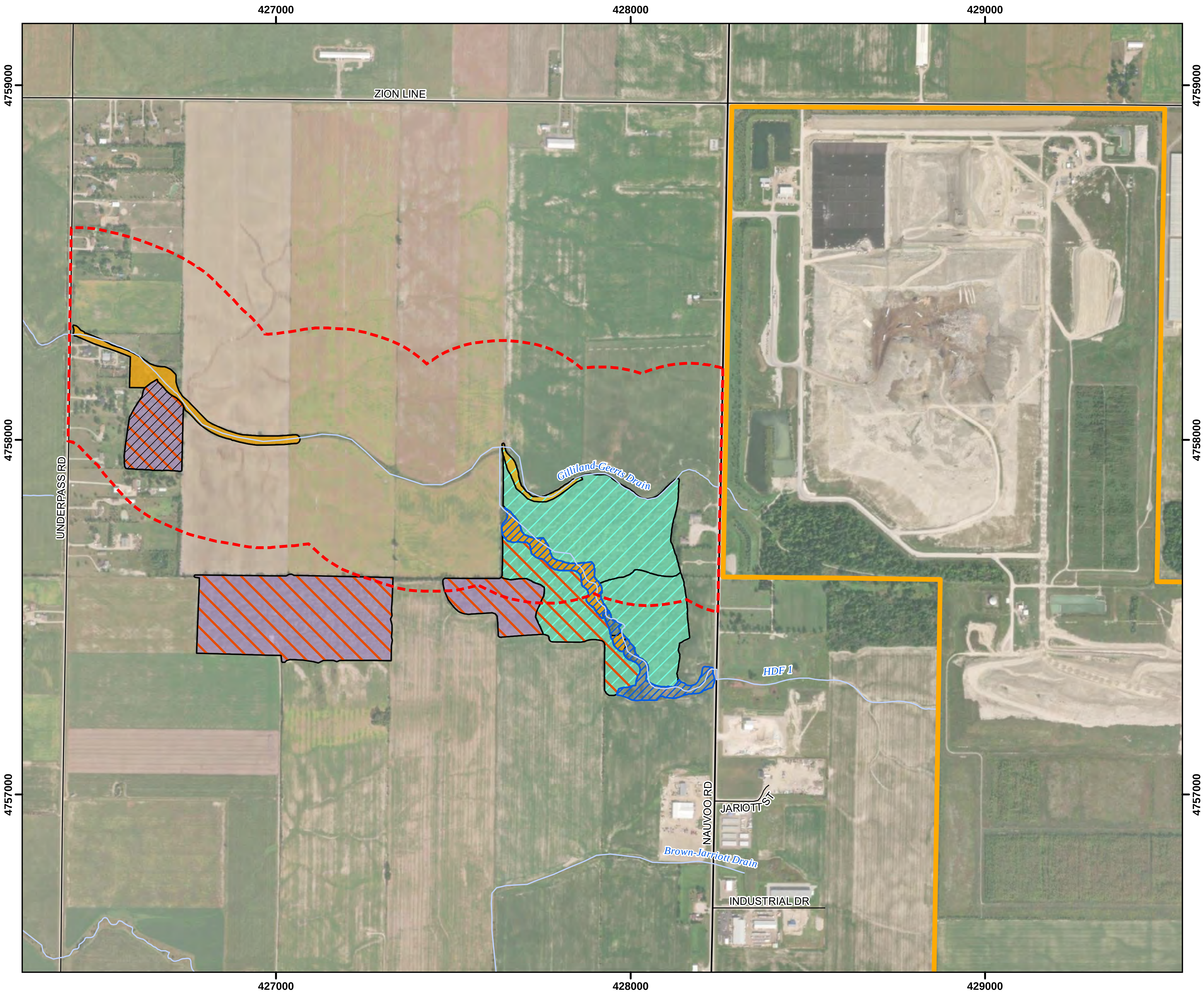
N

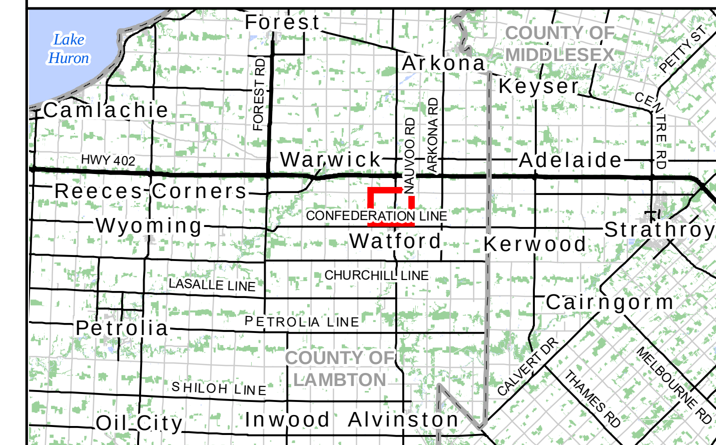
Path: X:\2538_TwinCreeksLandfillEA\NRSI_2538_Map3_VegetationCommunities_12K_2023_11_30_MV.mxd

Map 4

TCEC PTTW Ecological Study

Significant Wildlife Habitat





Legend

- Twin Creeks Environmental Centre (TCEC)
- Study Area
- Primary Road
- Secondary Road
- Surface Water Feature

Confirmed Significant Wildlife Habitat (SWH)

- Terrestrial Crayfish

Snake Hibernaculum*

Confirmed Habitat of Special Concern / Rare Wildlife Species

- Eastern Wood-Pewee (*Contopus virens*)
- Western Chorus Frog - Great Lakes / St. Lawrence - Canadian Shield population (*Pseudacris triseriata pop. 2*)

Candidate Significant Wildlife Habitat (SWH)

- Bat Maternity Colonies

Candidate Habitat of Special Concern / Rare Wildlife Species

- Canada Warbler (*Cardellina canadensis*)
- Tufted Titmouse (*Baeolophus bicolor*)
- Eastern Wood-Pewee (*Contopus virens*)

* Hibernacula may occur in any southern Ontario ecosite other than very wet ones; this SWH category is not shown on the map due to logistical considerations. The likelihood for a snake hibernaculum to occur within the study area is considered low but cannot be ruled out entirely.

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Project: 2538
Date: November 30, 2023

NAD83 - UTM Zone 17
Size: 11x17"
1:10,500

0 200 400 600 Meters

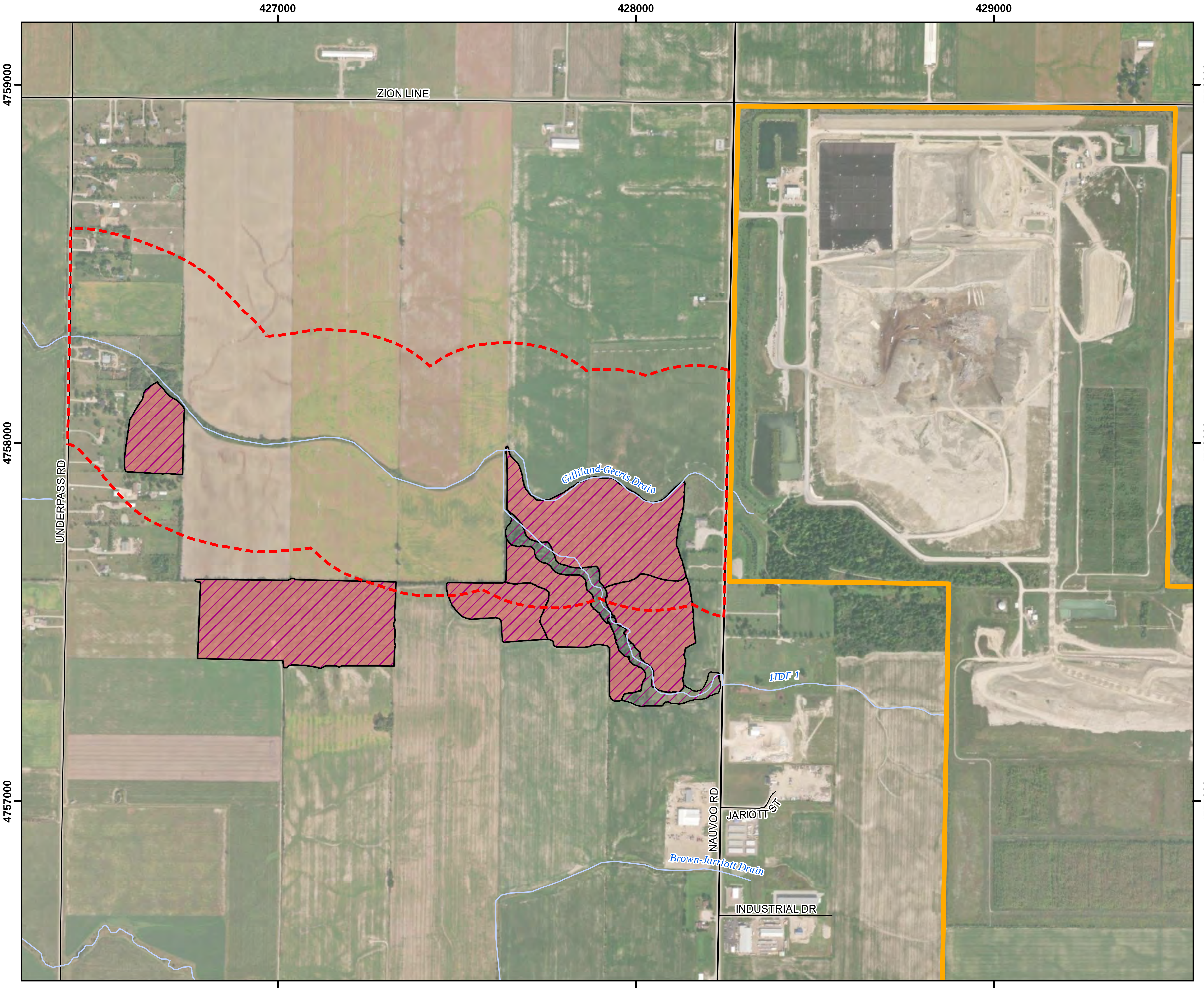
N

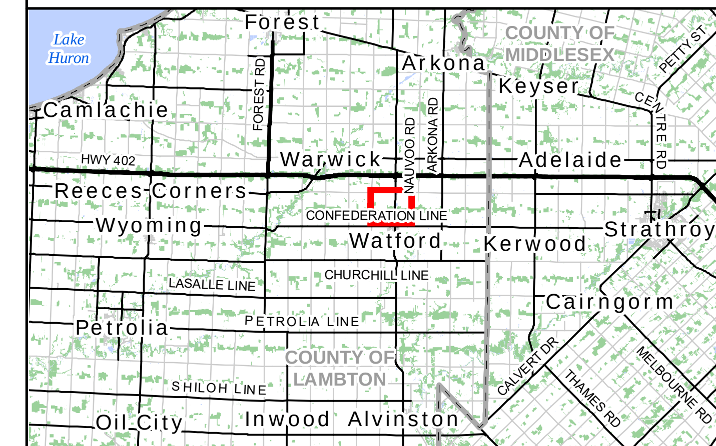
Path: X:\2538_TwinCreeksLandfillEA\NRSI_2538_Map4_SWH_12K_2023_11_30_MV.mxd

Map 5

TCEC PTTW Ecological Study

Potential Species at Risk Habitat





Legend

- Twin Creeks Environmental Centre (TCEC)
- Study Area
- Primary Road
- Secondary Road
- Surface Water Feature

Species at Risk (SAR)

- SAR Bats

Eastern Small-footed Myotis *(Myotis leibii)*

Little Brown Myotis *(Myotis lucifungus)*

Tri-colored Bat *(Perimyotis subflavus)*

Northern Myotis *(Myotis septentrionalis)*

Potential Species at Risk (SAR) Habitat

- Eastern Hog-nosed Snake *(Heterodon platirhinos)*

* Hibernacula may occur in any southern Ontario ecosite other than very wet ones; this SWH category is not shown on the map due to logistical considerations. The likelihood for a snake hibernaculum to occur within the study area is considered low but cannot be ruled out entirely.

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

Project: 2538 Date: November 30, 2023	NAD83 - UTM Zone 17 Size: 11x17" **1:10,500**

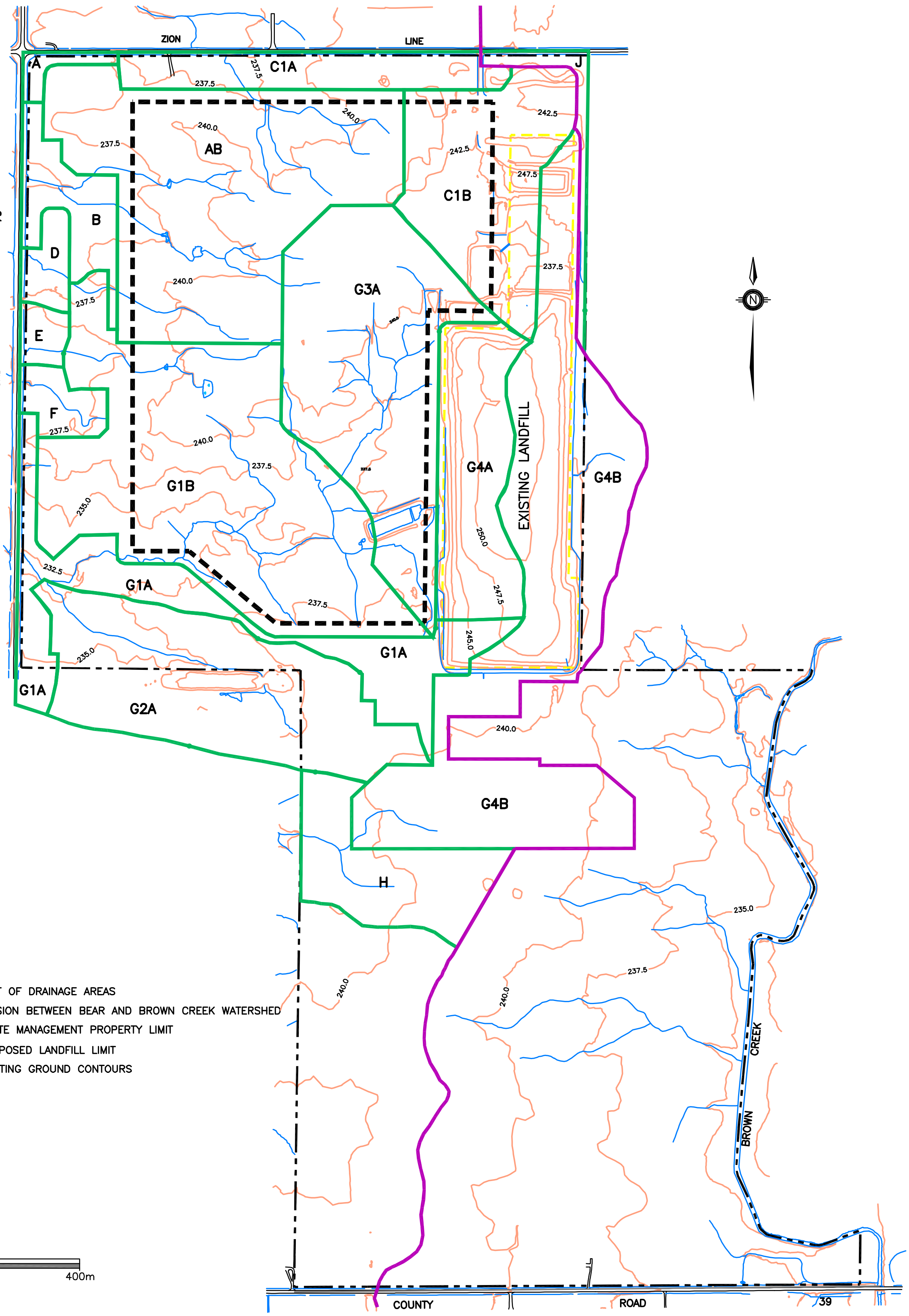
0 200 400 600 Meters

N

Path: X:\2538_TwinCreeksLandfillEA\NRSI_2538_Map5_SAR_12K_2023_11_30_MV.mxd

Appendix I

Drainage Areas and Surface Water Systems



LEGEND :

- LIMIT OF DRAINAGE AREAS
- DIVISION BETWEEN BEAR AND BROWN CREEK WATERSHED
- WASTE MANAGEMENT PROPERTY LIMIT
- PROPOSED LANDFILL LIMIT
- EXISTING GROUND CONTOURS

SCALE :

0 200 400m

SHEET FIG 8-2

DWN BY: T C G
CHK BY: F C F

DATE: DEC 21 07
SCALE: 1:12,500

WASTE MANAGEMENT OF CANADA CORP.

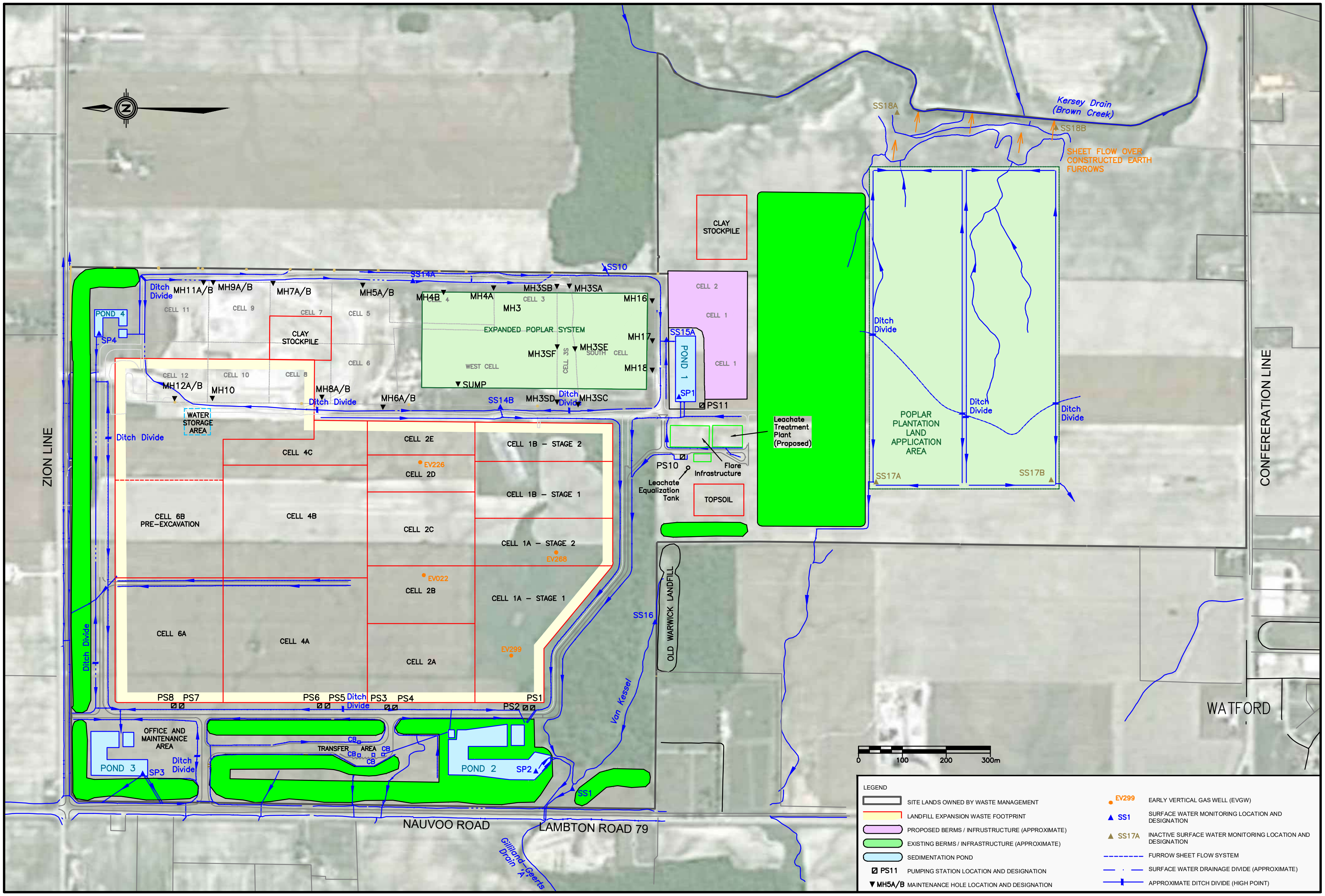
DRAWING NO. 197716–FIG 8–2

POST DEVELOPMENT
DRAINAGE AREAS

WARWICK LANDFILL

WASTE MANAGEMENT

HENDERSON, PADDON & ASSOCIATES LIMITED
CONSULTING ENGINEERS
OWEN SOUND • THE BLUE MOUNTAINS • GRIMSBY
Tele (519)376-7612 Fax (519)376-8008



MAP SOURCE:
AERIAL PHOTO PROVIDED BY GOOGLE EARTH (2011), ACCESSED ON JANUARY 2014.
FIGURE PROVIDED BY GENIVAR INC., FIGURE 3, FILE REF NO. 111-53111-00-F3-SP 12CM Q4, DATED JANUARY 2013.

NOTE:
LOCATION OF CONSTRUCTION SEDIMENTATION PONDS, BERMS, POPLAR PLANTATION, TREATMENT PLANT, & EFFLUENT LAGOONS FROM NOVEMBER 2010 SURVEY PLAN.

