Waterloo Landfill Liaison Committee
c/o Neil and Trudy Haffner
36 Westhill Drive
Waterloo, Ontario
N2J 3Z4

February 1, 2020

Dear Liaison Committee members,

I have completed my independent review of the 2018 Progress Report for the Waterloo Landfill Site (hereafter referred to as “the 2018 Report”). The “operations” part of the report is prepared by the Waste Management Division of the Regional Municipality of Waterloo (the Region), and the “monitoring” part of the report is prepared for the Region by GHD Ltd (GHD).

My review of the 2018 Report focussed mainly on the results of the landfill groundwater and surface water monitoring programs and what they indicated about the landfill’s impacts. I also reviewed other sections of the 2018 Report (regarding other aspects of the general landfill operations), and reviewed other recent reports issued by the Region regarding the landfill.

Please note that due to the ever-changing composition of the membership of the Liaison Committee, I try to include background information about the landfill and its history and surroundings to make the monitoring data which I discuss in my review understandable. This unavoidably means that for more experienced members of the Committee many parts of my review will seem familiar, as I include similar material each year. I hope that this (and the resulting lengthiness of my comments) is not a problem - if it is, please let me know.

1) The Changing Nature of Waste Disposal at the Waterloo Landfill

The Waterloo Landfill began in 1972, when waste disposal commenced in a worked-out gravel pit