WASTE MANAGEMENT

SURFACE WATER SYSTEM

2022 COMPLIANCE MONITORING PROGRAM
TWIN CREEKS ENVIRONMENTAL CENTRE
TOWNSHIP OF WARWICK, ONTARIO

DWN BY: AJV
CHK BY: JCL
DATE: NOVEMBER 2022
SCALE: 1:8,000
WASTE MANAGEMENT OF CANADA CORP.
PROJECT FILE REF. NO. 2202861

FIGURE 3

Appendix II

Significant Species Screening Table

Scientific Name	Common Name	S-RANK[1]	SARO[1]	COSEWIC[2]	SARA[2]	SARA Schedule[2]	Background Source	Habitat Requirements	Analysis
Birds									
Asio flammeus	Short-eared Owl	S4?B,S2S3N	THR	T	SC	Schedule 1	eBird 2023	Grasslands, open areas or meadows that are grassy or bushy; marshes, bogs or tundra. Nests on the ground and requires 75-100 ha of contiguous open habitat.[4]	Preferred, good quality habitat for Short-eared Owl is not likely present within the study area. eBird observations of the species within the vicinity of the landfill are generally made outside of the nesting season (April 15-August 15), and are most consistent with migrating individuals.
Baeolophus bicolor	Tufted Titmouse	S3					eBird 2023	Deciduous woodlands or mixed evergreen-deciduous woodlands with tall trees, typically in areas with a dense canopy and many tree species. Common in orchards, parks, and suburban areas. Generally found at low elevations.[9]	A single adult male was heard singing (indicating evidence of possible breeding) from the deciduous woodland west of Nauvoo Road on May 17, 2022. The woodland where the singing male was heard provides suitable breeding habitat for the species. Although Tufted Titmouse was not subsequently detected during breeding bird surveys, nesting can begin in May and the species is considered to be potentially breeding in the study area.
Cardellina canadensis	Canada Warbler	S5B	SC	SC	T	Schedule 1	NRSI Observations 2022	Moist, mixed coniferous and deciduous forests with well-developed, dense shrub layer and closed canopy; wet bottomlands of cedar or alder; shrubby undergrowth in cool moist mature woodlands; riparian habitat. Most often found in large forest tracks.[4,9]	A single adult male was heard singing (indicating evidence of possible breeding) from the deciduous woodlot immediately east of Underpass Road. The woodland in this location is smaller than the forested tracts usually preferred by the species, however the habitat in this woodland, as well as elsewhere within the study area, are suitable for Canada Warbler. The species is considered to be potentially breeding within the deciduous woodlot near Underpass Road.
Chaetura pelagica	Chimney Swift	S3B	THR	T	T	Schedule 1	BSC et al. 2006; eBird 2023	Commonly found in urban areas near buildings; nests in chimneys, hollow trees, and crevices of rock cliffs. Feeds over open water.[3,4]	Cultural woodlands and deciduous forests present within the study area may contain suitable cavity trees with diameter (dbh) > 50cm, however this species prefers to nest in uncapped chimneys which are rare within the study area. The species was not observed during 2022 field surveys.
Contopus virens	Eastern Wood-Pewee	S4B	SC	SC	SC	Schedule 1	Gartner Lee Ltd. 2004; BSC et al. 2006; eBird 2023	Mid-canopy layer of forest clearings and edges of deciduous and mixed forest. Abundant in intermediate-age mature forest stands with little understory vegetation.[3,4]	During breeding bird surveys, adult males were heard singing (indicating evidence of possible breeding) at BMB-01, and BMB-02. The species was observed occupying a permanent territory (indicating evidence of probable breeding) at BMB-03. An active Eastern Wood-Pewee nest was observed (indicating evidence of confirmed breeding) at BMB-04. An occupied nest was observed in the portion of the woodland south of BMB-03 but outside the study area. The deciduous woodland west of Nauvoo Road is considered confirmed breeding habitat for Eastern Wood-Pewee, and the species is considered to be potentially breeding within other deciduous woodlands throughout the study area.

Scientific Name	Common Name	S-RANK[1]	SARO[1]	COSEWIC[2]	SARA[2]	SARA Schedule[2]	Background Source	Habitat Requirements	Analysis
Dolichonyx oryzivorus	Bobolink	S4B	THR	SC	T	Schedule 1	Gartner Lee Ltd. 2004; BSC et al. 2006; MNRF 2023; eBird 2023	Large (>10 ha), open expansive grasslands, pastures, hayfields, meadows or fallow fields with dense ground cover. Occasionally nest in large (>50 ha) fields of winter wheat and rye in southwestern Ontario. [3,4]	Active agricultural lands, particularly row crops, found within the majority of the Off-site Study Area are generally unsuitable for Bobolink. Based on a review of historical aerial imagery, hay is grown in some of the fields within the study area as part of a regular rotation with row crops. In years when hay is planted, Bobolink have the potential to breed within these fields, but when row crops (e.g., corn, soybean) are planted, habitat for the species will not be present. Whether a particular hayfield provides suitable breeding habitat for Bobolink also depends on the harvest schedule. When hay is cut early and/or regularly within the breeding season, these fields may act as an ecological "trap" by attracting Bobolink to nest in seemingly suitable habitat, but harvest activities may destroy nests or broods before they are fledged.
Euphagus carolinus	Rusty Blackbird	S4B,S3N	SC	SC	SC	Schedule 1	eBird 2023	Breeds in habitats dominated by coniferous forest with wetlands including bogs, marshes, swamps and beaver ponds.[4]	Coniferous forests with wetlands are not present in the study area. The species was not observed during breeding bird surveys or other field surveys in 2022.
Haliaeetus leucocephalus	Bald Eagle	S4	SC	NAR	NS	No schedule	eBird 2023	A variety of mature forest types adjacent to large lakes or rivers. Generally nest in tall supercanopy trees, a short distance from shore.[4]	A single adult was observed flying over the study area on October 24, 2022. Due to the absence of suitable mature forests adjacent to large lakes or rivers within the study area, this observation was likely an individual migrating or travelling to preferred habitats elsewhere.
Hirundo rustica	Barn Swallow	S4B	SC	SC	T	Schedule 1	BSC et al. 2006	Farmlands, rural areas and other open or semi-open areas near body of water. Nests almost exclusively on human-made structures such as open barns, buildings, bridges and culverts.[3,4]	Adult Barn Swallows were observed foraging over the agricultural fields within the study area, which contains many barns, structures and bridges, and the availability of nesting habitat for Barn Swallow is high.
Hylocichla mustelina	Wood Thrush	S4B	SC	T	T	Schedule 1	Gartner Lee Ltd. 2004; BSC et al. 2006	Carolinian and Great Lakes-St. Lawrence forest zones. Undisturbed moist mature deciduous or mixed forest with deciduous sapling growth. Near pond or swamp. Must have some trees higher than 12 m.[3,4]	Suitable undisturbed, moist deciduous forest habitat with dense understorey growth is present within the study area, however the species was not observed during 2022 breeding bird surveys.
Progne subis	Purple Martin	S3B					BSC et al. 2006; eBird 2023	Open, treed areas such as farmland, parks, yards, marshes; usually near large bodies of water; colonial; nests in tree cavities, cliff ledges; most common in nest boxes; requires open space for foraging; prefers trees >15 cm dbh.[4]	The species usually nests colonially in artificial, multi-compartment structures, which were not observed but may be present in the study area. Open treed farmland, parks, and yards are also present.
Riparia riparia	Bank Swallow	S4B	THR	T	T	Schedule 1	BSC et al. 2006	Nests in burrows in natural and human-made settings with vertical faces in silt and sand deposits. Usually on banks of river and lakes, but also found in sand and gravel pits.[3,4]	Suitable nesting habitat for the species is not present within the study area, and the species was not observed during 2022 breeding bird surveys.
Sturnella magna	Eastern Meadowlark	S4B, S3N	THR	T	T	Schedule 1	Gartner Lee Ltd. 2004; BSC et al. 2006; MNRF 2023	Open pastures, hayfields, grasslands or grassy meadows with elevated singing perches (small trees, shrubs or fence posts). Also weedy borders of croplands, roadsides, orchards, airports, shrubby overgrown fields or other open areas. Generally prefers larger tracts of habitat >10 ha, but will sometimes use smaller tracts.[3,4]	The majority of the lands within the study area are used for active agriculture, particularly row crops, and are not suitable for Eastern Meadowlark. The species was not observed during breeding bird surveys or other field surveys in 2022.

Scientific Name	Common Name	S-RANK[1]	SARO[1]	COSEWIC[2]	SARA[2]	SARA Schedule[2]	Background Source	Habitat Requirements	Analysis
Tringa flavipes	Lesser Yellowlegs	S3S4B,S5M		T	NS	No schedule	eBird 2023	Use a wide variety of fresh and brackish wetlands, including mudflats, marshes, lake and pond edges, wet meadows, sewage ponds, and flooded agricultural fields during migration. During breeding season utilizes open or semi-open woodlands and wet meadows interspersed with marshes, bogs, and ponds. Nest in altered habitats such as gas line rights-of-way and mine clearings. Often found in vegetated wetlands and shallow, vegetation-filled ponds surrounded by trees or sedges.[9]	Suitable wetland habitats with preferred vegetation composition and structure are not present within the study area. The species was not observed during breeding bird surveys or other field surveys in 2022.
Herpetofauna									
Turtles									
Apalone spinifera	Spiny Softshell	S2	END	E	E	Schedule 1	iNaturalist 2023	Large rivers and lakes, as well as seasonally in streams, creeks, marshes, ponds, and oxbows, especially those near large rivers or lakes. Key habitat requirements: open areas for basking with basking structures, open sand or gravel nesting areas, shallow muddy or sandy substrates to bury in, deep pools for hibernation. These habitats may be spread over a large area as long as the turtles can travel between them. [3,4]	Large rivers and lakes are not present, and suitable waterbodies near large rivers and lakes are not present within the study area. The species was not observed during field surveys in 2022.
Chelydra serpentina	Snapping Turtle	S4	SC	SC	SC	Schedule 1	Ontario Nature 2019	Slow-flowing rivers and streams, lakes, and permanent or semi-permanent wetlands with soft substrates and vegetation. Key habitat requirements: open areas with structures for basking, open sand or gravel areas for nesting, shallow areas with soft substrates to bury in, soft banks or substrates for hibernation.[3]	No Snapping Turtles or other turtle species were observed during field surveys in 2022. Turtles have the potential to use the Gilliland-Geerts Drain as a movement corridor, however no turtles were observed in these features during field surveys.
Snakes									
Heterodon platirhinos	Eastern Hog-nosed Snake	S3	THR	T	T	Schedule 1	MECP 2021	Open habitats, such as open woods, brushland or forest edges, with well-drained loose or sandy soils, well-drained substrates. Specializes in hunting and eating toads; occurs in habitats near or adjacent to wetland habitats where toads are present. Rocks, logs, stumps, etc. are used for shelter. Uses snout to dig nests as well as to dig burrows for overwintering.[5]	Loose, well-drained sandy soils are not present in the study area; substrates generally have a high clay content. Suitable nesting and overwintering habitat for Eastern Hog-nosed Snake is therefore not present. Deciduous forest communities have the potential to provide suitable summer foraging and thermoregulation habitat. Watercourses may provide travel corridors for individuals moving from sandy overwintering and nesting habitats that could be present outside of the study area, and the presence of this species cannot be ruled out entirely. American Toad (*Anaxyrus americanus*), the primary prey species of Eastern Hog-nosed Snake, are also abundant throughout the study area. Due to its cryptic nature, targeted surveys for Eastern Hog-nosed Snake are not recommended, and so the species will be assumed present where its habitat is present.
Anurans									
Pseudacris triseriata pop.2	Western Chorus Frog (Great Lakes - St. Lawrence - Canadian Shield population)	S4	NAR	T	T	Schedule 1	NRSI Observations 2022	Moist forest, prairie, meadows, cultural meadows, or marshes. Breeds in shallow, temporary, fishless wetlands, including flooded ditches, marshes, flooded fields, pastures, temporary ponds, pools, and swamps. Hibernates in terrestrial habitats under rocks, logs, leaf litter, loose soil, or in animal burrows.[6]	Daytime and evening anuran call surveys detected full choruses of Western Chorus Frog at several locations throughout the study area. Seasonal standing water in several vegetation communities was confirmed to support breeding populations of Western Chorus Frog (i.e., call code level 3, full chorus) in 2022.

Scientific Name	Common Name	S-RANK[1]	SARO[1]	COSEWIC[2]	SARA[2]	SARA Schedule[2]	Background Source	Habitat Requirements	Analysis
Mammals									
Bats									
Myotis leibii	Eastern Small-footed Myotis	S2S3	END				Dobbyn 1994; Humphrey 2017	Primarily roosts in open, sunny, rocky habitats, including cracks and crevices in cliffs and boulders, in talus slopes, beneath stones on rock barrens and in rock outcrops containing crevices. Occasionally roosts in buildings (including barns, sheds, and exterior walls). Maternity roosts have been documented in rocky habitats, on bridge structures, and in or on buildings. Overwinters in caves and abandoned mines. Hunts in forests.[10]	The study area lacks rocky cliffs, boulders, talus slopes and rock barren habitats, however there are suitable buildings in the study area that have the potential to provide maternity roosting habitat for the species. Forested habitats also have the potential to be used by the species for foraging, and flyways may also be present.
Myotis lucifungus	Little Brown Myotis	S3	END	E	E	Schedule 1	Dobbyn 1994, Humphrey and Fotherby 2019	Uses caves, quarries, tunnels, hollow trees or buildings for roosting. Winters in humid caves. Maternity sites in dark warm areas such as attics and barns. Feeds primarily in wetlands and forest edges.[11]	All forested habitats within the study area are potential roosting and foraging habitat for this species; flyways may also be present. Bat habitat assessments in 2022 indicated a relatively low roost tree density of 2.4 candidate roost trees/ha in the woodland west of the TCEC which suggests that the quality of potential roosting habitat is low in this feature. A roost tree density of 10 trees/ha is considered high quality roosting habitat.
Myotis septentrionalis	Northern Myotis	S3	END	E	E	Schedule 1	Dobbyn 1994, Humphrey and Fotherby 2019	Roosts in houses and man-made structures but prefers hollow trees or under loose bark. Hibernates in mines or caves. Hunts within forest, below the canopy.[11]	All forested habitats within the study area are potential roosting and foraging habitat for this species; flyways may also be present. Bat habitat assessments in 2022 indicated a relatively low roost tree density of 2.4 candidate roost trees/ha in the woodland west of the TCEC which suggests that the quality of potential roosting habitat is low in this feature. A roost tree density of 10 trees/ha is considered high quality roosting habitat.
Perimyotis subflavus	Tri-colored Bat	S3?	END	E	E	Schedule 1	Dobbyn 1994, Humphrey and Fotherby 2019	Roosts and maternity colonies in umbrella-shaped clusters of live or dead leaves, most often oaks (*Quercus* spp.) or maples (*Acer* spp.). Will occasionally roost in barns or other structures. Forages over water and along streams in the forest. Hibernate in caves.[11]	All forested habitats within the study area are potential roosting and foraging habitat for this species; flyways may also be present. Trees with suitable leaf clusters for Tri-colored Bat are anticipated to be present within forested habitats, however their location and density can change yearly and are not currently known.
Other Mammals									
Microtus pinetorum	Woodland Vole	S3?	SC	SC	SC	Schedule 1	Dobbyn 1994	Mature deciduous forest in the Carolinian region where there is a deep litter layer that allows it to burrow.[3]	Mature deciduous forest is present within the study area, however a deep litter layer required by the species was not observed by NRSI biologists during field surveys. It is considered unlikely that the woodland features are habitat for Woodland Vole.
Taxidea taxus jacksoni	American Badger (Southwestern Ontario population)	S1	END	E	E	Schedule 1	Dobbyn 1994	Open grasslands and oak savannahs; dens in new hole or enlarged existing hole; sometimes makes food caches.[4]	Suitable grassland and oak savannah habitat is not present within the study area. No candidate den sites were observed during 2022 field surveys.
Insects									
Butterflies									
Danaus plexippus	Monarch	S2N, S4B	SC	E	SC	Schedule 1	iNaturalist 2023	Adults found in a diversity of habitats with a variety of wildflowers. Caterpillars are confined to meadows and open areas where milkweeds grow (larval food plants).[3]	A few foraging adult Monarchs were occasionally observed during 2022 field surveys; however, no caterpillars were observed, nor were there areas with high concentrations of milkweeds (*Asclepias* spp.), the species' larval food plant documented within the study area.

Scientific Name	Common Name	S-RANK[1]	SARO[1]	COSEWIC[2]	SARA[2]	SARA Schedule[2]	Background Source	Habitat Requirements	Analysis
Dragonflies and Damselflies									
Argia tibialis	Blue-tipped Dancer	S3					OOAD 2021	Flowing waters including fast or slow-flowing rivers and streams. Species also occurs at swamps and ponds with less frequency.[12]	Suitable habitat may be present within the Gilliland-Geerts Drain. Although targeted surveys were not completed, the species was not observed by NRSI biologists in 2022.
Aquatic Species									
Fish									
Lepomis peltastes pop. 2	Northern Sunfish (Great Lakes - Upper St. Lawrence populations)	S3	SC	SC	SC	Schedule 1	DFO 2019	Shallow vegetated areas of quiet, slow-flowing rivers and streams, as well as warm lakes and ponds, with sandy banks or rocky bottoms.[7]	Suitable habitat may be present within the Gilliland-Geerts Drain. However, targeted electrofishing studies completed in 2022 did not detect Northern Sunfish.
Mussels									
Epioblasma rangiana	Northern Riffleshell	S1	END	E	E	Schedule 1	iNaturalist 2023	Riffle areas within rivers or streams with rocky, sand, or gravel bottoms. Host fish include; Blackside Darter, Fantail Darter, Iowa Darter, Johnny Darter, Rainbow Darter, Logperch, Brown Trout and Mottled Sculpin.[3]	The Gilliland-Geerts Drain is intermittent and therefore not compatible with mussels; riffles are also limited or absent and suitable rocky, sand, or gravel substrates are not present.
Lampsilis fasciola	Wavy-rayed Lampmussel	S2	THR	SC	SC	Schedule 1	iNaturalist 2023	Small to medium rivers with clear water. Shallow riffle areas with clean gravel or sand bottoms. Fish hosts include: Largemouth bass and Smallmouth bass.[3]	TThe Gilliland-Geerts Drain is intermittent and therefore not compatible with mussels; water clarity is generally poor and shallow riffles are limited or absent. Suitable clean gravel or sand substrates are not present.
Ptychobranchus fasciolaris	Kidneyshell	S1	END	E	E	Schedule 1	iNaturalist 2023	Small to medium sized rivers. Prefers shallow, clear, swift-moving water with gravel and sand. Also used to occur on gravel shoals in the Great Lakes. Fish hosts include: Blackside Darter, Fantail Darter, and Johnny Darter.[3]	The Gilliland-Geerts Drain is intermittent and therefore not compatible with mussels; water clarity is generally poor and shallow swift-flowing areas with gravel and sand substrates are not present.
Plants									
Aplectrum hyemale	Puttyroot	S2	-	-	-	-	MNRF 2023	Rich forests, both upland beech-maple and swamps in moist ground.[8]	Deciduous forest and swamp communities within the study area may provide suitbale growing conditions, however the species was not observed during comprehensive 3-season vascular flora inventories in 2022.
Arisaema dracontium	Green Dragon	S3	SC	SC	SC	Schedule 3	MNRF 2023	Moist forests, especially along river banks and floodplains.[8]	Deciduous swamp communities within the study area may provide suitbale growing conditions, however the species was not observed during comprehensive 3-season vascular flora inventories in 2022.
Asimina triloba	Pawpaw	S3					iNaturalist 2023	Deciduous forests; especially bottomlands along larger rivers; swamps, thickets along streams.[8]	Deciduous forest and swamp communities within the study area may provide suitbale growing conditions, however the species was not observed during comprehensive 3-season vascular flora inventories in 2022.
Diarrhena obovata	Ovate Beak Grass	S1					iNaturalist 2023	Floodplain swamps, river banks.[8]	Deciduous swamp communities within the study area may provide suitbale growing conditions, however the species was not observed during comprehensive 3-season vascular flora inventories in 2022.
Fraxinus nigra	Black Ash	S4	END	T	NS	No Schedule	Gartner Lee Ltd. 2004	Usually on mucky or peaty soils in swamps, such as river floodplains.[8]	Deciduous swamp communities within the study area may provide suitbale growing conditions, however the species was not observed during comprehensive 3-season vascular flora inventories in 2022.

Scientific Name	Common Name	S-RANK[1]	SARO[1]	COSEWIC[2]	SARA[2]	SARA Schedule[2]	Background Source	Habitat Requirements	Analysis
Fraxinus quadrangulata	Blue Ash	S2?	THR	T	SC	Schedule 1	iNaturalist 2023	Deciduous forests, usually on floodplains, occassionally on uplands.[8]	Deciduous swamp communities within the study area may provide suitbale growing conditions, however the species was not observed during comprehensive 3-season vascular flora inventories in 2022.
Juglans cinerea	Butternut	S2?	END	E	E	Schedule 1	Gartner Lee Ltd. 2004	Stream banks and swamps, as well as upland beech-maple, oak-hickory, and mixed hardwood stands.[8]	Deciduous forests within the study area may provide suitable growing conditions, however NRSI biologists did not observe the species during comprehensive 3-season vascular flora inventories in 2022.

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Appendix III

Significant Wildlife Habitat Screening Table

Table 1. Characteristics of Seasonal Concentration Areas for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Waterfowl Stopover and Staging Areas (Terrestrial)					Not Present
Habitat important to migrating waterfowl	American Black Duck Northern Pintail Gadwall Blue-winged Teal Green-winged Teal American Wigeon Northern Shoveler Tundra Swan	CUM1 CUT1 - Plus evidence of annual spring flooding from melt water or run-off within these Ecosites. - Fields with seasonal flooding and waste grain in the Long Point, Rondeau, Lake. St. Clair, Grand Bend and Pt. Pelee areas may be important to Tundra Swans.	Fields with sheet water during Spring (mid March to May). • Fields flooding during spring melt and run-off provide important invertebrate foraging habitat for migrating waterfowl. • Agricultural fields with waste grains are commonly used by waterfowl, these are not considered SWH unless they have spring sheet water available[cxlviii] <u>Information Sources</u> • Anecdotal information from the landowner, adjacent landowners or local naturalist clubs may be good information in determining occurrence. • Reports and other information available from Conservation Authorities (CAs) • Sites documented through waterfowl planning processes (eg. EHJV implementation plan) • Field Naturalist Clubs • Ducks Unlimited Canada • Natural Heritage Information Centre (NHIC) Waterfowl Concentration Area	Studies carried out and verified presence of an annual concentration of any listed species, evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • Any mixed species aggregations of 100[i] or more individuals required. • The area of the flooded field ecosite habitat plus a 100-300m radius buffer dependant on local site conditions and adjacent land use is the significant wildlife habitat[cxlviii]. • Annual use of habitat is documented from information sources or field studies (annual use can be based on studies or determined by past surveys with species numbers and dates). • SWHMIST[cxlix] Index #7 provides development effects and mitigation measures.	There is no evidence of annual spring flooding in the agricultural fields, cultural meadows, or cultural thicket habitats within the study area.
Wildlife Habitat: Waterfowl Stopover and Staging Areas (Aquatic)					Not Present
Important for local and migrant waterfowl populations during the spring or fall migration or both periods combined. Sites identified are usually only one of a few in the eco-district	Canada Goose Cackling Goose Snow Goose Green-winged Teal American Black Duck Northern Pintail Northern Shoveler American Wigeon Gadwall Blue-winged Teal Hooded Merganser Common Merganser Red-breasted Merganser Lesser Scaup Greater Scaup Common Goldeneye Bufflehead Long-tailed Duck Surf Scoter White-winged Scoter Black Scoter Canvasback Redhead Ruddy Duck Brant White-winged Scoter Black Scoter	MAS1 MAS2 MAS3 SAS1 SAM1 SAF1 SWD1 SWD2 SWD3 SWD4 SWD5 SWD6 SWD7	• Ponds, marshes, lakes, bays, coastal inlets, and watercourses used during migration. Sewage treatment ponds and storm water ponds do not qualify as a SWH, however a reservoir managed as a large wetland or pond/lake does qualify. • These habitats have an abundant food supply (mostly aquatic invertebrates and vegetation in shallow water). <u>Information Sources</u> • Environment Canada • Naturalist clubs often are aware of staging/stopover areas • OMNRF Wetland Evaluations indicate presence of locally and regionally significant waterfowl staging. • Sites documented through waterfowl planning processes (eg. EHJV implementation plan) • Ducks Unlimited projects • Element occurrence specification by Nature Serve: http://www.natureserve.org • Natural Heritage Information Centre (NHIC) Waterfowl Concentration Area	Studies carried out and verified presence of: • Aggregations of 100[i] or more of listed species for 7 days[i], results in >700 waterfowl use days. • Areas with annual staging of ruddy ducks, canvasbacks, and redheads are SWH[cxlix] • The combined area of the ELC ecosites and a 100m radius area is the SWH[cxlviii] • Wetland area and shorelines associated with sites identified within the SWHTG[cxlviii] Appendix K[cxlix] are significant wildlife habitat. • Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • Annual Use of Habitat is Documented from Information Sources or Field Studies (Annual can be based on completed studies or determined from past surveys with species numbers and dates recorded). • SWHMIST[cxlix] Index #7 provides development effects and mitigation measures.	Suitable ponds, marshes, lakes, bays, coastal inlets, and watercourses are not present within the study area.

Table 1. Characteristics of Seasonal Concentration Areas for Ecoregion 7E (MNRF 2015)

Rationale	Candidate SWH: Wildlife Species	Candidate SWH: ELC Ecosite Codes	Candidate SWH: Habitat Criteria and Information Sources	Confirmed SWH: Defining Criteria	Assessment Details: Study Area
Wildlife Habitat: Shorebird Migratory Stopover Area					Not Present
High quality shorebird stopover habitat is extremely rare and typically has a long history of use	Greater Yellowlegs Lesser Yellowlegs Marbled Godwit Hudsonian Godwit Black-bellied Plover American Golden-Plover Semipalmated Plover Solitary Sandpiper Spotted Sandpiper Semipalmated Sandpiper Pectoral Sandpiper White-rumped Sandpiper Baird's Sandpiper Least Sandpiper Purple Sandpiper Stilt Sandpiper Short-billed Dowitcher Red-necked Phalarope Whimbrel Ruddy Turnstone Sanderling Dunlin	BBO1 BBO2 BBS1 BBS2 BBT1 BBT2 SDO1 SDS2 SDT1 MAM1 MAM2 MAM3 MAM4 MAM5	Shorelines of lakes, rivers and wetlands, including beach areas, bars and seasonally flooded, muddy and un-vegetated shoreline habitats. Great Lakes coastal shorelines, including groynes and other forms of armour rock lakeshores, are extremely important for migratory shorebirds in May to mid-June and early July to October. Sewage treatment ponds and storm water ponds do not qualify as a SWH. Information Sources • Western hemisphere shorebird reserve network • Canadian Wildlife Service (CWS) Ontario Shorebird Survey • Bird Studies Canada • Ontario Nature • Local birders and naturalist clubs • Natural Heritage Information Center (NHIC) Shorebird Migratory Concentration Area	Studies confirming: • Presence of 3 or more of listed species and > 1000[i] shorebird use days during spring or fall migration period (shorebird use days are the accumulated number of shorebirds counted per day over the course of the fall or spring migration period). • Whimbrel stop briefly (<24hrs) during spring migration, any site with >100[i] Whimbrel used for 3 years or more is significant. • The area of significant shorebird habitat includes the mapped ELC shoreline ecosites plus a 100m radius area[cxlviii] • Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • SWHMIST[cxlix] Index #8 provides development effects and mitigation measures.	Suitable shorelines of lakes, rivers and wetlands are not present within the study area.
Wildlife Habitat: Raptor Wintering Area					Not Present
Sites used by multiple species, a high number of individuals and used annually are most significant	Rough-legged Hawk Red-tailed Hawk Northern Harrier American Kestrel Snowy Owl Special Concern: Short-eared Owl Bald Eagle	Hawks/Owls: Combination of ELC Community Series; need to have present one Community Series from each land class. Forest: FOD, FOM, FOC Upland: CUM, CUT, CUS, CUW Bald Eagle: Forest Community Series: FOD, FOM, FOC, SWD, SWM, or SWC, on shoreline areas adjacent to large rivers or adjacent to lakes with open water (hunting area).	The habitat provides a combination of fields and woodlands that provide roosting, foraging and resting habitats for wintering raptors. Raptor wintering (hawk/owl) sites need to be > 20ha[cxlviii, cxlix] with a combination of forest and upland[xvi, xvii, xviii, xix, xx, xxi]. Least disturbed sites, idle/fallow or lightly grazed field/meadow (>15ha) with adjacent woodlands[cxlix] Field area of the habitat is to be wind swept with limited snow depth or accumulation. Eagle sites have open water and large trees and snags aviable for roosting[cxlix] Information Sources • OMNRF Districts • Natural clubs • Natural Heritage Information Centre (NHIC) Raptor Winter Concentration Area • Data from Bird Studies Canada • Reports and other information available from CAs • Results of Christmas Bird Counts	Studies confirm the use of these habitats by: • One or more Short-eared Owls, or, One of more Bald Eagles or; at least 10 individuals and two listed hawk/owl species • To be significant a site must be used regularly (3 in 5 years)[cxlix] for a minimum of 20 days by the above number of birds[i]. • The habitat area for an Eagle winter site is the shoreline forest ecosites directly adjacent to the prime hunting area. • Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • SWHMIST[cxlix] Index #10 and #11 provides development effects and mitigation measures.	Although large woodlands are present, naturalized upland communities are limited. Lands within the study area are highly disturbed; indicator species are not tolerant of human disturbance.

Table 1. Characteristics of Seasonal Concentration Areas for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Bat Hibernacula					Not Present
Bat hibernacula, are rare habitats in all Ontario landscapes.	Big Brown Bat Eastern Pipistrelle/Tri-colored Bat	Bat Hibernacula may be found in these ecosites: CCR1 CCR2 CCA1 CCA2 (Note: buildings are not considered to be SWH)	Hibernacula may be found in caves, mine shafts, underground foundations and Karsts. Active mine sites should not be considered The locations of bat hibernacula are relatively poorly known. Information Sources • OMNRF for possible locations and contact for local experts • Natural Heritage Information Centre (NHIC) Bat Hibernaculum • Ministry of Northern Development and Mines for location of mine shafts • Clubs that explore caves (eg. Sierra Club) • University Biology Departments with bat experts	• All sites with confirmed hibernating bats are SWH[i]. • The area includes 200m radius around the entrance of the hibernaculum[cxlviii, ccvii, i]. for the development types and 1000m for wind farms [ccv]. • Studies are to be conducted during the peak swarming period (Aug. – Sept.). Surveys should be conducted following methods outlined in the[ccv]."Bats and Bat Habitats: Guidelines for Wind Power Projects" [ccv] • SWHMIST[cxlix] Index #1 provides development effects and mitigation measures.	The MNRF identifies bat hibernacula, and has not identified such from the study area. Caves, mine shafts, and karst are not present.
Wildlife Habitat: Bat Maternity Colonies					Not Present
Known locations of forested bat maternity colonies are extremely rare in all Ontario landscapes.	Big Brown Bat Silver-haired Bat	Maternity colonies considered SWH are found in forested Ecosites. All ELC Ecosites in ELC Community Series: FOD FOM SWD SWM	Maternity colonies can be found in tree cavities, vegetation and often in building [sxxii, xxv, xxvi, xxvii, xxxi] (buildings are not considered to be SWH). • Maternity roosts are not found in caves and mines in Ontario[xxii]. • Maternity colonies located in Mature deciduous or mixed forest stands[ccix, ccx] with >10/ha large diameter (>25cm dbh) wildlife trees[ccvii]. • Female Bats prefer wildlife tree (snags) in early stages of decay, class 1-3[ccxiv] or class 1 or 2[ccxii]. • Silver-haired Bats prefer older mixed or deciduous forest and form maternity colonies in tree cavities and small hollows. Older forest areas with at least 21 snags/ha are preferred[ccx]. Information Sources • OMNRF for possible locations and contact for local experts • University Biology Departments with bat experts	Maternity Colonies with confirmed use by: • >10 Big Brown Bats[i] • >5 Adult Female Silver-haired Bats[i] • The area of the habitat includes the entire woodland or the forest stand ELC Ecosite containing the maternity colonies[i]. • Evaluation methods for maternity colonies should be conducted following methods outlined in the "Bats and Bat Habitats: Guidelines for Wind Power Projects"[ccv]. • SWHMIST[cxlix] Index #12 provides development effects and mitigation measures.	Big Brown Bat and Silver-haired Bat are reported from the vicinity of the study area. Results of plot-based bat habitat assessments completed in woodlands where site access was available indicate that the density of large-diameter (>25cm dbh) candidate roost trees did not exceed the threshold of >10/ha. Suitable forested ecosites are present on properties within the study area where site access was not available, and plot-based habitat assessments could not be completed. These features are identified as Candidate Bat Maternity Colony SWH.

Table 1. Characteristics of Seasonal Concentration Areas for Ecoregion 7E (MNRF 2015)

Rationale	Candidate SWH: Wildlife Species	Candidate SWH: ELC Ecosite Codes	Candidate SWH: Habitat Criteria and Information Sources	Confirmed SWH: Defining Criteria	Assessment Details: Study Area
Wildlife Habitat: Turtle Wintering Area					Not Present
Generally sites are the only known sites in the area. Sites with the highest number of individuals are most significant.	Midland Painted Turtle <u>Special Concern</u>: Northern Map Turtle Snapping Turtle	Snapping and Midland Painted Turtles: ELC Community Classes: SW, MA, OA and SA ELC Community Series: FEO and BOO Northern Map Turtle: Open Water areas such as deeper rivers or streams and lakes with current can also be used as over-wintering habitat.	• For most turtles, wintering areas are in the same general area as their core habitat. Water has to be deep enough not to freeze and have soft mud substrates. • Over-wintering sites are permanent water bodies, large wetlands, and bogs or fens with adequate Dissolved Oxygen[cix, cx, cxi, cxviii]. • Man-made ponds such as sewage lagoons or storm water ponds should not be considered SWH <u>Information Sources</u> • EIS studies carried out by Conservation Authorities • Field naturalists clubs • OMNRF Ecologist or Biologist • Natural Heritage Information Centre (NHIC)	• Presence of 5 over-wintering Midland Painted Turtles is significant[i]. • One or more Northern Map Turtle or Snapping Turtle over-wintering within a wetland is significant[i]. • The mapped ELC ecosite area with the over wintering turtles is the SWH. If the hibernation site is within a stream or river, the deep-water pool where the turtles are over wintering is the SWH. • Over wintering areas may be identified by searching for congregations (Basking Areas) of turtles on warm, sunny days during the fall (Sept. – Oct.) or spring (Mar. – Apr)[cvii]. Congregation of turtles is more common where wintering areas are limited and therefore significant[cix, cx, cxi, cxii]. • SWHMIST[cxlix] Index #28 provides development effects and mitigation measures for turtle wintering habitat.	Deciduous swamp communities within the study area did not contain permanent water of a sufficient depth to support overwintering turtles.
Wildlife Habitat: Reptile Hibernaculum					Not Present
Generally sites are the only known sites in the area. Sites with the highest number of individuals are most significant	<u>Snakes:</u> Eastern Gartersnake Northern Watersnake Northern Red-bellied Snake Northern Brownsnake Smooth Green Snake Northern Ring-necked Snake <u>Special Concern</u>: Milksnake Eastern Ribbonsnake	For all snakes, habitat may be found in any ecosite in southern Ontario other than very wet ones. Talus, Rock Barren, Crevice and Cave, and Alvar sites may be directly related to these habitats. Observations of congregations of snakes on sunny warm days in the spring or fall is a good indicator. The existence of rock piles or slopes, stone fences, and crumbling foundations assist in identifying candidate SWH.	For snakes, hibernation takes place in sites located below frost lines in burrows, rock crevices and other natural locations. Areas of broken and fissured rock are particularly valuable since they provide access to subterranean sites below the frost line[xliv, l, li, lii, cxii]. Wetlands can also be important over-wintering habitat in conifer or shrub swamps and swales, poor fens, or depressions in bedrock terrain with sparse trees or shrubs with sphagnum moss or sedge hummock ground cover. <u>Information Sources</u> • In spring, local residents or landowners may have observed the emergence of snakes on their property (e.g. old dug wells). • Reports and other information available from CAs • Local naturalists and experts, as well as university herpetologists may also know where to find some of these sites. • Natural Heritage Information Centre (NHIC)	Studies confirming: • Presence of snake hibernacula used by a minimum of five individuals of a snake sp., or, individuals of two or more snake spp. • Congregations of a minimum of five individuals of a snake sp., or, individuals of two or more snake spp. near potential hibernacula (eg. foundation or rocky slope) on sunny warm days in Spring (Apr/May) and Fall (Sept/Oct)[i]. • Note: If there are Special Concern Species present, then site is SWH • Note: Sites for hibernation possess specific habitat parameters (e.g. temperature, humidity, etc.) and consequently are used annually, often by many of the same individuals of a local population (i.e. strong hibernation site fidelity). Other critical life processes (e.g. mating) often take place in close proximity to hibernacula. The feature in which the hibernacula is located plus a 30m buffer is the SWH[i]. • SWHMIST[cxlix] Index #13 provides development effects and mitigation measures for snake hibernacula.	Wildlife surveys in 2022 did not uncover any potential hibernacula features (e.g. rock piles, wells, crumbling foundations), and only a few observations of Eastern Gartersnake were documented within the study area. However, the absence of reptile hibernaculum SWH cannot be ruled out without extensive surveys, which were not undertaken as part of this study. Candidate Reptile Hibernaculum SWH is identified for the forested ecosites within the study area.

Table 1. Characteristics of Seasonal Concentration Areas for Ecoregion 7E (MNRF 2015)

Rationale	Candidate SWH			Confirmed SWH	Assessment Details
	Wildlife Species	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Colonially - Nesting Bird Breeding Habitat (Bank and Cliff)					Not Present
Historical use and number of nests in a colony make this habitat significant. An identified colony can be very important to local populations. All swallow population are declining in Ontario.	Cliff Swallow Northern Rough-winged Swallow (this species is not colonial but can be found in Cliff Swallow colonies)	Eroding banks, sandy hills, borrow pits, steep slopes, and sand piles Cliff faces, bridge abutments, silos, barns Habitat found in the following ecosites: CUM1 CUT1 CUS1 BLO1 BLS1 BLT1 CLO1 CLS1 CLT1	• Any site or areas with exposed soil banks, undisturbed or naturally eroding that is not a licensed/permitted aggregate area. • Does not include man-made structures (bridges or buildings) or recently (2 years) disturbed soil areas, such as berms, embankments, soil or aggregate stockpiles. • Does not include a licensed/permitted Mineral Aggregate Operation. <u>Information Sources</u> • Reports and other information available from CAs • Ontario Breeding Bird Atlas[ccv]. • Bird Studies Canada: Nature Counts http://www.birdscanada.org/birdmon/ • Field Naturalist clubs	Studies confirming: • Presence of 1 or more nesting sites with 8[cxlvix] or more cliff swallow pairs and/or rough-winged swallow pairs during the breeding season. • A colony identified as SWH will include a 50m radius habitat area from the peripheral nests[ccvii]. • Field surveys to observe and count swallow nests are to be completed during the breeding season. Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi]. • SWHMIST[cxlix] Index #4 provides development effects and mitigation measures.	Suitable eroding banks are not present along the Gilliland-Geerts Drain. Cliff Swallow was not observed within the study area during breeding bird surveys in 2022.
Wildlife Habitat: Colonially - Nesting Bird Breeding Habitat (Tree/Shrubs)					Not Present
Large colonies are important to local bird population, typically sites are only known colony in area and are used annually.	Great Blue Heron Black-crowned Night-Heron Great Egret Green Heron	SWM2 SWM3 SWM5 SWM6 SWD1 SWD2 SWD3 SWD4 SWD5 SWD6 SWD7 FET1	• Nests in live or dead standing trees in wetlands, lakes, islands, and peninsulas. Shrubs and occasionally emergent vegetation may also be used. • Most nests in trees are 11 to 15 m from ground, near the top of the tree. <u>Information Sources</u> • Ontario Breeding Bird Atlas[ccv], colonial nest records. • Ontario Heronry Inventory 1991 available from Bird Studies Canada or NHIC (OMNRF). • Natural Heritage Information Centre (NHIC) Mixed Wader Nesting Colony • Aerial photographs can help identify large heronries. • Reports and other information available from CAs • MNRF District Offices • Field naturalist clubs	Studies confirming: • Presence of 2 or more active nests of Great Blue Heron or other list species. • The habitat extends from the the edge of the colony and a minimum 300m radius or extent of the Forest Ecosite containing the colony or any island <15.0ha with a colony is the SWH[cc, ccvii]. • Confirmation of active colonies must be achieved through site visits conducted during the nesting season (April to August) or by evidence such as the presence of fresh guano, dead young and/or eggshells • SWHMIST[cxlix] Index #5 provides development effects and mitigation measures.	No suitable habitat is present within the study area. No active or inactive nests of any of the indicator species were observed within the study area.

Table 1. Characteristics of Seasonal Concentration Areas for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Colonially - Nesting Bird Breeding Habitat (Ground)					Not Present
Colonies are important to local bird population, typically sites are only known colony in area and are used annually.	Herring Gull Great Black-backed Gull Little Gull Ring-billed Gull Common Tern Caspian Tern Brewer's Blackbird	Any rocky island or peninsula (natural or artificial) within a lake or large river (two-lined on a 1:50,000 NTS map). Close proximity to watercourses in open fields or pastures with scattered trees or shrubs (Brewer's Blackbird) MAM1 – 6 MAS1 – 3 CUM CUT CUS	• Nesting colonies of gulls and terns are on islands or peninsulas associated with open water or in marshy areas. • Brewers Blackbird colonies are found loosely on the ground in or in low bushes in close proximity to streams and irrigation ditches within farmlands. <u>Information Sources</u> • Ontario Breeding Bird Atlas[ccv], rare/colonial species records. • Canadian Wildlife Service • Reports and other information available from CAs • Natural Heritage Information Centre (NHIC) Colonial Waterbird Nesting Area • MNRF District Offices • Field naturalist clubs	Studies confirming: • Presence of >25 active nests for Herring Gulls, >5 active nests for Common Tern or >2 active nests for Caspian Tern[i]. • Any active nesting colony of one or more Little Gull, and Great Black-backed Gull is significant[i]. • Presence of 5 or more pairs for Brewer's Blackbird[i]. • The edge of the colony and a minimum 150m radius area of the habitat, or the extent of the ELC ecosites containing the colony or any island <3.0ha with a colony is the SWH[cc, ccvii]. • Studies would be done during May/June when actively nesting. Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi]. • SWHMIST[cxlix] Index #6 provides development effects and mitigation measures.	Rocky islands or peninsulas are not present in the study area.
Wildlife Habitat: Migratory Butterfly Stopover Areas					Not Present
<u>Rationale:</u> Butterfly stopover areas are extremely rare habitats and are biologically important for butterfly species that migrate south for the winter	Painted Lady Red Admiral <u>Special Concern</u>: Monarch	Combination of ELC Community Series; need to have present one Community Series from each landclass: Field: CUM CUT CUS Forest: FOC FOD FOM CUP Anecdotally, a candidate site for butterfly stopover will have a history of butterflies being observed.	A butterfly stopover area will be a minimum of 10ha in size with a combination of field and forest habitat present, and will be located within 5km of Lake Ontario and Erie[cxlix]. • The habitat is typically a combination of field and forest, and provides the butterflies with a location to rest prior to their long migration south [xxxii, xxxiii, xxxiv, xxxv, xxxvi]. • The habitat should not be disturbed, fields/meadows with an abundance of preferred nectar plants and woodland edge providing shelter are requirements for this habitat [cxlviii, cxlix]. • Staging areas usually provide protection from the elements and are often spits of land or areas with the shortest distance to cross the Great Lakes [xxxvii, xxxviii, xxxix, xl, xli]. <u>Information Sources</u> • MNRF District Offices • Natural Heritage Information Centre (NHIC) • Agriculture Canada in Ottawa may have list of butterfly experts. • Field Naturalist Clubs • Toronto Entomologists Association • Conservation Authorities	Studies confirm: • The presence of Monarch Use Days (MUD) during fall migration (Aug/Oct)[xliii]. MUD is based on the number of days a site is used by Monarchs, multiplied by the number of individuals using the site. Numbers of butterflies can range from 100-500/day[xxxvii], significant variation can occur between years and multiple years of sampling should occur[xl, xlii]. • Observational studies are to be completed and need to be done frequently during the migration period to estimate MUD • MUD of >5000 or >3000 with the presence of Painted Ladies or White Admiral's is to be considered significant[i]. • SWHMIST[cxlix] Index #16 provides development effects and mitigation measures.	The study area is not within 5km or Lake Ontario or Lake Erie.

Table 1. Characteristics of Seasonal Concentration Areas for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	Wildlife Species	ELC Ecosite Codes	Habitat Criteria and Information Sources	Defining Criteria	Study Area
Wildlife Habitat: Landbird Migratory Stopover Areas					Not Present
Sites with a high diversity of species as well as high numbers are most significant	All migratory songbirds Canadian Wildlife Service Ontario website: http://www.on.ec.gc.ca/wildlife_e.html All migrant raptors species Ontario Ministry of Natural Resources: Fish and Wildlife Conservation Act, 1997. Schedule 7: Specially Protected Birds (Raptors)	All Ecosites associated with these ELC Community Series: FOC FOM FOD SWC SWM SWD	Woodlots need to be >5 ha[i] in size and within 5km [iv, v, vi, vii, viii, ix, x, xi, xii, xiii, xiv, xv] of Lake Ontario and Erie. If woodlands are rare in an area of shoreline, woodland fragments 2-5ha can be considered for this habitat • If multiple woodlands are located along the shoreline those Woodlands <2km from Lake Erie or Ontario are more significant[cxlix]. • Sites have a variety of habitats: forest, grassland and wetland complexes[cxlix]. • The largest sites are more significant[cxlix] • Woodlots and forest fragments are important habitats to migrating birds[ccxviii], these features located along the shore and located within 5km of Lake Ontario and Lake Erie are Candidate SWH[cxlviii]. Information Sources • Bird Studies Canada • Ontario Nature • Local birders and naturalist clubs • Ontario Important Bird Areas (IBA) Program	Studies confirm: • Use of the habitat by >200 birds/day and with >35 spp. with at least 10 bird spp. recorded on at least 5 different survey dates[i]. This abundance and diversity of migrant bird species is considered above average and significant. • Studies should be completed during spring (March/May) and fall (Aug/Oct) migration using standardized assessment techniques. Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi]. • SWHMIST[cxlix] Index #9 provides development effects and mitigation measures.	The study area is not within 5km or Lake Ontario or Lake Erie.
Wildlife Habitat: Deer Winter Congregation Areas					Not Present
Deer movement during winter in the southern areas of Ecoregion 7E are not constrained by snow depth, however deer will annually congregate in large numbers in suitable woodlands to reduce or avoid the impacts of winter conditions [cxlviii]	White-tailed Deer	All Forested Ecosites with these ELC Community Series: FOC FOM FOD SWC SWM SWD Conifer plantations (CUP) smaller than 50 ha may also be used.	• Woodlots >100 ha in size or if large woodlots are rare in a planning area woodlots>50ha[i]. • Deer movement during winter in Ecoregion 7E are not constrained by snow depth, however deer will annually congregate in large numbers in suitable woodlands[cxlviii]. • Large woodlots > 100ha and up to 1500 ha are known to be used annually by densities of deer that range from 0.1-1.5 deer/ha[ccxxiv]. • Woodlots with high densities of deer due to artificial feeding are not significant[i]. Information Sources • MNRF District Offices • LIO/NRVIS	Studies confirm: • Deer management is an MNRF responsibility, deer winter congregation areas considered significant will be mapped by MNRF[cxlviii]. • Use of the woodlot by white-tailed deer will be determined by MNRF, all woodlots exceeding the area criteria are significant, unless determined not to be significant by MNRF[i]. • Studies should be completed during winter (Jan/Feb) when >20cm of snow is on the ground using aerial survey techniques[ccxxiv], ground or road surveys, or a pellet count deer density survey[ccxxv]. • SWHMIST[cxlix] Index #2 provides development effects and mitigation measures.	The MNRF has not identified deer winter congregation areas within the study area.

Table 2. Characteristics of Rare Vegetation Communities for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**ELC Ecosite Codes**	**Habitat Description**	**Detailed Information and Sources**	**Defining Criteria**	**Study Area**
Cliff and Talus Slopes					Not Present
Cliffs and Talus Slopes are extremely rare habitats in Ontario.	Any ELC Ecosite within Community Series: TAO TAS TAT CLO CLS CLT	A Cliff is vertical to near vertical bedrock >3m in height. A Talus Slope is rock rubble at the base of a cliff made up of coarse rocky debris.	Most cliff and talus slopes occur along the Niagara Escarpment. Information Sources • The Niagara Escarpment Commission has detailed information on location of these habitats. • OMNRF Districts • Natural Heritage Information Centre (NHIC) has location information available on their website • Field naturalist clubs • Conservation Authorities	• Confirm any ELC Vegetation Type for Cliffs or Talus Slopes[lxxviii] • SWHMIST[cxlix] Index #21 provides development effects and mitigation measures.	Cliff and talus slope habitat is not present within the study area.
Sand Barrens					Not Present
Sand barrens are rare in Ontario and support rare species. Most Sand Barrens have been lost due to cottage development and forestry.	ELC Ecosites: SBO1 SBS1 SBT1 Vegetation cover varies from patchy and barren to continuous meadow (SBO1), thicket-like (SBS1), or more closed and treed (SBT1). Tree cover always ≤ 60%.	Sand Barrens typically are exposed sand, generally sparsely vegetated and caused by lack of moisture, periodic fires and erosion. They have little or no soil and the underlying rock protrudes through the surface. Usually located within other types of natural habitat such as forest or savannah. Vegetation can vary from patchy and barren to tree covered but less than 60%.	A sand barren area >0.5ha in size Information Sources • OMNRF Districts • Natural Heritage Information Centre (NHIC) has location information available on their website • Field naturalist clubs • Conservation Authorities	• Confirm any ELC Vegetation Type for Sand Barrens[lxxviii] • Site must not be dominated by exotic or introduced species (<50% vegetative cover are exotics sp)[i]. • SWHMIST[cxlix] Index #20 provides development effects and mitigation measures.	Sand barren habitat is not present within the study area.

Table 2. Characteristics of Rare Vegetation Communities for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**ELC Ecosite Codes**	**Habitat Description**	**Detailed Information and Sources**	**Defining Criteria**	**Study Area**
Alvar					Not Present
Alvars are extremely rare habitats in Ecoregion 7E	ALO1 ALS1 ALT1 FOC1 FOC2 CUM2 CUS2 CUT2-1 CUW2 Five Alvar Indicator Species: 1) *Carex crawei* 2) *Panicum philadelphicum* 3) *Eleocharis compressa* 4) *Scutellaria parvula* 5) *Trichostema brachiatum* These indicator species are very specific to Alvars within Ecoregion 7E[cxlix]	An alvar is typically a level, mostly unfractured calcareous bedrock feature with a mosaic of rock pavements and bedrock overlain by a thin veneer of soil. The hydrology of alvars is complex, with alternating periods of inundation and drought. Vegetation cover varies from sparse lichen-moss associations to grasslands and shrublands and comprising a number of characteristic or indicator plant. Undisturbed alvars can be phyto- and zoogeographically diverse, supporting many uncommon or are relict plant and animals species. Vegetation cover varies from patchy to barren with a less than 60% tree cover[lxxviii].	An Alvar site > 0.5ha in size[lxxv]. Alvar is particularly rare in Ecoregion 7E where the only known sites are found in the western islands of Lake Erie[cxcix]. <u>Information Sources</u> • Alvars of Ontario (2000), Federation of Ontario Naturalists[lxxvi]. • Ontario Nature – Conserving Great Lakes Alvars[ccviii]. • Natural Heritage Information Centre (NHIC) has location information available on their website • OMNRF Staff • Field Naturalist clubs • Conservation Authorities	Field studies identify four of the five **Alvar indicator species**[lxxv] at a candidate Alvar site is Significant • Site must not be dominated by exotic or introduced species (<50% vegetative cover exotics). • The alvar must be in excellent condition and fit in with surrounding landscape with few conflicting land uses[lxxv]. • SWHMIST[cxlix] Index #17 provides development effects and mitigation measures.	Alvar habitat is not present within the study area.

Table 2. Characteristics of Rare Vegetation Communities for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**ELC Ecosite Codes**	**Habitat Description**	**Detailed Information and Sources**	**Defining Criteria**	**Study Area**
Old Growth Forest					Not Present
Due to historic logging practices and land clearance for agriculture, old growth forest is rare in Ecoregion 7E.	Forest Community Series: FOD FOC FOM SWD SWC SWM	Old growth forests are characterized by heavy mortality or turnover of overstorey trees resulting in a mosaic of gaps that encourage development of a multi-layered canopy and an abundance of snags and downed woody debris.	Woodland area is >0.5ha Information Sources • OMNRF Forest Resource Inventory mapping • OMNRF Districts • Field naturalist clubs • Conservation Authorities • Sustainable Forestry Licence (SFL) companies will possibly know locations through field operations. • Municipal forestry departments	Field Studies will determine: • If dominant trees species of the ecosite are >140 years old, then stand is Significant Wildlife Habitat[cxlviii]. • The forested area containing the old growth characteristics will have experienced no recognizable forestry activities [cxlviii] (cut stumps will not be present) • Determine ELC Vegetation Type for forest area containing the old growth characteristics[lxxviii]. • SWHMIST[cxlix] Index #23 provides development effects and mitigation measures.	The forest communities within the study area do not contain old growth forest habitat.
Savannah					Not Present
Savannahs are extremely rare habitats in Ontario.	TPS1 TPS2 TPW1 TPW2 CUS2	A Savannah is a tallgrass prairie habitat that has tree cover between 25 – 60%. In Ecoregion 7E, known Tallgrass Prairie and savannah remnants are scattered between Lake Huron and Lake Erie, near Lake St. Clair, north of and along the Lake Erie shoreline, in Brantford and in the Toronto area (north of Lake Ontario)[cc].	No minimum size to site[i] Site must be restored or a natural site. Remnant sites such as railway right of ways are not considered to be SWH. Information Sources • OMNRF Districts • Natural Heritage Information Centre (NHIC) has location data available on their website • Field naturalists clubs • Conservation Authorities	Field studies confirm one or more of the Savannah indicator species listed in[lxxv] Appendix N should be present[i]. Note: Savannah plant spp. list from Ecoregion 7E should be used. • Area of the ELC Vegetation type is the SWH[lxxviii]. • Site must not be dominated by exotic or introduced species (<50% vegetative cover exotics). • SWHMIST[cxlix] Index #18 provides development effects and mitigation measures.	Savannah habitat is not present within the study area.

Table 2. Characteristics of Rare Vegetation Communities for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**ELC Ecosite Codes**	**Habitat Description**	**Detailed Information and Sources**	**Defining Criteria**	**Study Area**
Tallgrass Prairie					Not Present
Tallgrass Prairies are extremely rare habitats in Ontario.	TPO1 TPO2	A Tallgrass Prairie has ground cover dominated by prairie grasses. An open Tallgrass Prairie habitat has < 25% tree cover. In Ecoregion 7E, known Tallgrass Prairie and savannah remnants are scattered between Lake Huron and Lake Erie, near Lake St. Clair, north of and along the Lake Erie shoreline, in Brantford and in the Toronto area (north of Lake Ontario)[cc].	No minimum size to site[i]. Site must be restored or a natural site. Remnant sites such as railway right of ways are not considered to be SWH. <u>Information Sources</u> • Natural Heritage Information Centre (NHIC has location information available on their website • OMNRF Districts • Field naturalists clubs • Conservation Authorities	Field studies confirm one or more of the Prairie indicator species listed in[lxxv] Appendix N should be present[i]. Note: Prairie plant spp. list from Ecoregion 7E should be used. • Area of the ELC Vegetation Type is the SWH[lxxviii]. • Site must not be dominated by exotic or introduced species (<50% vegetative cover exotics). • SWHMIST[cxlix] Index #19 provides development effects and mitigation measures.	Tallgrass prairie habitat is not present within the study area.
Other Rare Vegetation Communities					Not Present
Plant communities that often contain rare species which depend on the habitat for survival.	Provincially Rare S1, S2 and S3 vegetation communities are listed in Appendix M of the SWHTG[cxlviii]. Any ELC Ecosite Code that has a possible ELC Vegetation Type that is Provincially Rare is Candidate SWH.	Rare Vegetation Communities may include beaches, fens, forest, marsh, barrens, dunes and swamps.	ELC Ecosite codes that have the potential to be a rare ELC Vegetation Type as outlined in appendix M[cxlviii]. The OMNRF/NHIC will have up to date listing for rare vegetation communities. <u>Information Sources</u> • Natural Heritage Information Centre (NHIC) has location information available on their website • OMNRF Districts • Field naturalists clubs • Conservation Authorities	Field studies should confirm if an ELC Vegetation Type is a rare vegetation community based on listing within Appendix M of SWHTG[cxlviii]. • Area of the ELC Vegetation Type polygon is the SWH. • SWHMIST[cxlix] Index #37 provides development effects and mitigation measures.	No other rare vegetation communities were observed within the study area.

Table 3. Characteristics of Specialized Wildlife Habitat for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Waterfowl Nesting Area					Not Present
Important to local waterfowl populations, sites with greatest number of species and highest number of individuals are significant	American Black Duck Northern Pintail Northern Shoveler Gadwall Blue-winged Teal Green-winged Teal Wood Duck Hooded Merganser Mallard	All upland habitats located adjacent to these wetland ELC Ecosites are Candidate SWH: MAS1 MAS2 MAS3 SAS1 SAM1 SAF1 MAM1 MAM2 MAM3 MAM4 MAM5 MAM6 SWT1 SWT2 SWD1 SWD2 SWD3 SWD4 Note: includes adjacency to Provincially Significant Wetlands	A waterfowl nesting area extends: 120m[cxlix] from a wetland (>0.5ha) or a wetland (>0.5ha) with small wetlands (0.5ha) within 120m or a cluster of 3 or more small (<0.5 ha) wetlands within 120m of each individual wetland where waterfowl nesting is known to occur[cxlix]. • Upland areas should be at least 120m wide so that predators such as racoons, skunks, and foxes have difficulty finding nests. • Wood Ducks and Hooded Mergansers utilize large diameter trees (>40cm dbh) in woodlands for cavity nest sites. <u>Information Sources</u> • Ducks Unlimited staff may know the locations of particularly productive nesting sites. • OMNRF Wetland Evaluations for indication of significant waterfowl nesting habitat. • Reports and other information available from CAs	Studies confirmed: • Presence of 3 or more nesting pairs for listed species excluding Mallards[i], or, • Presence of 10 or more nesting pairs for listed species including Mallards[i]. • Any active nesting site of an American Black Duck is considered significant. • Nesting studies should be completed during the spring breeding season (April - June). Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • A field study confirming waterfowl nesting habitat will determine the boundary of the waterfowl nesting habitat for the SWH, this may be greater or less than 120m[cxlviii] from the wetland and will provide enough habitat for waterfowl to successfully nest. • SWHMIST[cxlix] Index #25 provides development effects and mitigation measures.	Upland areas adjacent to the swamp and marsh habitats are not present within the study area are not sufficiently wide. Nesting pairs of the listed indicator species were not observed by NRSI biologists during 2022 breeding bird surveys.

Table 3. Characteristics of Specialized Wildlife Habitat for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Bald Eagle and Osprey Nesting, Foraging and Perching Habitat					Not Present
Nest sites are fairly uncommon in Ecoregion 7E and are used annually by these species. Many suitable nesting locations may be lost due to increasing shoreline development pressures and scarcity of habitat.	Osprey <u>Special Concern</u>: Bald Eagle	ELC Forest Community Series: FOD, FOM, FOC, SWD, SWM and SWC directly adjacent to riparian areas – rivers, lakes, ponds and wetlands.	Nests are associated with lakes, ponds, rivers or wetlands along forested shorelines, islands, or on structures over water. Osprey nests are usually at the top a tree whereas Bald Eagle nests are typically in super canopy trees in a notch within the tree's canopy. Nests located on man-made objects are not to be included as SWH (e.g. telephone poles and constructed nesting platforms). <u>Information Sources</u> • Natural Heritage Information Center (NHIC) compiles all known nesting sites for Bald Eagles in Ontario • MNRF values information (LIO/NRVIS) will list known nesting locations, Note: data from NRVIS is provided as a point format and does not include all the habitat. • Nature Counts, Ontario Nest Records Scheme data • OMNRF Districts • Check the Ontario Breeding Bird Atlas[ccv] or Rare Breeding Birds in Ontario for species documented • Reports and other information available from CAs • Field naturalists clubs	Studies confirm the use of these nests by: • One or more active Osprey or Bald Eagle nests in an area[cxlviii]. • Some species have more than one nest in a given area and priority is given to the primary nest with alternate nests included within the area of the SWH. • For an Osprey, the active nest and a 300m radius around the nest or the contiguous woodland stand is the SWH[ccvii], maintaining undisturbed shorelines with large trees within this area is important[cxlviii]. • For a Bald Eagle the active nest and a 400-800m radius around the nest is the SWH[cvi, ccvii]. Area of the habitat from 400-800m is dependant on site lines from the nest to the development and inclusion of perching and foraging habitat[cvi]. • To be significant a site must be used annually. When found inactive, the site must be known to be inactive for <u>></u>3 years or suspected of not being used for >5 years before being considered not significant[ccvii]. • Observational studies to determine nest site use, perching sites and foraging areas need to be done from mid March to mid August. • Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • SWHMIST[cxlix] Index #26 provides development effects and mitigation measures.	Forest communities adjacent to suitable rivers, lakes, ponds and wetlands are not present within the study area. Neither Osprey nor Bald Eagle were observed nesting within the study area in 2022.

Table 3. Characteristics of Specialized Wildlife Habitat for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Woodland Raptor Nesting Habitat					Not Present
Nests sites for these species are rarely identified; these area sensitive habitats are often used annually by these species.	Northern Goshawk Cooper's Hawk Sharp-shinned Hawk Red-shouldered Hawk Barred Owl Broad-winged Hawk	May be found in all forested ELC Ecosites. May also be found in SWC, SWM, SWD and CUP3	All natural or conifer plantation woodland/forest stands combined >30ha or with >4ha of interior habitat[lxxxviiii, lxxxix, xc, xci, xciii, xciv, xcv,xcvi, cxxxiii]. Interior habitat determined with a 200m buffer[cxlviii]. • Stick nests found in a variety of intermediate-aged to mature conifer, deciduous or mixed forests within tops or crotches of trees. Species such as Coopers hawk nest along forest edges sometimes on peninsulas or small off-shore islands. • In disturbed sites, nests may be used again, or a new nest will be in close proximity to old nest. <u>Information Sources</u> • OMNRF Districts • Check the Ontario Breeding Bird Atlas[ccv] or Rare Breeding Birds in Ontario for species documented. • Check data from Bird Studies Canada • Reports and other information available from CAs	Studies confirm: • Presence of 1 or more active nests from species list is considered significant[cxlviii]. • Red-shouldered Hawk and Northern Goshawk – A 400m radius around the nest or 28 ha of habitat is the SWH[ccvii].(the 28ha habitat area would be applied where optimal habitat is irregularly shaped around the nest) • Barred Owl – A 200m radius around the nest is the SWH[ccvii]. • Broad-winged Hawk and Coopers Hawk – A 100m radius around the nest is the SWH[ccvii]. • Sharp-Shinned Hawk – A 50m radius around the nest is the SWH[ccvii]. • Conduct field investigations from early March to end of May. The use of call broadcasts can help in locating territorial (courting/nesting) raptors and facilitate the discovery of nests by narrowing down the search area. • SWHMIST[cxlix] Index #27 provides development effects and mitigation measures.	Natural woodlands with interior habitat are present, however interior areas >100m from the edge are <4ha. None of the listed indicator species were observed nesting within the study area in 2022.
Wildlife Habitat: Turtle Nesting Area					Not Present
These habitats are rare and when identified will often be the only breeding site for local populations of turtles.	Midland Painted Turtle <u>Special Concern</u>: Northern Map Turtle Snapping Turtle	Exposed mineral soil (sand or gravel) areas adjacent (<100m)[cxlviii] or within the following ELC Ecosites: MAS1 MAS2 MAS3 SAS1 SAM1 SAF1 BOO1 FEO1	• Best nesting habitat for turtles are close to water and away from roads and sites less prone to loss of eggs by predation from skunks, raccoons or other animals. • For an area to function as a turtle-nesting area, it must provide sand and gravel that turtles are able to dig in and are located in open, sunny areas. Nesting areas on the sides of municipal or provincial road embankments and shoulders are not SWH. • Sand and gravel beaches adjacent to undisturbed shallow weedy areas of marshes, lakes, and rivers are most frequently used. <u>Information Sources</u> • Use Ontario Soil Survey reports and maps to help find suitable substrate for nesting turtles (well-drained sands and fine gravels). • Check the Ontario Herpetofaunal Summary Atlas records or other similar atlases for uncommon turtles; location information may help to find potential nesting habitat for them. • Natural Heritage Information Center (NHIC) Field naturalist clubs	Studies confirm: • Presence of 5 or more nesting Midland Painted Turtles[l] • One or more Northern Map Turtle or Snapping Turtle nesting is a SWH[l] • The area or collection of sites within an area of exposed mineral soils where the turtles nest, plus a radius of 30-100m around the nesting area dependant on slope, riparian vegetation and adjacent land use is the SWH[cxlviii]. • Travel routes from wetland to nesting area are to be considered within the SWH as part of the 30-100m area of habitat[cxlix]. • Field investigations should be conducted in prime nesting season typically late spring to early summer. Observation studies observing the turtles nesting is a recommended method. • SWHMIST[cxlix] Index #28 provides development effects and mitigation measures for turtle nesting habitat.	Areas with exposed mineral soils close to water and away from roads are not present within the study area.

Table 3. Characteristics of Specialized Wildlife Habitat for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Seeps and Springs					Not Present
Seeps/Springs are typical of headwater areas and are often at the source of coldwater streams	Wild Turkey Ruffed Grouse Spruce Grouse White-tailed Deer Salamander spp.	Seeps/Springs are areas where ground water comes to the surface. Often they are found within headwater areas within forested habitats. Any forested Ecosite within the headwater areas of a stream could have seeps/springs.	Any forested area (with <25% meadow/field/pasture) within the headwaters of a stream or river system[cxvii, cxlix]. • Seeps and springs are important feeding and drinking areas especially in the winter will typically support a variety of plant and animal species[cxix, cxx, cxxi, cxxii, cxiii, cxiv]. <u>Information Sources</u> • Topographical Map • Thermography • Hydrological surveys conducted by CAs and MOE • Field naturalists and landowners • Municipalities and Conservation Authorities may have drainage maps and headwater areas mapped	Field Studies confirm: • Presence of a site with 2 or more[i] seeps/springs should be considered SWH. • The area of a ELC forest ecosite containing the seeps/springs is the SWH. The protection of the recharge area considering the slope, vegetation, height of trees and groundwater condition need to be considered in delineation of the habitat[cxlviii]. • SWHMIST[cxlix] Index #30 provides development effects and mitigation measures.	Seeps or springs were not observed by NRSI biologists in any of the forested areas within the study area.
Wildlife Habitat: Amphibian Breeding Habitat (Woodland)					Not Present
These habitats are extremely important to amphibian biodiversity within a landscape and often represent the only breeding habitat for local amphibian populations	Eastern Newt Blue-spotted Salamander Spotted Salamander Gray Treefrog Spring Peeper Western Chorus Frog Wood Frog	All Ecosites associated with these ELC Community Series: FOC FOM FOD SWC SWM SWD Breeding pools within the woodland or the shortest distance from forest habitat are more significant because they are more likely to be used due to reduced risk to migrating amphibians.	• Presence of a wetland, pond or woodland pool (including vernal pools) >500m^2 (about 25m diameter) [ccvii] within or adjacent (within 120m) to a woodland (no minimum size)[clxxxii, lxiii, lxv, lxvi, lxvii, lxviii, lxix, lxx]. Some small wetlands may not be mapped and may be important breeding pools for amphibians. • Woodlands with permanent ponds or those containing water in most years until mid-July are more likely to be used as breeding habitat[cxlviii]. <u>Information Sources</u> • Ontario Herpetofaunal Summary Atlas (or other similar atlases) for records • Local landowners may also provide assistance as they may hear spring-time choruses of amphibians on their property. • OMNRF Districts and wetland evaluations • Field naturalist clubs • Canadian Wildlife Service Amphibian Road Call Survey • Ontario Vernal Pool Association: http://www.ontariovernalpools.org	Studies confirm: • Presence of breeding population of 1 or more of the listed newt/salamander species or 2 or more of the listed frog/toad species with at least 20 individuals (adults or eggs masses) or 2 or more of the listed frog/toad species with Call Level Codes of 3. • A combination of observational study and call count surveys [cviii] will be required during the spring (March-June) when amphibians are concentrated around suitable breeding habitat within or near the woodland/wetlands. • The habitat is the wetland area plus a 230m radius of woodland area[lxiii, lxv, lxvi, lxvii, lxviii, lxix, lxx, lxxi]. If a wetland area is adjacent to a woodland, a travel corridor connecting the wetland to the woodland is to be included in the habitat. • SWHMIST[cxlix] Index #14 provides development effects and mitigation measures.	No woodlands within the study area meet SWH criteria.

Table 3. Characteristics of Specialized Wildlife Habitat for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Amphibian Breeding Habitat (Wetland)					Not Present
Wetlands supporting breeding for these amphibian species are extremely important and fairly rare within Central Ontario Landscapes	Eastern Newt American Toad Spotted Salamander Four-toed Salamander Blue-spotted Salamander Gray Treefrog Western Chorus Frog Northern Leopard Frog Pickerel Frog Green Frog Mink Frog Bullfrog	ELC Community Classes SW, MA, FE, BO, OA and SA. Typically these wetland ecosites will be isolated (>120m) from woodland ecosites, however larger wetlands containing predominantly aquatic species (e.g. Bull Frog) may be adjacent to woodlands.	• Wetlands >500m^2 (about 25m diameter)[ccvii] supporting high species diversity are significant: some small or ephemeral habitats may not be identified on MNR mapping and could be important amphibian breeding habitats[clxxxiv]. • Presence of shrubs and logs increase significance of pond for some amphibian species because of available structure for calling, foraging, escape and concealment from predators. • Bullfrogs require permanent water bodies with abundant emergent vegetation. <u>Information Sources</u> • Ontario Herpetofaunal Summary Atlas (or other similar atlases) • Canadian Wildlife Service Amphibian Road Surveys and Backyard Amphibian Call Count. • OMNRF Districts and wetland evaluations • Reports and other information available from CAs	Studies confirm: • Presence of breeding population of 1or more of the listed newt/salamander species or 2 or more of the listed frog or toad species and with at least 20 breeding individuals (adults and eggs masses)[lxxi, lxxiii] or 2 or more of the listed frog/toad species with Call Level of 3. or; Wetland with confirmed breeding Bullfrogs are significant[i]. • The ELC ecosite wetland area and the shoreline are the SWH. • A combination of observational study and call count surveys cviii to determine breeding/larval stages will be required during the spring (May March-June) when amphibians are concentrated around suitable breeding habitat within or near the woodland/wetlands. • If a SWH is determined for Amphibian Breeding Habitat (Wetlands) then Movement Corridors are to be considered as outlined in Table 1.4.1 of this Schedule. • SWHMIST[cxlix] Index #15 provides development effects and mitigation measures.	No wetlands within the study area meet SWH criteria.
Wildlife Habitat: Woodland Area-Sensitive Bird Breeding Habitat					Not Present
Large, natural blocks of mature woodland habitat within the settled areas of Southern Ontario are important habitats for area sensitive interior forest song birds.	Yellow-bellied Sapsucker Red-breasted Nuthatch Veery Blue-headed Vireo Northern Parula Black-throated Green Warbler Blackburnian Warbler Black-throated Blue Warbler Ovenbird Scarlet Tanager Winter Wren Pileated Woodpecker <u>Special Concern</u>: Cerulean Warbler Canada Warbler	All Ecosites associated with these ELC Community Series: FOC FOM FOD SWC SWM SWD	• Habitats where interior forest breeding birds are breeding, typically large mature (>60 yrs. old) forest stands or woodlots >30ha[cv, cxxxi, cxxxii, cxxxiii, cxxxiv, cxxxv, cxxxvi, cxxxvii, cxxxviii, cxxxix, cxl, cxli, cxlii, cxliii, cxliv, cxlv, cxlvi, cl, cli, clii, cliii, cliv, clv, clvi, clvii, clviii, clix]. • Interior forest habitat is at least 200m from forest edge habitat[clxiv]. <u>Information Sources</u> • Local birder clubs • Canadian Wildlife Service (CWS) for the location of forest bird monitoring • Bird Studies Canada conducted a 3-year study of 287 woodlands to determine the effects of forest fragmentation on forest birds and to determine what forests were of greatest value to interior species. • Reports and other information available from CAs	Studies confirm: • Presence of nesting or breeding pairs of 3 or more of the listed wildlife species[i]. • Note: any site with breeding Cerulean Warblers or Canada Warbler is to be considered SWH[i]. • Conduct field investigations in early summer when birds are singing and defending their territories. • Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • SWHMIST[cxlix] Index #34 provides development effects and mitigation measures.	Woodlands with interior habitats >200m from the edge are not present. None of the listed indicator species were observed nesting within the study area in 2022. Canada Warbler was observed exhibiting possible breeding evidence in the small (<4ha) decidous woodlot near Underpass Road, however habitat in this location is marginal and nesting was not confirmed. Canada Warbler was not heard elsewhere within the study area during 2022 surveys.

Table 4. Characteristics of Habitat for Species of Conservation Concern for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Marsh Bird Breeding Habitat					Not Present
Wetlands for these bird species are typically productive and fairly rare in Southern Ontario landscapes.	American Bittern Virginia Rail Sora Common Gallinule American Coot Pied-billed Grebe Marsh Wren Sedge Wren Common Loon Green Heron Trumpeter Swan <u>Special Concern</u>: Black Tern Yellow Rail	MAM1 MAM2 MAM3 MAM4 MAM5 MAM6 SAS1 SAM1 SAF1 FEO1 BOO1 For Green Heron: All SW, MA and CUM1 sites	• Nesting occurs in wetlands • All wetland habitat is to be considered as long as there is shallow water with emergent aquatic vegetation present[cxxiv]. • For Green Heron, habitat is at the edge of water such as sluggish streams, ponds and marshes sheltered by shrubs and trees. Less frequently, it may be found in upland shrubs or forest a considerable distance from water. <u>Information Sources</u> • OMNRF Districts and wetland evaluations • Field naturalist clubs • Natural Heritage Information Centre (NHIC) • Reports and other information available from CAs • Ontario Breeding Bird Atlas[ccv]	Studies confirm: • Presence of 5 or more nesting pairs of Sedge Wren or Marsh Wren or breeding by any combination of 4 or more of the listed species[i]. • Note: any wetland with breeding of 1 or more Trumpeter Swans, Black Terns, Green Heron or Yellow Rail is SWH[i]. • Area of the ELC ecosite is the SWH • Breeding surveys should be done in May/June when these species are actively nesting in wetland habitats. • Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • SWHMIST[cxlix] Index #35 provides development effects and mitigation measures	Suitable marsh habitat with shallow water and emergent aquatic vegetation is not present in the study area. None of the listed indicator species were confirmed as nesting during 2022 breeding bird surveys.
Wildlife Habitat: Open Country Bird Breeding Habitat					Not Present
This wildlife habitat is declining throughout Ontario and North America. Species such as the Upland Sandpiper have declined significantly the past 40 years based on CWS (2004) trend records.	Upland Sandpiper Grasshopper Sparrow Vesper Sparrow Northern Harrier Savannah Sparrow <u>Special Concern</u>: Short-eared Owl	CUM1 CUM2	Large grassland areas (includes natural and cultural fields and meadows) >30ha[clx, clxi, clxii, clxiii, clxiv, clxv, clxvi, clxvii, clxviii, clxix]. Grasslands not Class 1 or 2 agricultural lands, and not being actively used for farming (i.e. no row cropping or intensive hay or livestock pasturing in the last 5 years)[i]. Grassland sites considered significant should have a history of longevity, either abandoned fields, mature hayfields and pasturelands that are at least 5 years or older. The Indicator bird species are area sensitive requiring larger grassland areas than the common grassland species. <u>Information Sources</u> • Agricultural land classification maps Ministry of Agriculture • Local birder clubs • Ontario Breeding Bird Atlas[ccv] • EIS Reports and other information available from CAs	Field Studies confirm: • Presence of nesting or breeding of 2 or more of the listed species[i]. • A field with 1 or more breeding Short-eared Owls is to be considered SWH. • The area of SWH is the contiguous ELC ecosite field areas. • Conduct field investigations of the most likely areas in spring and early summer when birds are singing and defending their territories. • Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • SWHMIST[cxlix] Index #32 provides development effects and mitigation measures	Cultural meadow habitats within the study area are generally small (<15ha), and do not have histories of longevity as naturalized grassland habitats. None of the listed indicator species were confirmed as nesting during 2022 breeding bird surveys anywhere within the study area.

Table 4. Characteristics of Habitat for Species of Conservation Concern for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Shrub/Early Successional Bird Breeding Habitat					Not Present
This wildlife habitat is declining throughout Ontario and North America. The Brown Thrasher has declined significantly over the past 40 years based on CWS (2004) trend records.	Indicator Spp: Brown Thrasher Clay-coloured Sparrow Common Spp. Field Sparrow Black-billed Cuckoo Eastern Towhee Willow Flycatcher <u>Special Concern</u>: Yellow-breasted Chat Golden-winged Warbler	CUT1 CUT2 CUS1 CUS2 CUW1 CUW2 Patches of shrub ecosites can be complexed into a larger habitat such as woodland area for some bird species.	Large natural field areas succeeding to shrub and thicket habitats >10ha[clxiv] in size. Shrub land or early successional fields, not class 1 or 2 agricultural lands, not being actively used for farming (i.e. no row-cropping, haying or live-stock pasturing in the last 5 years)[i]. Shrub thicket habitats (>10 ha) are most likely to support and sustain a diversity of these species[clxxiii]. Shrub and thicket habitat sites considered significant should have a history of longevity, either abandoned fields or pasturelands. <u>Information Sources</u> • Agricultural land classification maps, Ministry of Agriculture. • Local bird clubs • Ontario Breeding Bird Atlas[ccv] • Reports and other information available from CAs	Field Studies confirm: • Presence of nesting or breeding of 1 of the indicator species and at least 2 of the common species[i]. • A field with breeding Yellow-breasted Chat or Golden-winged Warbler is to be considered as Significant Wildlife Habitat[i]. • The area of the SWH is the contiguous ELC ecosite field/thicket area. • Conduct field investigations of the most likely areas in spring and early summer when birds are singing and defending their territories • Evaluation methods to follow "Bird and Bird Habitats: Guidelines for Wind Power Projects"[ccxi] • SWHMIST[cxlix] Index #33 provides development effects and mitigation measures.	Large (>10ha) natural field areas succeeding to shrub and thicket habitats are not present in the study area.
Wildlife Habitat: Terrestrial Crayfish					Not Present
Terrestrial Crayfish are only found within SW Ontario in Canada and their habitats are very rare. [Ccii]	Chimney or Digger Crayfish (*Fallicambarus fodiens*) Devil Crawfish or Meadow Crayfish (*Cambarus Diogenes*)	MAM1 MAM2 MAM3 MAM4 MAM5 MAM6 MAS1 MAS2 MAS3 SWD SWT SWM CUM1 with inclusions of above meadow marsh ecosites can be used by terrestrial crayfish.	Wet meadow and edges of shallow marshes (no minimum size) identified should be surveyed for terrestrial crayfish. • Constructs burrows in marshes, mudflats, meadows, the ground can't be too moist. Can often be found far from water. • Both species are a semi-terrestrial burrower which spends most of its life within burrows consisting of a network of tunnels. Usually the soil is not too moist so that the tunnel is well formed. <u>Information Sources</u> • Information sources from "Conservation Status of Freshwater Crayfishes" by Dr. Premek Hamr for the WWF and CNF March 1998.	Studies Confirm: • Presence of 1 or more individuals of species listed or their chimneys (burrows) in suitable marsh meadow or terrestrial sites[cci]. • Area of ELC Ecosite or an ecoelement area of meadow marsh or swamp within the large ecosite area is the SWH • Surveys should be done April to August in temporary or permanent water. Note the presence of burrows or chimneys are often the only indicator of presence, observance or collection of individuals is very difficult [cci] • SWHMIST[cxlix] Index #36 provides development effects and mitigation measures.	Terrestrial Crayfish chimneys were observed in the meadow marsh community west of Nauvoo Road. Terrestrial Crayfish SWH is confirmed within the study area.

Table 4. Characteristics of Habitat for Species of Conservation Concern for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Special Concern and Rare Wildlife Species					Not Present
These species are quite rare or have experienced significant population declines in Ontario	All Special Concern and Provincially Rare (S1-S3, SH) plant and animal species. Lists of these species are tracked by the Natural Heritage Information Centre (NHIC).	All plant and animal element occurrences (EO) within a 1 or 10km grid. Older element occurrences were recorded prior to GPS being available, therefore location information may lack accuracy.	When an element occurrence is identified within a 1 or 10 km grid for a Special Concern or provincially Rare species; linking candidate habitat on the site needs to be completed to ELC Ecosites[lxxviii]. Information Sources • Natural Heritage Information Centre (NHIC) will have the Special Concern and Provincially Rare (S1-S3, SH) species lists and element occurrences for these species. • NHIC Website: "Get Information" http://nhic.mnr.gov.on.ca • Ontario Breeding Bird Atlas[ccv] • Expert advice should be sought as many of the rare spp. have little information available about their requirements.	Studies Confirm: • Assessment/inventory of the site for the identified special concern or rare species needs to be completed during the time of year when the species is present or easily identifiable. • The area of the habitat to the finest ELC scale that protects the habitat form and function is the SWH, this must be delineated through detailed field studies. The habitat neess to be easily mapped and cover an important life stage component for a species e.g. specific nesting habitat for foraging habitat. • SWHMIST[cxlix] Index #37 provides development effects and mitigation measures.	Several Special Concern and Provincially Rare Species have candidate and/or confirmed habitat within the study area: • Western Chorus Frog (Great Lakes / St. Lawrence - Canadian Shield population), confirmed breeding within study area • Eastern Wood-Pewee, confirmed breeding in the study area • Canada Warbler, candidate breeding within the study area • Tufted Titmouse, candidate breeding within the study area

Table 5. Characteristics of Animal Movement Corridors for Ecoregion 7E (MNRF 2015)

	Candidate SWH			Confirmed SWH	Assessment Details
Rationale	**Wildlife Species**	**ELC Ecosite Codes**	**Habitat Criteria and Information Sources**	**Defining Criteria**	**Study Area**
Wildlife Habitat: Amphibian Movement Corridors					Not Present
Movement corridors for amphibians moving from their terrestrial habitat to breeding habitat can be extremely important for local populations.	Eastern Newt American Toad Blue-spotted Salamander Spotted Salamander Four-toed Salamander Gray Treefrog Northern Leopard Frog Pickerel Frog Western Chorus Frog	Corridors may be found in all ecosites associated with water. • Corridors will be determined based on identifying the significant breeding habitat for these species in Table 1.1.	Movement corridors between breeding habitat and summer habitat[clxxiv, clxxv, clxxvi, clxxvii, clxxviii, clxxix, clxxx, clxxxi] Movement corridors must be considered when Amphibian breeding habitat is confirmed as SWH from Table 1.2.2 (Amphibian Breeding Habitat – Wetland) of this Schedule[i]. <u>Information Sources</u> • MNRF District Office • Natural Heritage Information Centre NHIC • Reports and other information available from CAs • Field naturalist Clubs	• Field Studies must be conducted at the time of year when species are expected to be migrating or entering breeding sites. • Corridors should consist of native vegetation, with several layers of vegetation. Corridors unbroken by roads, waterways or bodies, and undeveloped areas are most significant[cxlix]. • Corridors should have at least 15m of vegetation on both sides of waterwaycxlix or be up to 200m widecxlix of woodland habitat and with gaps <20m[cxlix] • Shorter corridors are more significant than longer corridors, however amphibians must be able to get to and from their summer and breeding habitat[cxlix]. • SWHMIST[cxlix] Index #40 provides development effects and mitigation measures.	No Amphibian Breeding Habitat SWH is considered present within the study area. No suitable movement corridor habitat with water connecting breeding and summer foraging habitats is not present.

Appendix IV

Vascular Flora Species Observed within the Subject Property

Plant Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	CW	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Sensitivity to Hydrological Change	Lambton County Status	Natural Environment and Resource Baseline - Warwick Landfill Expansion EA	iNaturalist Research-Grade Observations	NHIC Data*	NRSI Observed	FOD6-5	SWT2-2 (Incl.)	CUM1 (Incl.)	FOD9-4	MAM2-10	SWT2-8 (Incl.)	SWT2-5	CUT1
		Oldham et al. 1995	MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	TRCA 2017	Oldham 2017	Gartner Lee Ltd. 2004	iNaturalist 2023	MNRF 2023b	NRSI Results From 2022								
Pteridophytes	**Ferns & Allies**																				
Dennstaedtiaceae	**Bracken Fern Family**																				
Pteridium aquilinum ssp. latiusculum	Eastern Bracken Fern	3	S5							X											
Dryopteridaceae	**Wood Fern Family**																				
Athyrium filix-femina	Common Lady Fern	0	S5										X	X							
Athyrium filix-femina var. angustum	Northeastern Lady Fern	0	S5							X											
Cystopteris fragilis	Fragile Fern	3	S4							X											
Dryopteris carthusiana	Spinulose Wood Fern	-3	S5					Medium	X	X			X	X			X				
Dryopteris cristata	Crested Wood Fern	-5	S5					Medium	R				X	X							
Dryopteris marginalis	Marginal Wood Fern	3	S5						R				X	X			X				
Onoclea sensibilis	Sensitive Fern	-3	S5					Medium	C	X			X		X		X	X		X	
Polystichum acrostichoides	Christmas Fern	3	S5						X				X	X			X				
Equisetaceae	**Horsetail Family**																				
Equisetum arvense	Field Horsetail	0	S5						X	X			X	X							X
Thelypteridaceae	**Beech Fern Family**																				
Thelypteris palustris	Marsh Fern	-3	S5						X	X											
Dicotyledons	**Dicots**																				
Aceraceae	**Maple Family**																				
Acer negundo	Manitoba Maple	0	S5						X	X			X				X				
Acer nigrum	Black Maple	3	S4?						X	X			X	X			X				
Acer rubrum	Red Maple	0	S5						X	X											
Acer saccharinum	Silver Maple	-3	S5					Medium	X	X											
Acer saccharum	Sugar Maple	3	S5						X	X			X	X	X		X				
Acer x freemanii	Freeman's Maple	-5	SNA					Medium	hyb				X				X				
Anacardiaceae	**Sumac or Cashew Family**																				
Rhus typhina	Staghorn Sumac	3	S5						X	X			X		X	X					
Toxicodendron radicans	Poison Ivy	0	S5							X			X				X				
Toxicodendron radicans var. radicans	Eastern Poison Ivy	0	S5						C				X	X			X				
Toxicodendron radicans var. rydbergii	Western Poison Ivy	0	S5						X				X				X				
Annonaceae	**Custard-apple Family**																				
Asimina triloba	Pawpaw	0	S3						R		X										
Apiaceae	**Carrot or Parsley Family**																				
Daucus carota	Wild Carrot	5	SE5						IX	X			X				X				
Sanicula marilandica	Maryland Sanicle	3	S5						X	X											
Apocynaceae	**Dogbane Family**																				
Apocynum androsaemifolium	Spreading Dogbane	5	S5						X	X			X				X				
Apocynum cannabinum	Hemp Dogbane	0	S5										X				X				
Araliaceae	**Ginseng Family**																				
Aralia nudicaulis	Wild Sarsaparilla	3	S5						X	X											
Asclepiadaceae	**Milkweed Family**																				
Asclepias exaltata	Poke Milkweed	5	S4						X				X				X				
Asclepias incarnata	Swamp Milkweed	-5	S5						X	X			X				X	X		X	
Asclepias syriaca	Common Milkweed	5	S5						X	X											
Asteraceae	**Composite or Aster Family**																				
Achillea millefolium	Common Yarrow	3	SE5?							X											
Ambrosia artemisiifolia	Common Ragweed	3	S5						X	X											
Ambrosia trifida	Great Ragweed	0	S5						X	X											
Antennaria neglecta	Field Pussytoes	5	S5						R	X											
Arctium lappa	Great Burdock	3	SE5						IX				X	X				X			
Arctium minus	Common Burdock	3	SE5						IX	X											
Bidens cernua	Nodding Beggarticks	-5	S5					Low	X				X				X				
Bidens connata	Purple-stemmed Beggarticks	-3	S4?										X				X				
Bidens frondosa	Devil's Beggarticks	-3	S5					Low	X	X			X				X	X		X	
Centaurea jacea	Brown Knapweed	5	SE5						IX				X				X				
Cichorium intybus	Chicory	5	SE5						IX	X			X				X				
Cirsium arvense	Creeping Thistle	3	SE5						IX	X											
Cirsium vulgare	Bull Thistle	3	SE5						IX	X			X		X	X					
Erigeron annuus	Annual Fleabane	3	S5						X	X											
Erigeron philadelphicus	Philadelphia Fleabane	-3	S5						X	X			X				X				
Erigeron strigosus	Rough Fleabane	3	S5						X				X		X		X			X	
Eupatorium perfoliatum	Common Boneset	-3	S5					Low	X	X			X					X		X	
Eurybia macrophylla	Large-leaved Aster	5	S5						X	X											
Euthamia graminifolia	Grass-leaved Goldenrod	0	S5						X				X		X		X	X		X	
Eutrochium maculatum var. maculatum	Spotted Joe Pye Weed	-5	S5					Low		X											
Inula helenium	Elecampane	3	SE5						IX		X										
Lactuca biennis	Tall Blue Lettuce	0	S5						X	X											
Leucanthemum vulgare	Oxeye Daisy	5	SE5						IX	X											

Plant Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	CW	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Sensitivity to Hydrological Change	Lambton County Status	Natural Environment and Resource Baseline - Warwick Landfill Expansion EA	iNaturalist Research-Grade Observations	NHIC Data*	NRSI Observed	FOD6-5	SWT2-2 (Incl.)	CUM1 (Incl.)	FOD9-4	MAM2-10	SWT2-8 (Incl.)	SWT2-5	CUT1
		Oldham et al. 1995	MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	TRCA 2017	Oldham 2017	Gartner Lee Ltd. 2004	iNaturalist 2023	MNRF 2023b	NRSI Results From 2022								
Matricaria discoidea	Pineappleweed	3	SE5						IX	X											
Rudbeckia triloba	Brown-eyed Susan	3	SE4						IX	X											
Solidago altissima var. altissima	Eastern Tall Goldenrod	3	S5										X		X	X	X	X		X	
Solidago caesia	Blue-stemmed Goldenrod	3	S5						X	X			X				X				
Solidago canadensis	Canada Goldenrod	3	S5							X											
Solidago flexicaulis	Zigzag Goldenrod	3	S5						R				X	X			X				
Solidago gigantea	Giant Goldenrod	-3	S5						C				X	X			X			X	
Sonchus arvensis	Field Sow-thistle	3	SE5						IX				X		X	X					
Sonchus oleraceus	Common Sow-thistle	3	SE5						IX	X											
Symphyotrichum ericoides	White Heath Aster	3	S5										X				X				
Symphyotrichum firmum	Glossy-leaved Aster	-3	S4?										X		X		X				
Symphyotrichum lanceolatum	Panicled Aster	-3	S5						X	X			X	X	X		X	X	X	X	
Symphyotrichum lateriflorum	Calico Aster	0	S5						X				X	X			X				
Symphyotrichum novae-angliae	New England Aster	-3	S5						X	X			X		X		X	X		X	X
Symphyotrichum pilosum var. pilosum	Old Field Aster	3	S5						X				X				X				
Symphyotrichum puniceum	Swamp Aster	-5	S5						R	X											
Taraxacum officinale	Common Dandelion	3	SE5						IX	X			X		X	X	X			X	
Xanthium strumarium	Rough Cocklebur	0	S5						X	X											
Balsaminaceae	**Touch-me-not Family**																				
Impatiens capensis	Spotted Jewelweed	-3	S5					Medium	X	X			X		X		X		X	X	
Berberidaceae	**Barberry Family**																				
Berberis thunbergii	Japanese Barberry	3	SE5						IX				X				X				
Berberis vulgaris	European Barberry	3	SE5						IX	X											
Podophyllum peltatum	May-apple	3	S5						C	X			X				X				
Betulaceae	**Birch Family**																				
Betula papyrifera	Paper Birch	3	S5						X	X											
Carpinus caroliniana	Blue-beech	0	S5						X	X			X	X			X				
Corylus cornuta	Beaked Hazelnut	3	S5						R	X											
Ostrya virginiana	Eastern Hop-hornbeam	3	S5						C	X			X	X			X				
Boraginaceae	**Borage Family**																				
Cynoglossum officinale	Common Hound's-tongue	5	SE5						IX	X											
Echium vulgare	Common Viper's Bugloss	5	SE5						IX	X											
Symphytum officinale	Common Comfrey	5	SE5						IX				X				X				
Brassicaceae	**Mustard Family**																				
Alliaria petiolata	Garlic Mustard	0	SE5						IX				X				X				
Barbarea vulgaris	Bitter Wintercress	0	SE5						IX	X			X							X	
Cardamine concatenata	Cut-leaved Toothwort	3	S5						X		X		X	X							
Cardamine diphylla	Two-leaved Toothwort	3	S5						R		X										
Erysimum cheiranthoides	Wormseed Wallflower	3	S5?						IX	X											
Hesperis matronalis	Dame's Rocket	3	SE5						IX	X			X				X				X
Campanulaceae	**Bellflower Family**																				
Lobelia cardinalis	Cardinal Flower	-5	S5					Medium	R		X		X							X	
Caprifoliaceae	**Honeysuckle Family**																				
Lonicera dioica	Limber Honeysuckle	3	S5						X	X											
Lonicera tatarica	Tatarian Honeysuckle	3	SE5						IX	X			X	X			X				X
Lonicera x bella	*(Lonicera morrowii X Lonicera tatarica)*	3	SNA						hyb				X		X						
Sambucus canadensis	Common Elderberry	-3	S5						X	X			X				X				
Sambucus racemosa	Red Elderberry	3	S5						R		X										
Triosteum aurantiacum	Orange-fruited Horse-gentian	5	S4S5						X		X		X	X			X				
Viburnum lentago	Nannyberry	0	S5						X	X			X				X			X	
Viburnum opulus	Cranberry Viburnum	-3	S5							X			X								X
Viburnum opulus var. opulus	Cranberry Viburnum	-3	SE4?										X				X				
Caryophyllaceae	**Pink Family**																				
Cerastium fontanum	Common Mouse-ear Chickweed	3	SE5						IX	X											
Dianthus armeria	Deptford Pink	5	SE5						IX	X	X										
Saponaria officinalis	Bouncing-bet	3	SE5						IX	X											
Celastraceae	**Staff-tree Family**																				
Euonymus obovatus	Running Strawberry Bush	5	S4						X	X			X	X			X				
Clusiaceae	**St. John's-wort Family**																				
Hypericum perforatum	Common St. John's-wort	5	SE5						IX	X			X				X				
Hypericum punctatum	Spotted St. John's-wort	0	S5						R	X											
Convolvulaceae	**Morning-glory Family**																				
Convolvulus arvensis	Field Bindweed	5	SE5						IX	X											
Cornaceae	**Dogwood Family**																				
Cornus alternifolia	Alternate-leaved Dogwood	3	S5						X	X											
Cornus obliqua	Pale Dogwood	-3	S5					Medium	X				X		X		X		X	X	
Cornus racemosa	Gray Dogwood	0	S5						X	X			X		X		X	X			X

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Cornus sericea	Red-osier Dogwood	-3	S5						X	X			X		X		X			X	
Crassulaceae	**Stonecrop Family**																				
Penthorum sedoides	Ditch-stonecrop	-5	S5					Medium	X				X					X			
Cucurbitaceae	**Gourd Family**																				
Echinocystis lobata	Wild Mock-cucumber	-3	S5						X	X											
Dipsacaceae	**Teasel Family**																				
Dipsacus fullonum	Common Teasel	3	SE5						IX	X			X		X	X	X	X			X
Euphorbiaceae	**Spurge Family**																				
Acalypha rhomboidea	Common Three-seeded Mercury	3	S5						X	X											
Fabaceae	**Pea Family**																				
Lotus corniculatus	Garden Bird's-foot Trefoil	3	SE5						IX	X			X				X				
Medicago lupulina	Black Medic	3	SE5						IX	X											
Melilotus albus	White Sweet-clover	3	SE5						IX	X											
Melilotus officinalis	Yellow Sweet-clover	3	SE5						IX	X											
Trifolium campestre	Low Hop Clover	5	SE5						IX	X											
Trifolium hybridum	Alsike Clover	3	SE5						IX	X											
Trifolium pratense	Red Clover	3	SE5						IX	X											
Trifolium repens	White Clover	3	SE5						IX	X											
Fagaceae	**Beech Family**																				
Fagus grandifolia	American Beech	3	S4						X	X			X	X			X				
Quercus alba	White Oak	3	S5						X				X				X				
Quercus bicolor	Swamp White Oak	-3	S4						X				X				X				
Quercus macrocarpa	Bur Oak	3	S5						C	X	X		X		X		X				
Quercus muehlenbergii	Chinquapin Oak	3	S4						X	X	X		X				X				
Quercus rubra	Northern Red Oak	3	S5						X	X			X	X			X				
Geraniaceae	**Geranium Family**																				
Erodium cicutarium	Common Storksbill	5	SE3						IX		X										
Geranium maculatum	Spotted Geranium	3	S5						C	X			X	X			X				
Geranium robertianum	Herb-Robert	3	S5						X	X			X				X				
Grossulariaceae	**Currant Family**																				
Ribes americanum	Wild Black Currant	-3	S5						C	X			X	X	X		X			X	X
Ribes cynosbati	Prickly Gooseberry	3	S5						C	X			X	X			X			X	
Ribes rubrum	Northern Red Currant	5	SE5						IX				X	X	X	X	X				
Haloragaceae	**Water-milfoil Family**																				
Proserpinaca palustris	Marsh Mermaid-weed	-5	S4					Medium	R	X											
Hydrophyllaceae	**Water-leaf Family**																				
Hydrophyllum virginianum	Virginia Waterleaf	0	S5						C	X			X				X				
Juglandaceae	**Walnut Family**																				
Carya cordiformis	Bitternut Hickory	0	S5						X	X	X		X	X			X			X	
Carya ovata	Shagbark Hickory	3	S5						X	X			X	X	X		X			X	
Juglans cinerea	Butternut	3	S2?	END	E	E	Schedule 1		X	X											
Juglans nigra	Black Walnut	3	S4?						X	X			X		X						
Lamiaceae	**Mint Family**																				
Clinopodium vulgare	Field Basil	5	S5						X				X	X	X	X	X				
Glechoma hederacea	Ground Ivy	3	SE5						IX	X											
Lycopus americanus	American Water-horehound	-5	S5					Medium	X	X			X		X		X	X		X	
Lycopus europaeus	European Water-horehound	-5	SE5						IX				X							X	
Lycopus uniflorus	Northern Water-horehound	-5	S5					Medium	X				X				X			X	
Mentha canadensis	Canada Mint	-3	S5						X				X		X						
Nepeta cataria	Catnip	3	SE5						IX	X											
Prunella vulgaris	Self-heal	0	S5							X			X				X				
Stachys palustris	Marsh Hedge-nettle	-5	SE5						IX	X											
Lythraceae	**Loosestrife Family**																				
Lythrum salicaria	Purple Loosestrife	-5	SE5						IX	X			X				X				
Menispermaceae	**Moonseed Family**																				
Menispermum canadense	Canada Moonseed	0	S4						X				X				X				
Oleaceae	**Olive Family**																				
Fraxinus americana	White Ash	3	S4						X	X			X	X			X				
Fraxinus nigra	Black Ash	-3	S4	END	T	NS	No schedule	Medium	X	X											
Fraxinus pennsylvanica	Green Ash	-3	S4						X	X			X	X	X		X			X	X
Fraxinus quadrangulata	Blue Ash	3	S2?	THR	T	SC	Schedule 1		R		X										
Onagraceae	**Evening-primrose Family**																				
Circaea canadensis	Broad-leaved Enchanter's Nightshade	3	S5						X	X			X	X			X				
Epilobium ciliatum	Northern Willowherb	-3	S5							X			X							X	
Epilobium coloratum	Purple-veined Willowherb	-5	S5					Low	R				X					X			
Epilobium hirsutum	Hairy Willowherb	-3	SE5						IX	X											
Oenothera biennis	Common Evening-primrose	3	S5						X	X			X				X				

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Oxalidaceae	**Wood Sorrel Family**																				
Oxalis corniculata	Creeping Wood-sorrel	3	SE1						?				X				X				
Oxalis stricta	Upright Yellow Wood-sorrel	3	SE5						X	X			X				X				
Papaveraceae	**Poppy Family**																				
Sanguinaria canadensis	Bloodroot	3	S5						X				X	X			X				
Plantaginaceae	**Plantain Family**																				
Plantago lanceolata	English Plantain	3	SE5						IX	X											
Plantago major	Common Plantain	3	SE5						IX	X			X				X				X
Plantago rugelii	Rugel's Plantain	0	S5						X				X				X				
Polygonaceae	**Smartweed Family**																				
Persicaria lapathifolia	Pale Smartweed	-3	S5					Low	X	X											
Persicaria maculosa	Spotted Lady's-thumb	-3	SE5						IX	X			X				X				
Persicaria virginiana	Virginia Smartweed	0	S4						C	X			X	X			X			X	
Rumex crispus	Curly Dock	0	SE5						IX	X			X		X	X	X	X		X	
Portulacaceae	**Purslane Family**																				
Claytonia caroliniana	Carolina Spring Beauty	3	S5						R				X							X	
Claytonia virginica	Narrow-leaved Spring Beauty	3	S5						X				X	X			X				
Primulaceae	**Primrose Family**																				
Lysimachia ciliata	Fringed Loosestrife	-3	S5						X	X			X				X				X
Lysimachia nummularia	Creeping Jennie	-3	SE5						IX	X	X		X				X				
Ranunculaceae	**Buttercup Family**																				
Actaea rubra	Red Baneberry	3	S5						X	X											
Anemonastrum canadense	Canada Anemone	-3	S5							X											
Anemone quinquefolia	Wood Anemone	0	S5						X		X										
Caltha palustris	Yellow Marsh Marigold	-5	S5					Medium	X				X				X				
Ranunculus abortivus	Kidney-leaved Buttercup	0	S5						C	X			X							X	
Ranunculus acris	Tall Buttercup	0	SE5						IX	X											
Ranunculus recurvatus	Hooked Buttercup	-3	S5						X	X	X		X				X				
Ranunculus repens	Creeping Buttercup	0	SE5						IX	X											
Thalictrum dioicum	Early Meadow-rue	3	S5						X	X			X	X			X			X	
Thalictrum pubescens	Tall Meadow-rue	-3	S5						X				X				X				
Rhamnaceae	**Buckthorn Family**																				
Frangula alnus	Glossy Buckthorn	0	SE5						IX				X				X				
Rhamnus cathartica	Common Buckthorn	0	SE5						IC	X			X	X			X			X	X
Rosaceae	**Rose Family**																				
Agrimonia gryposepala	Hooked Agrimony	3	S5						X	X			X	X	X	X	X	X		X	
Agrimonia parviflora	Swamp Agrimony	-3	S4						R				X				X				
Agrimonia striata	Woodland Agrimony	3	S4										X				X				
Amelanchier arborea	Downy Serviceberry	3	S5						X				X				X				
Comarum palustre	Marsh Cinquefoil	-5	S5					Medium	R	X											
Crataegus sp.	Hawthorn sp.									X			X	X	X	X	X			X	X
Crataegus crus-galli	Cockspur Hawthorn	0	S4						X	X											
Crataegus monogyna	English Hawthorn	3	SE4						IX	X											
Fragaria vesca	Woodland Strawberry	3	S5						R	X											
Fragaria virginiana	Wild Strawberry	3	S5						X	X			X	X			X				X
Geum aleppicum	Yellow Avens	0	S5						R	X			X				X				
Geum canadense	White Avens	0	S5						C	X			X				X				
Malus pumila	Common Apple	5	SE4						IX	X			X				X				
Potentilla recta	Sulphur Cinquefoil	5	SE5						IX	X											
Potentilla simplex	Old-field Cinquefoil	3	S5						X				X				X				
Prunus avium	Sweet Cherry	5	SE4						IX				X	X			X				
Prunus serotina	Black Cherry	3	S5						X	X			X	X			X				
Prunus virginiana	Choke Cherry	3	S5						C	X			X	X			X				
Rosa canina	Dog Rose	5	SE2						IX				X		X						
Rosa multiflora	Multiflora Rose	3	SE5						IX	X			X	X			X				
Rosa palustris	Swamp Rose	-5	S5					Medium	X	X											
Rubus allegheniensis	Allegheny Blackberry	3	S5						X				X	X			X				
Rubus idaeus	Common Red Raspberry	3	S5							X											
Rubus idaeus ssp. strigosus	Wild Red Raspberry	3	S5						X				X				X				
Rubus occidentalis	Black Raspberry	5	S5						C	X			X				X				X
Rubus odoratus	Purple-flowering Raspberry	5	S5						H	X											
Rubus pubescens	Dewberry	-3	S5					Medium	X				X	X			X				
Spiraea alba	White Meadowsweet	-3	S5					Low	X	X											

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Rubiaceae	**Madder Family**																				
Galium aparine	Cleavers	3	S5						X				X	X						X	
Galium triflorum	Three-flowered Bedstraw	3	S5						X	X											
Salicaceae	**Willow Family**																				
Populus alba	White Poplar	5	SE5						IX	X											
Populus deltoides	Eastern Cottonwood	0	S5						X	X			X	X	X		X				
Populus grandidentata	Large-toothed Aspen	5	S5						X	X											
Populus tremuloides	Trembling Aspen	0	S5						X	X			X		X		X			X	
Salix amygdaloides	Peach-leaved Willow	-3	S5					Medium	X				X		X						
Salix discolor	Pussy Willow	-3	S5					Low	X	X			X		X						
Salix eriocephala	Heart-leaved Willow	-3	S5					Medium	X	X			X		X		X				X
Salix interior	Sandbar Willow	-3	S5						X	X			X		X						
Salix purpurea	Purple Willow	-3	SE4						IH				X		X						
Saxifragaceae	**Saxifrage Family**																				
Tiarella cordifolia	Heart-leaved Foam-flower	3	S5						X				X	X							
Scrophulariaceae	**Figwort Family**																				
Mimulus ringens	Square-stemmed Monkeyflower	-5	S5					Medium	R				X							X	
Penstemon digitalis	Foxglove Beardtongue	0	S4S5						X		X		X				X				
Verbascum thapsus	Common Mullein	5	SE5						IX	X			X	X			X				
Veronica officinalis	Common Speedwell	5	SE5						IX	X			X				X				
Veronica serpyllifolia	Thyme-leaved Speedwell	0	SU						IX	X			X				X				
Solanaceae	**Nightshade Family**																				
Solanum dulcamara	Bittersweet Nightshade	0	SE5						IX	X											
Tiliaceae	**Linden Family**																				
Tilia americana	American Basswood	3	S5						C	X			X	X	X		X				
Ulmaceae	**Elm Family**																				
Ulmus americana	American Elm	-3	S5						C	X			X	X	X		X			X	X
Ulmus pumila	Siberian Elm	3	SE3						IX	X											
Urticaceae	**Nettle Family**																				
Boehmeria cylindrica	False Nettle	-5	S5					Medium	X				X	X			X			X	
Laportea canadensis	Wood Nettle	-3	S5						X	X											
Pilea pumila	Dwarf Clearweed	-3	S5					Medium	X	X			X				X			X	
Urtica gracilis	Slender Stinging Nettle	0	S5						X	X			X					X			
Verbenaceae	**Vervain Family**																				
Verbena hastata	Blue Vervain	-3	S5						X	X											
Verbena urticifolia	White Vervain	0	S5						X				X		X						
Violaceae	**Violet Family**																				
Viola labradorica	Labrador Violet	0	S5					Medium	X				X				X				
Viola pubescens	Yellow Violet	3	S5						X	X			X				X				
Viola rostrata	Long-spurred Violet	3	S5						R		X		X	X							
Viola sororia	Woolly Blue Violet	0	S5						X	X			X	X			X			X	
Vitaceae	**Grape Family**																				
Parthenocissus quinquefolia	Virginia Creeper	3	S4?						X	X			X	X			X				
Parthenocissus vitacea	Thicket Creeper	3	S5						X				X	X			X				
Vitis riparia	Riverbank Grape	0	S5						C	X			X		X	X	X			X	
Monocotyledons	**Monocots**																				
Araceae	**Arum Family**																				
Arisaema dracontium	Green Dragon	-3	S3	SC	SC	SC	Schedule 3		X			X									
Arisaema triphyllum	Jack-in-the-pulpit	-3	S5					Medium	X	X			X	X			X				
Cyperaceae	**Sedge Family**																				
Carex bebbii	Bebb's Sedge	-5	S5						X	X											
Carex blanda	Woodland Sedge	0	S5						X	X	X		X	X	X	X	X				
Carex bromoides	Brome-like Sedge	-3	S5					Medium	R				X							X	
Carex canescens	Hoary Sedge	-5	S5						H	X											
Carex comosa	Bristly Sedge	-5	S5					Medium	X	X											
Carex crinita	Fringed Sedge	-5	S5					Medium	X	X			X				X	X	X	X	
Carex cristatella	Crested Sedge	-3	S5						X				X				X	X			
Carex digitalis	Slender Woodland Sedge	5	S4S5						R				X				X				
Carex gracillima	Graceful Sedge	3	S5						C	X			X	X			X			X	
Carex grayi	Gray's Sedge	-3	S4					High	X				X				X				
Carex grisea	Gray Sedge	0	S4						X				X	X			X				
Carex hirtifolia	Pubescent Sedge	5	S4S5						X				X	X			X				
Carex intumescens	Bladder Sedge	-3	S5					Medium	C				X				X				
Carex lacustris	Lake Sedge	-5	S5					Medium	X	X											
Carex laxiflora	Loose-flowered Sedge	0	S5						R	X											
Carex lupulina	Hop Sedge	-5	S5					High	X	X			X	X			X	X		X	
Carex lurida	Sallow Sedge	-5	S4S5					Medium	R		X		X					X		X	

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Carex molesta	Troublesome Sedge	0	S4S5						X				X					X			
Carex pensylvanica	Pennsylvania Sedge	5	S5						X	X			X	X							
Carex pseudocyperus	Cyperus-like Sedge	-5	S5					Medium	R				X					X			
Carex radiata	Eastern Star Sedge	0	S5						X	X											
Carex rosea	Rosy Sedge	5	S5						C				X	X			X			X	
Carex sprengelii	Sprengel's Sedge	0	S5						R	X											
Carex stipata	Awl-fruited Sedge	-5	S5					Low	X	X			X				X			X	
Carex stricta	Tussock Sedge	-5	S5					Medium	X				X				X				
Carex vulpinoidea	Fox Sedge	-5	S5						X	X			X		X		X	X		X	
Carex woodii	Wood's Sedge	3	S4						X				X	X			X				
Eleocharis erythropoda	Red-stemmed Spikerush	-5	S5					Medium	R	X											
Eleocharis obtusa	Blunt Spikerush	-5	S5					Medium	X	X	X										
Schoenoplectus tabernaemontani	Soft-stemmed Bulrush	-5	S5					Medium	X				X				X	X			
Scirpus atrovirens	Dark-green Bulrush	-5	S5					Low	X	X			X		X		X	X		X	
Scirpus cyperinus	Cottongrass Bulrush	-5	S5					Medium	X	X			X				X	X		X	
Iridaceae	**Iris Family**																				
Sisyrinchium montanum	Strict Blue-eyed-grass	0	S5						X	X											
Juncaceae	**Rush Family**																				
Juncus dudleyi	Dudley's Rush	-3	S5						X				X				X				
Juncus effusus	Soft Rush	-5	S5					Medium					X				X	X			
Juncus nodosus	Knotted Rush	-5	S5					Medium	X	X											
Juncus tenuis	Path Rush	0	S5						X	X											
Juncus torreyi	Torrey's Rush	-3	S5					Low	X		X										
Lemnaceae	**Duckweed Family**																				
Lemna minor	Lesser Duckweed	-5	S5						X	X											
Liliaceae	**Lily Family**																				
Erythronium americanum	Yellow Trout-lily	5	S5						X		X		X				X				
Maianthemum canadense	Wild Lily-of-the-valley	3	S5						X	X											
Maianthemum racemosum	Large False Solomon's Seal	3	S5						X				X	X			X				
Maianthemum stellatum	Star-flowered False Solomon's Seal	0	S5						X	X			X				X				
Trillium erectum	Red Trillium	3	S5						X		X		X				X				
Trillium grandiflorum	White Trillium	3	S5						X		X		X	X			X				
Orchidaceae	**Orchid Family**																				
Aplectrum hyemale	Puttyroot	0	S2						R			X									
Epipactis helleborine	Eastern Helleborine	3	SE5						IX	X			X	X			X				
Poaceae	**Grass Family**																				
Agropyron cristatum	Crested Wheatgrass	5	SE2						IR	X											
Agrostis gigantea	Redtop	-3	SE5						IX	X			X				X	X		X	
Alopecurus pratensis	Meadow Foxtail	-3	SE5						IX	X											
Bromus inermis	Smooth Brome	5	SE5						IX	X											
Calamagrostis canadensis	Bluejoint Reedgrass	-5	S5						X	X											
Cinna arundinacea	Stout Woodreed	-3	S4					Medium	X				X							X	
Dactylis glomerata	Orchard Grass	3	SE5						IX	X											
Diarrhena obovata	Ovate Beak Grass	-3	S1						R		X										
Dichanthelium linearifolium	Linear-leaved Panicgrass	5	S5						R	X											
Elymus virginicus	Virginia Wildrye	-3	S5							X			X					X		X	
Glyceria striata	Fowl Mannagrass	-5	S5						C	X	X		X				X			X	
Hordeum jubatum	Foxtail Barley	0	S5?							X	X										
Leersia oryzoides	Rice Cutgrass	-5	S5					Low	X				X		X		X	X		X	
Leersia virginica	Virginia Cutgrass	-3	S4					Medium	X				X				X				
Lolium pratense	Meadow Fescue	3	SE5						IX	X			X				X				
Muhlenbergia mexicana	Mexican Muhly	-3	S5						X	X											
Panicum capillare	Common Panicgrass	0	S5						X	X											
Phalaris arundinacea	Reed Canary Grass	-3	S5						X	X			X		X	X	X				X
Phleum pratense	Common Timothy	3	SE5						IX	X			X				X				
Phragmites australis	Common Reed	-3	SU							X			X		X		X	X			
Poa compressa	Canada Bluegrass	3	SE5						IX	X											
Poa pratensis	Kentucky Bluegrass	3	S5										X		X	X					
Poa pratensis ssp. pratensis	Kentucky Bluegrass	3	SE5						IX	X											

Plant Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	CW	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Sensitivity to Hydrological Change	Lambton County Status	Natural Environment and Resource Baseline - Warwick Landfill Expansion EA	iNaturalist Research-Grade Observations	NHIC Data*	NRSI Observed	FOD6-5	SWT2-2 (Incl.)	CUM1 (Incl.)	FOD9-4	MAM2-10	SWT2-8 (Incl.)	SWT2-5	CUT1
		Oldham et al. 1995	MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	TRCA 2017	Oldham 2017	Gartner Lee Ltd. 2004	iNaturalist 2023	MNRF 2023b	NRSI Results From 2022								
Typhaceae	**Cattail Family**																				
Typha angustifolia	Narrow-leaved Cattail	-5	SE5						IX	X			X	X	X			X			
Typha latifolia	Broad-leaved Cattail	-5	S5					Low	X	X			X				X	X			
TOTAL										**216**	**28**	**2**	**208**	**70**	**50**	**15**	**167**	**34**	**4**	**57**	**18**

*NHIC Atlas Squares: 17MH2657, 17MH2658, 17MH2857, 17MH2858, 17MH2757, 17MH2758

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Appendix V

Bird Species Report from the Study Area

Bird Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resource Baseline - Warwick Landfill Expansion EA	eBird Hotspot: Watford--Twin Creeks Landfill and Surrounding Fields	iNaturalist Research-Grade Observations	OBBA*	NHIC Data**	NRSI Observed: Highest Level of Breeding Evidence	BMB-01	BMB-02	BMB-03	Other Observations
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	eBird 2023	iNaturalist 2023	BSC et al. 2006	MNRF 2023b	NRSI Results from 2022				
Anatidae	**Ducks, Geese & Swans**															
Aix sponsa	Wood Duck	S5B,S3N						X		CO						
Anas platyrhynchos	Mallard	S5					B	X		CO						
Branta canadensis	Canada Goose	S5						X		CO		**OB**		OB		
Lophodytes cucullatus	Hooded Merganser	S5						X								
Spatula discors	Blue-winged Teal	S3B,S4M						X								
Phasianidae	**Partridges, Grouse & Turkeys**															
Meleagris gallopavo	Wild Turkey	S5						X				**OB**				OB
Columbidae	**Pigeons & Doves**															
Columba livia	Rock Pigeon	SNA						X		PR						
Zenaida macroura	Mourning Dove	S5					B	X		PR		**PO**	PO			OB
Cuculiformes	**Cuckoos & Anis**															
Coccyzus americanus	Yellow-billed Cuckoo	S4B						X								
Coccyzus sp.	Black/Yellow-billed Cuckoo	NP								PO						
Apodidae	**Swifts**															
Chaetura pelagica	Chimney Swift	S3B	THR	T	T	Schedule 1		X		PO						
Trochilidae	**Hummingbirds**															
Archilochus colubris	Ruby-throated Hummingbird	S5B						X		PR						
Charadriidae	**Plovers & Lapwings**															
Charadrius vociferus	Killdeer	S4B					B	X		CO		**PO**	PO			OB
Scolopacidae	**Sandpipers & Allies**															
Actitis macularia	Spotted Sandpiper	S5B						X		PR		**OB**	OB			
Gallinago delicata	Wilson's Snipe	S5B						X								
Scolopax minor	American Woodcock	S4B										**OB**				OB
Tringa flavipes	Lesser Yellowlegs	S3S4B,S5M	THR	T	NS	No schedule		X								
Tringa melanoleuca	Greater Yellowlegs	S4B,S5M						X								
Tringa solitaria	Solitary Sandpiper	S4B,S5M						X								
Laridae	**Gulls, Terns & Skimmers**															
Chroicocephalus philadelphia	Bonaparte's Gull	S5						X								
Larus argentatus	Herring Gull	S4B,S5N						X								
Larus delawarensis	Ring-billed Gull	S5					F	X								
Larus glaucoides	Iceland Gull	S4N						X								
Larus hyperboreus	Glaucous Gull	S4N						X								
Larus marinus	Great Black-backed Gull	S1B,S4N						X								
Graviidae	**Loons**															
Gavia immer	Common Loon	S5	NAR	NAR	NS	No schedule		X								
Phalacrocoracidae	**Cormorants**															
Nannopterum auritum	Double-crested Cormorant	S5B,S4N	NAR	NAR	NS	No schedule		X								
Ardeidae	**Herons & Bitterns**															
Ardea herodias	Great Blue Heron	S4						X								
Butorides virescens	Green Heron	S4B						X								
Cathartidae	**Vultures**															
Cathartes aura	Turkey Vulture	S5B,S3N					F	X								

Bird Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resource Baseline - Warwick Landfill Expansion EA	eBird Hotspot: Watford--Twin Creeks Landfill and Surrounding Fields	iNaturalist Research-Grade Observations	OBBA*	NHIC Data**	NRSI Observed: Highest Level of Breeding Evidence	BMB-01	BMB-02	BMB-03	Other Observations
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	eBird 2023	iNaturalist 2023	BSC et al. 2006	MNRF 2023b	NRSI Results from 2022				
Accipitridae	**Hawks, Kites, Eagles & Allies**															
Accipiter cooperii	Cooper's Hawk	S4	NAR	NAR	NS	No schedule		X								
Accipiter striatus	Sharp-shinned Hawk	S5	NAR	NAR	NS	No schedule		X		PO						
Buteo jamaicensis	Red-tailed Hawk	S5	NAR	NAR	NS	No schedule	A	X		CO						
Buteo lagopus	Rough-legged Hawk	S1B,S4N	NAR	NAR	NS	No schedule		X								
Circus hudsonius	Northern Harrier	S5B,S4N	NAR	NAR	NS	No schedule		X								
Haliaeetus leucocephalus	Bald Eagle	S4	SC	NAR	NS	No schedule		X								
Strigidae	**Typical Owls**															
Asio flammeus	Short-eared Owl	S4?B,S2S3N	THR	T	SC	Schedule 1		X								
Bubo scandiacus	Snowy Owl	S4N	NAR					X	X							
Bubo virginianus	Great Horned Owl	S4					OB					**PO**			PO	OB
Megascops asio	Eastern Screech-Owl	S4	NAR	NAR	NS	No schedule				PR						
Alcedinidae	**Kingfishers**															
Megaceryle alcyon	Belted Kingfisher	S5B,S4N						X								
Picidae	**Woodpeckers**															
Colaptes auratus	Northern Flicker	S5					B	X		PR		**PR**	PO		PR	OB
Dryobates pubescens	Downy Woodpecker	S5					B	X	X	PO		**PO**	PO		PO	
Dryobates villosus	Hairy Woodpecker	S5						X				**PR**	PR		PR	
Melanerpes carolinus	Red-bellied Woodpecker	S5						X		PO		**PO**			PO	
Sphyrapicus varius	Yellow-bellied Sapsucker	S5B,S3N						X								
Falconidae	**Caracaras & Falcons**															
Falco columbarius	Merlin	S5	NAR	NAR	NS	No schedule		X		CO						
Falco sparverius	American Kestrel	S4					B	X		PO						
Tyrannidae	**Tyrant Flycatchers**															
Contopus virens	Eastern Wood-Pewee	S4B	SC	SC	SC	Schedule 1	A	X		PO	X	**PR**	PO	PO	PR	
Empidonax alnorum	Alder Flycatcher	S5B										**PO**	PO			
Empidonax minimus	Least Flycatcher	S5B						X								
Empidonax traillii	Willow Flycatcher	S4B						X		PO						
Myiarchus crinitus	Great Crested Flycatcher	S5B					OB	X		PO		**PR**		PO	PR	
Sayornis phoebe	Eastern Phoebe	S5B					B	X								
Tyrannus tyrannus	Eastern Kingbird	S4B					B	X		CO						
Vireonidae	**Vireos**															
Vireo flavifrons	Yellow-throated Vireo	S4B								PR						
Vireo gilvus	Warbling Vireo	S5B					OB	X		PO		**OB**				OB
Vireo olivaceus	Red-eyed Vireo	S5B					A	X		PO		**PR**		PO	PR	
Vireo solitarius	Blue-headed Vireo	S5B						X								
Corvidae	**Crows & Jays**															
Corvus brachyrhynchos	American Crow	S5					B	X		PO		**PO**		PO	PO	
Corvus corax	Common Raven	S5						X								
Cyanocitta cristata	Blue Jay	S5					B	X		PO		**PR**		PR	PO	
Alaudidae	**Larks**															
Eremophila alpestris	Horned Lark	S4						X		CO		**PO**	PO	PO		
Hirundinidae	**Swallows**															
Hirundo rustica	Barn Swallow	S4B	SC	SC	T	Schedule 1		X		CO						
Petrochelidon pyrrhonota	Cliff Swallow	S4S5B						X		CO						
Progne subis	Purple Martin	S3B						X		CO						
Riparia riparia	Bank Swallow	S4B	THR	T	T	Schedule 1		X								
Stelgidopteryx serripennis	Northern Rough-winged Swallow	S4B						X		CO						
Tachycineta bicolor	Tree Swallow	S4S5B					B	X		CO						

Bird Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resource Baseline - Warwick Landfill Expansion EA	eBird Hotspot: Watford--Twin Creeks Landfill and Surrounding Fields	iNaturalist Research-Grade Observations	OBBA*	NHIC Data**	NRSI Observed: Highest Level of Breeding Evidence	BMB-01	BMB-02	BMB-03	Other Observations
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	eBird 2023	iNaturalist 2023	BSC et al. 2006	MNRF 2023b	NRSI Results from 2022				
Paridae	**Chickadees & Titmice**															
Baeolophus bicolor	Tufted Titmouse	S3						X				**PO**				PO
Poecile atricapillus	Black-capped Chickadee	S5					B	X		PO		**PO**	PO	PO		
Sittidae	**Nuthatches**															
Sitta canadensis	Red-breasted Nuthatch	S5						X								
Sitta carolinensis	White-breasted Nuthatch	S5						X		PR		**PR**			PR	
Certhiidae	**Creepers**															
Certhia americana	Brown Creeper	S5						X								
Troglodytidae	**Wrens**															
Troglodytes aedon	House Wren	S5B					B	X		PO		**PO**	PO			
Regulidae	**Kinglets**															
Corthylio calendula	Ruby-crowned Kinglet	S5B,S3N						X								
Regulus satrapa	Golden-crowned Kinglet	S5						X								
Turdidae	**Thrushes**															
Hylocichla mustelina	Wood Thrush	S4B	SC	T	T	Schedule 1	A	X		PO	X					
Sialia sialis	Eastern Bluebird	S5B,S4N	NAR	NAR	NS	No schedule				PO						
Turdus migratorius	American Robin	S5					B	X		CO		**CO**	CO	PO	PO	OB
Mimidae	**Mockingbirds, Thrashers & Allies**															
Dumetella carolinensis	Gray Catbird	S5B,S3N					B	X		PR		**PR**	PO	PR		
Toxostoma rufum	Brown Thrasher	S4B						X				**PO**	PO			
Sturnidae	**Starlings**															
Sturnus vulgaris	European Starling	SNA					B	X		CO						
Bombycillidae	**Waxwings**															
Bombycilla cedrorum	Cedar Waxwing	S5					OB	X		PR		**PO**	PO		PO	
Passeridae	**Old World Sparrows**															
Passer domesticus	House Sparrow	SNA						X		CO						
Motacillidae	**Pipits**															
Anthus rubescens	American Pipit	S4B						X								
Fringillidae	**Finches & Allies**															
Acanthis flammea	Common Redpoll	S5						X								
Haemorhous mexicanus	House Finch	SNA						X		PO						
Haemorhous purpureus	Purple Finch	S5						X								
Spinus tristis	American Goldfinch	S5						X		CO		**PR**	PO	PR		
Emberizidae	**New World Sparrows & Allies**															
Junco hyemalis	Dark-eyed Junco	S5						X								
Melospiza georgiana	Swamp Sparrow	S5B,S4N						X								
Melospiza lincolnii	Lincoln's Sparrow	S5B						X								
Melospiza melodia	Song Sparrow	S5					B	X		PR		**PR**	PO	PR	PR	
Passerculus sandwichensis	Savannah Sparrow	S5B,S3N					B	X		CO						
Pooecetes gramineus	Vesper Sparrow	S4B						X		PO		**PO**		PO		
Spizella passerina	Chipping Sparrow	S5B,S3N						X	X	CO		**PR**	PR		PO	
Spizella pusilla	Field Sparrow	S4B,S3N						X		PO						
Zonotrichia albicollis	White-throated Sparrow	S5						X								
Zonotrichia leucophrys	White-crowned Sparrow	S5B,S3N						X	X							
Icteridae	**Troupials & Allies**															
Agelaius phoeniceus	Red-winged Blackbird	S5					B	X		CO		**PR**	PR	PR	PO	OB
Dolichonyx oryzivorus	Bobolink	S4B	THR	SC	T	Schedule 1	B	X		CO	X					
Euphagus carolinus	Rusty Blackbird	S4B,S3N	SC	SC	SC	Schedule 1		X								
Icterus galbula	Baltimore Oriole	S4B					B	X		PR		**PR**	PO	PR	PO	
Icterus spurius	Orchard Oriole	S4B						X								

Bird Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resource Baseline - Warwick Landfill Expansion EA	eBird Hotspot: Watford--Twin Creeks Landfill and Surrounding Fields	iNaturalist Research-Grade Observations	OBBA*	NHIC Data**	NRSI Observed: Highest Level of Breeding Evidence	BMB-01	BMB-02	BMB-03	Other Observations
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	eBird 2023	iNaturalist 2023	BSC et al. 2006	MNRF 2023b	NRSI Results from 2022				
Molothrus ater	Brown-headed Cowbird	S5					B	X		CO		**PR**	PO	PR	PO	
Quiscalus quiscula	Common Grackle	S5					B	X		CO		**PR**	PR	PR	PR	
Sturnella magna	Eastern Meadowlark	S4B,S3N	THR	T	T	Schedule 1	B			PR	X					
Parulidae	**Wood Warblers**															
Cardellina canadensis	Canada Warbler	S5B	SC	SC	T	Schedule 1						**PO**	PO			
Geothlypis trichas	Common Yellowthroat	S5B,S3N						X		PO		**PR**	PO	PR	PO	
Leiothlypis peregrina	Tennessee Warbler	S5B						X								
Leiothlypis ruficapilla	Nashville Warbler	S5B						X								
Seiurus aurocapilla	Ovenbird	S5B						X		PO						
Setophaga caerulescens	Black-throated Blue Warbler	S5B						X								
Setophaga coronata	Yellow-rumped Warbler	S5B,S4N						X								
Setophaga magnolia	Magnolia Warbler	S5B						X								
Setophaga petechia	Yellow Warbler	S5B					B	X		CO		**PO**	PO			
Setophaga pinus	Pine Warbler	S5B,S3N						X								
Setophaga ruticilla	American Redstart	S5B								PO		**PO**	PO			
Setophaga striata	Blackpoll Warbler	S5B						X								
Setophaga tigrina	Cape May Warbler	S5B						X								
Cardinalidae	**Cardinals, Grosbeaks & Allies**															
Cardinalis cardinalis	Northern Cardinal	S5					B	X		PO		**PR**	PR	PR		OB
Passerina cyanea	Indigo Bunting	S5B						X		CO		**PO**		PO	PO	
Pheucticus ludovicianus	Rose-breasted Grosbeak	S5B					OB	X		PO		**PO**		PO		
Piranga olivacea	Scarlet Tanager	S5B								PO						
Spiza americana	Dickcissel	S2M						X								
Total							**37**	**115**	**4**	**64**	**4**	**42**	**27**	**21**	**21**	**11**

*OBBA Atlas Square: 17MH25

**NHIC Atlas Squares: 17MH2657, 17MH2658, 17MH2857, 17MH2858, 17MH2757, 17MH2758

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Appendix VI

Herpetofauna Species Reported from the Study Area

Reptile and Amphibian Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resources Baseline - Warwick Landfill Expansion EA	MECP Background Information	iNaturalist Research-Grade Observations	ORAA*	NHIC Data**	NRSI Observed	Anuran Call Surveys
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	MECP 2021	iNaturalist 2023	Ontario Nature 2019	MNRF 2023b	NRSI Results from 2022	
Turtles													
Chelydra serpentina	Snapping Turtle	S4	SC	SC	SC	Schedule 1				X			
Snakes													
Heterodon platirhinos	Eastern Hog-nosed Snake	S3	THR	T	T	Schedule 1		X					
Thamnophis sirtalis sirtalis	Eastern Gartersnake	S5					X		X	X		X	
Salamanders													
Notophthalmus viridescens viridescens	Red-spotted Newt	S5								X			
Frogs and Toads													
Anaxyrus americanus	American Toad	S5								X		X	X
Dryophytes versicolor	Gray Treefrog	S5					X			X		X	X
Pseudacris triseriata pop. 2	Western Chorus Frog (Great Lakes / St. Lawrence - Canadian Shield population)	S4	NAR	T	T	Schedule 1						X	X
Pseudacris crucifer	Spring Peeper	S5										X	X
Lithobates clamitans	Green Frog	S5					X			X			
Lithobates pipiens	Northern Leopard Frog	S5	NAR	NAR	NS	No schedule	X			X			
Lithobates sylvaticus	Wood Frog	S5										X	X
Total							**4**	**1**	**1**	**7**	**0**	**6**	**5**

*ORAA Atlas Square: 17MH25

**NHIC Atlas Squares: 17MH2657, 17MH2658, 17MH2857, 17MH2858, 17MH2757, 17MH2758

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Appendix VII

Mammal Species Reported from the Study Area

Mammal Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resources Baseline - Warwick Landfill Expansion EA	iNaturalist Research-Grade Observations	Ontario Mammal Atlas	NHIC Data**	NRSI Observed
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	iNaturalist 2023	Dobbyn 1994	MNRF 2023b	NRSI Results from 2022
Didelphimorphia	**Opossums**										
Didelphis virginiana	Virginia Opossum	S4							X		
Eulipotyphla	**Shrews, Moles, Hedgehogs, and Allies**										
Blarina brevicauda	Northern Short-tailed Shrew	S5							X		
Condylura cristata	Star-nosed Mole	S5							X		
Parascalops breweri	Hairy-tailed Mole	S4							X		
Sorex cinereus	Masked Shrew	S5							X		
Sorex fumeus	Smoky Shrew	S5							X		
Sorex hoyi	Pygmy Shrew	S4							X		
Sorex palustris	Water Shrew	S5							X		
Chiroptera	**Bats**										
Eptesicus fuscus	Big Brown Bat	S4							X		
Lasionycteris noctivagans	Silver-haired Bat	S4							X		
Lasiurus borealis	Eastern Red Bat	S4							X		
Lasiurus cinereus	Hoary Bat	S4							X		
Myotis leibii	Eastern Small-footed Myotis	S2S3	END						X		
Myotis lucifugus	Little Brown Myotis	S3	END	E	E	Schedule 1			X		
Myotis septentrionalis	Northern Myotis	S3	END	E	E	Schedule 1			X		
Perimyotis subflavus	Tri-colored Bat	S3?	END	E	E	Schedule 1			X		
Lagomorpha	**Rabbits and Hares**										
Lepus americanus	Snowshoe Hare	S5							X		
Lepus europaeus	European Hare	SNA							X		
Sylvilagus floridanus	Eastern Cottontail	S5					X		X		X
Rodentia	**Rodents**										
Castor canadensis	Beaver	S5							X		
Erethizon dorsatum	Porcupine	S5							X		
Glaucomys volans	Southern Flying Squirrel (Great Lakes Plains population)	S4	NAR	NAR	NS	No schedule			X		
Marmota monax	Woodchuck	S5					X		X		
Microtus pennsylvanicus	Meadow Vole	S5					X		X		
Microtus pinetorum	Woodland Vole	S3?	SC	SC	SC	Schedule 1			X		
Mus musculus	House Mouse	SNA							X		
Napaeozapus insignis	Woodland Jumping Mouse	S5							X		
Ondatra zibethicus	Muskrat	S5							X		
Peromyscus leucopus	White-footed Mouse	S5							X		
Peromyscus maniculatus	Deer Mouse	S5							X		
Rattus norvegicus	Norway Rat	SNA							X		
Sciurus carolinensis	Eastern Gray Squirrel	S5					X		X		X
Synaptomys cooperi	Southern Bog Lemming	S4							X		
Tamias striatus	Eastern Chipmunk	S5							X		X
Tamiasciurus hudsonicus	Red Squirrel	S5							X		
Zapus hudsonius	Meadow Jumping Mouse	S5							X		
Canidae	**Canines**										
Canis latrans	Coyote	S5							X		X
Vulpes vulpes	Red Fox	S5					X		X		
Felidae	**Felines**										
Lynx canadensis	Canada Lynx	S5	NAR	NAR	NS	No schedule			X		
Mephitidae	**Skunks and Stink Badgers**										
Mephitis mephitis	Striped Skunk	S5					X		X		X

Mammal Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resources Baseline - Warwick Landfill Expansion EA	iNaturalist Research-Grade Observations	Ontario Mammal Atlas	NHIC Data**	NRSI Observed
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	iNaturalist 2023	Dobbyn 1994	MNRF 2023b	NRSI Results from 2022
Mustelidae	**Weasels and Allies**										
Mustela frenata	Long-tailed Weasel	S4							X		
Mustela richardsonii	American Ermine	S5							X		
Neovison vison	American Mink	S4							X		
Taxidea taxus jacksoni	American Badger (Southwestern Ontario population)	S1	END	E	E	Schedule 1			X		
Procyonidae	**Raccoons and Allies**										
Procyon lotor	Northern Raccoon	S5					X		X		X
Artiodactyla	**Deer and Bison**										
Cervus elaphus	Elk	SNA							X		
Odocoileus virginianus	White-tailed Deer	S5					X	X	X		X
Total							**8**	**1**	**47**	**0**	**7**

*Mammal Atlas Square Numbers: MT
**NHIC Atlas Squares: 17MH2657, 17MH2658, 17MH2857, 17MH2858, 17MH2757, 17MH2758

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Appendix VIII

Butterfly Species Reported from the Study Area

Butterfly Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resource Baseline - Warwick Landfill Expansion EA	Ontario Butterfly Atlas*	NHIC Data**	NRSI Observed
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	Macnaughton et al. 2023	MNRF 2023b	NRSI Results from 2022
Hesperiidae	**Skippers**									
Thymelicus lineola	European Skipper	SNA						X		
Pieridae										
Colias eurytheme	Orange Sulphur	S5						X		
Colias philodice	Clouded Sulphur	S5						X		
Pieris rapae	Cabbage White	SNA						X		X
Lycaenidae	**Harvesters, Coppers, Hairstreaks, Blues**									
Celastrina sp.	Azure species	SNA						X		
Nymphalidae	**Brush-footed Butterflies**									
Cercyonis pegala	Common Wood-Nymph	S5						X		
Coenonympha california	Common Ringlet	S5						X		
Euphydryas phaeton	Baltimore Checkerspot	S4						X		
Megisto cymela	Little Wood-Satyr	S5						X		
Nymphalis antiopa	Mourning Cloak	S5						X		
Polygonia comma	Eastern Comma	S5								X
Vanessa atalanta	Red Admiral	S5B						X		
Total							**0**	**11**	**0**	**2**

*OBA Atlas Square: 17MH25
**NHIC Atlas Squares: 17MH2657, 17MH2658, 17MH2857, 17MH2858, 17MH2757, 17MH2758

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Appendix IX

Odonata Species Reported from the Study Area

Odonate Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resources Baseline - Warwick Landfill Expansion EA	iNaturalist Research-Grade Observations	Odonate Atlas*	NHIC Data**
		MNRF 2023a	MECP 2023a	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	iNaturalist 2023	OOAD 2023	MNRF 2023b
Lestidae	**Spreadwings**									
Lestes rectangularis	Slender Spreadwing	S5							X	
Coenagrionidae	**Narrow-winged Damselflies**									
Argia apicalis	Blue-fronted Dancer	S4							X	
Argia tibialis	Blue-tipped Dancer	S3							X	
Enallagma exsulans	Stream Bluet	S5							X	
Ischnura verticalis	Eastern Forktail	S5							X	
Aeshnidae	**Darners**									
Aeshna constricta	Lance-tipped Darner	S5							X	
Anax junius	Common Green Darner	S5							X	
Libellulidae	**Skimmers**									
Celithemis elisa	Calico Pennant	S5							X	
Libellula pulchella	Twelve-spotted Skimmer	S5							X	
Pantala flavescens	Wandering Glider	S4							X	
Sympetrum vicinum	Autumn Meadowhawk	S5							X	
Tramea lacerata	Black Saddlebags	S4							X	
Total							**0**	**0**	**12**	**0**

*Odonate Atlas Square Numbers: 17MH25
**NHIC Atlas Squares: 17MH2657, 17MH2658, 17MH2857, 17MH2858, 17MH2757, 17MH2758

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Appendix X

Fish Species Reported from the Study Area

Fish Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA	SARA Schedule	Natural Environment and Resources Baseline - Warwick Landfill Expansion EA	iNaturalist Research-Grade Observations	Fisheries and Oceans SAR Data	Aquatic Resource Area Data	Gilliland-Geerts Drain (EMS-01)	Gilliland-Geerts Drain (EMS-02)	HDF 1 (EMS-03)
		MNRF 2023a	MECP2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	iNaturalist 2023	DFO 2023	MNRF 2023b	NRSI Results from 2022		
Cyprinidae	**Carps**												
Cyprinus carpio	Common Carp	SNA								X			
Leuciscidae	**Minnows**												
Lythrurus umbratilis	Redfin Shiner	S4	NAR	NAR	NS	No schedule				X			
Pimephales notatus	Bluntnose Minnow	S5	NAR	NAR	NS	No schedule		X					
Pimephales promelas	Fathead Minnow	S5						X		X	X	X	
Semotilus atromaculatus	Creek Chub	S5					X	X		X			
Catostomidae	**Suckers**												
Catostomus commersonii	White Sucker	S5								X			
Umbridae	**Mudminnows**												
Umbra limi	Central Mudminnow	S5								X			
Gasterosteidae	**Sticklebacks**												
Culaea inconstans	Brook Stickleback	S5					X	X					
Cottidae	**Sculpins**												
Cottus bairdii	Mottled Sculpin	S5					X						
Centrarchidae	**Sunfishes and Basses**												
Lepomis cyanellus	Green Sunfish	S4	NAR	NAR	NS	No schedule					X	X	
Lepomis gibbosus	Pumpkinseed	S5					X						
Percidae	**Perches and Darters**												
Etheostoma microperca	Least Darter	S4	NAR	NAR	NS	No schedule		X					
Etheostoma nigrum	Johnny Darter	S5						X					
Total							**4**	**6**	**0**	**6**	**2**	**2**	**0**

*NHIC Atlas Square(s): 17MH2657, 17MH2658, 17MH2857, 17MH2858, 17MH2757, 17MH2758

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Appendix XI

Fish Species Reported from the Study Area

Mussel Species Reported from the Study Area - Twin Creeks Environmental Centre PTTW Ecology Study (Project #2538B)

Scientific Name	Common Name	SRANK	SARO	COSEWIC	SARA Status	SARA Schedule	Natural Environment and Resources Baseline - Warwick Landfill Expansion EA	iNaturalist Research-Grade Observations	Fisheries and Oceans SAR Data	NHIC Data	NRSI Observed
		MNRF 2023a	MECP 2023	Government of Canada 2023	Government of Canada 2023	Government of Canada 2023	Gartner Lee Ltd. 2004	iNaturalist 2023	DFO 2023	MNRF 2023b	2022
Unionida	**Native Freshwater Mussels**										
Anodontinae											
Strophitus undulatus	Creeper	S5						X			
Lampsilinae											
Epioblasma rangiana	Northern Riffleshell	S1	END	E	E	Schedule 1		X			
Lampsilis fasciola	Wavy-rayed Lampmussel	S2	THR	SC	SC	Schedule 1		X			
Ptychobranchus fasciolaris	Kidneyshell	S1	END	E	E	Schedule 1		X			
Total							**0**	**4**	**0**	**0**	**0**

*NHIC Atlas Squares: 17MH2657, 17MH2658, 17MH2857, 17MH2858, 17MH2757, 17MH2758

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Ministry of Natural Resources and Forestry (MNRF). 2023a. Natural Heritage Information Centre (NHIC): Species List for Ontario. Published: 2014-07-17. All Species List Updated: 2023-05-17. Available: https://www.ontario.ca/page/get-natural-heritage-information

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APPENDIX D

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December 14, 2023

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Sarnia Ontario N7S 1P1
519.336.4030
E: sean.morrison@ontario.ca

Re: Condition 4.2 – Work Plan - Survey of Downstream Riparian Property Owners
Twin Creeks Environmental Centre – Permit To Take Water No. 4682-BLJRYJ
RWDI Reference No. 2303459.5000

Dear Mr. Morrison,

On behalf of Waste Management of Canada Corporation (WM), RWDI AIR Inc. (RWDI) is pleased to provide to the Ministry of the Environment, Conservation and Parks (MECP) the findings of the Survey of Downstream Riparian Property Owners component of the Work Plan approved by the MECP to satisfy the requirements of Condition 4.2 of the Permit To Take Water (System No. 4682-BLJRYJ), dated November 8, 2021 (PTTW).

Survey of Downstream Riparian Property Owners

Per the Work Plan, RWDI completed a survey of downstream riparian property owners along the Gilliand-Geerts Drain between Nauvoo Road and Underpass Road to determine the extent of any surface water uses by those property owners and assess any impacts of the water taking on those uses.

There are 11 properties that are located along the Gilliand-Geerts Drain between Nauvoo Road and Underpass Road. These 11 properties are displayed on Figure 1 of the Work Plan.

In advance of the physical survey polling, the owners (riparian water users) of these 11 properties were contacted by phone or physical mail to ask their desire to be surveyed. Of these 11 property owners, one riparian water user representing 2 properties did not wish to be surveyed. An additional 2 riparian water users of another 2 properties were not reachable by phone, nor did a response occur from the physical mailing request.

Notwithstanding for these 2 properties that did not respond to the physical mailing request, 3 physical attempts were made to try to see if someone was at the property to be surveyed, with no success. The riparian water users of the remaining 7 properties were all reachable in person or by phone, except one property owner. Therefore, 6 properties represented by 5 riparian water users were verbally spoken to by RWDI for the survey. Of these riparian water users, 4 owners representing 5 properties responded.

Copies of the survey forms, as completed by the noted 4 riparian water users (representing 5 properties), are included as **Attachment 1**.

In summary the survey indicated that there is no water taking that would be regulated by the Ontario Water Resources Act from the Gilliland-Geerts Drain. Therefore, in accordance with the Work Plan an assessment of potential impacts on riparian water users was not required to be completed. Also, as responses were not received from 5 owners (representing 6 properties) an assessment of potential impacts on riparian water users was not required to be completed for the properties they owned.

CONCLUSION

We trust that the findings of the Survey of Downstream Riparian Property Owners component of the Work Plan are satisfied for the requirements of Condition 4.2 of the Permit To Take Water (System No. 4682-BLJRYJ), dated November 8, 2021 (PTTW). Please contact us with any questions that you may have.

Respectfully submitted by:

RWDI AIR Inc.

Brent J. Langille, B.Sc., P.Geo.
Senior Technical Director | Principal

ATTACHMENT 1

Gilliand-Geerts Drain Downstream Riparian Property Owner Survey

Please complete the survey below to the best of your knowledge if you are currently or have historically utilized water from the Gilliand-Geerts Drain on the property. Responses will remain confidential.

PROPERTY OWNER

NAME(S) (Personal and/or Company): Buurma Farms Inc	TELEPHONE: 519 8787617
ADDRESS: 7177 LaSalle Line Watford N0M2S0	EMAIL: buurma-family@gmail.com

IS THE WATER FROM THE GILLIAND-GEERTS DRAIN USED ON THE PROPERTY?

Yes: ☐, No: ☑.

WATER USE (If answered "Yes" to the question above)

WHAT ARE THE USES OF THE WATER TAKEN FROM THE GILLIAND-GEERTS DRAIN? __________

HOW IS THE WATER USED? __________

HOW OFTEN IS THE WATER UTILIZED FOR THE LISTED USE(S) (Please check all that apply)?
Daily: ☐, Weekly: ☐, Monthly: ☐, Seasonally: ☐, Yearly: ☐

FOR HOW MANY YEARS HAS THE WATER BEEN UTILIZED AT THE PROPERTY?: __________

IS PUMPING EQUIPMENT USED TO TAKE WATER FROM THE GILLIAND-GEERTS DRAIN? Yes: ☐, No: ☐.
IF "YES", PLEASE PROVIDE PUMPING EQUIPMENT DETAILS (i.e. Pump Type, Size, Capacity, etc): __________

HAS ANY INFRASTRUCTURE BEEN INSTALLED IN THE GILLIAND-GEERTS DRAIN ON THE PROPERTY? Yes: ☐, No: ☐
IF "Yes", WHAT INFRASTRUCTURE HAS BEEN INSTALLED? __________

DOES THE PROPERTY OWNER HAVE/REQUIRE A PERMIT TO TAKE WATER FOR THE WATER USE? Yes: ☐, No: ☐
IF "Yes", PLEASE PROVIDE PERMIT TO TAKE WATER #: __________

The question is foolish - there is no water in this ditch - it is used to drain water away from farm fields & then goes back to being 6" deep. When WM discharges their black water into this ditch, we, as farmers, do not analize it to see if we can drink it. That is for MOE to determine. We are too busy feeding the world. Stupid question!

Name: Harry Buurma	Signature:	Date: Aug 7/23

Gilliand-Geerts Drain Downstream Riparian Property Owner Survey

Please complete the survey below to the best of your knowledge if you are currently or have historically utilized water from the Gilliand-Geerts Drain on the property. Responses will remain confidential.

PROPERTY OWNER	
NAME(S) (Personal and/or Company): JOHN + JILL VANLOON	TELEPHONE: 519-849-3912
ADDRESS: 8727 CONFEDERATION LINE, WATFORD, ON N0M 2S0	EMAIL: jandjvanloon@brktel.on.ca
IS THE WATER FROM THE GILLIAND-GEERTS DRAIN USED ON THE PROPERTY?	
Yes: ☐, No: ☑.	

WATER USE (If answered "Yes" to the question above)
WHAT ARE THE USES OF THE WATER TAKEN FROM THE GILLIAND-GEERTS DRAIN? ______
HOW IS THE WATER USED? ______
HOW OFTEN IS THE WATER UTILIZED FOR THE LISTED USE(S) (Please check all that apply)? Daily: ☐, Weekly: ☐, Monthly: ☐, Seasonally: ☐, Yearly: ☐
FOR HOW MANY YEARS HAS THE WATER BEEN UTILIZED AT THE PROPERTY?: ______
IS PUMPING EQUIPMENT USED TO TAKE WATER FROM THE GILLIAND-GEERTS DRAIN? Yes: ☐, No: ☐. IF "YES", PLEASE PROVIDE PUMPING EQUIPMENT DETAILS (i.e. Pump Type, Size, Capacity, etc): ______
HAS ANY INFRASTRUCTURE BEEN INSTALLED IN THE GILLIAND-GEERTS DRAIN ON THE PROPERTY? Yes: ☐, No: ☐ IF "Yes", WHAT INFRASTRUCTURE HAS BEEN INSTALLED? ______
DOES THE PROPERTY OWNER HAVE/REQUIRE A PERMIT TO TAKE WATER FOR THE WATER USE? Yes: ☐, No: ☐ IF "Yes", PLEASE PROVIDE PERMIT TO TAKE WATER #: ______

Name: JOHN VANLOON	**Signature:** [signature]	**Date:** JULY 11, 2023
JILL VANLOON	[signature]	

Gilliand-Geerts Drain Downstream Riparian Property Owner Survey

Please complete the survey below to the best of your knowledge if you are currently or have historically utilized water from the Gilliand-Geerts Drain on the property. Responses will remain confidential.

PROPERTY OWNER	
NAME(S) (Personal and/or Company): Kerwood Poultry Farms	TELEPHONE: 519 871-3795
ADDRESS: 1174 Mullifarry Dr Kerwood	EMAIL:
IS THE WATER FROM THE GILLIAND-GEERTS DRAIN USED ON THE PROPERTY?	
Yes: ☐, No: ☒.	

WATER USE (If answered "Yes" to the question above)
WHAT ARE THE USES OF THE WATER TAKEN FROM THE GILLIAND-GEERTS DRAIN?
HOW IS THE WATER USED?
HOW OFTEN IS THE WATER UTILIZED FOR THE LISTED USE(S) (Please check all that apply)? Daily: ☐, Weekly: ☐, Monthly: ☐, Seasonally: ☐, Yearly: ☐
FOR HOW MANY YEARS HAS THE WATER BEEN UTILIZED AT THE PROPERTY?:
IS PUMPING EQUIPMENT USED TO TAKE WATER FROM THE GILLIAND-GEERTS DRAIN? Yes: ☐, No: ☐. IF "YES", PLEASE PROVIDE PUMPING EQUIPMENT DETAILS (i.e. Pump Type, Size, Capacity, etc):
HAS ANY INFRASTRUCTURE BEEN INSTALLED IN THE GILLIAND-GEERTS DRAIN ON THE PROPERTY? Yes: ☐, No: ☐ IF "Yes", WHAT INFRASTRUCTURE HAS BEEN INSTALLED?
DOES THE PROPERTY OWNER HAVE/REQUIRE A PERMIT TO TAKE WATER FOR THE WATER USE? Yes: ☐, No: ☐ IF "Yes", PLEASE PROVIDE PERMIT TO TAKE WATER #:

Name: Dean Verhoeven	Signature:	Date: July 7/23

Gilliand-Geerts Drain Downstream Riparian Property Owner Survey

Please complete the survey below to the best of your knowledge if you are currently or have historically utilized water from the Gilliand-Geerts Drain on the property. Responses will remain confidential.

PROPERTY OWNER	
NAME(S) (Personal and/or Company): (Lorraine +) Martin J. Minten	TELEPHONE: 519 849 2984
ADDRESS: 5688 Underpass Rd. Watford	EMAIL:
IS THE WATER FROM THE GILLIAND-GEERTS DRAIN USED ON THE PROPERTY?	
Yes: ☑, No: ☐.	

WATER USE (If answered "Yes" to the question above)
WHAT ARE THE USES OF THE WATER TAKEN FROM THE GILLIAND-GEERTS DRAIN? our dog may drink from our creek
HOW IS THE WATER USED? → dog drinking water
HOW OFTEN IS THE WATER UTILIZED FOR THE LISTED USE(S) (Please check all that apply)? Daily: ☐, Weekly: ☐, Monthly: ☐, Seasonally: ☐, Yearly: ☐ unknown
FOR HOW MANY YEARS HAS THE WATER BEEN UTILIZED AT THE PROPERTY?: 16 years
IS PUMPING EQUIPMENT USED TO TAKE WATER FROM THE GILLIAND-GEERTS DRAIN? Yes: ☐, No: ☒ IF "YES", PLEASE PROVIDE PUMPING EQUIPMENT DETAILS (i.e. Pump Type, Size, Capacity, etc):
HAS ANY INFRASTRUCTURE BEEN INSTALLED IN THE GILLIAND-GEERTS DRAIN ON THE PROPERTY? Yes: ☐, No: ☒ IF "Yes", WHAT INFRASTRUCTURE HAS BEEN INSTALLED?
DOES THE PROPERTY OWNER HAVE/REQUIRE A PERMIT TO TAKE WATER FOR THE WATER USE? Yes: ☐, No: ☒ IF "Yes", PLEASE PROVIDE PERMIT TO TAKE WATER #:

→ Waste Management will be guilty of a myriad of health problems which those of us living in this area may experience. Water may not be as much an issue as the foul, toxic air we are breathing in EVERY DAY.

Name: L. Minten	**Signature:** [signature]	**Date:** July 26/2023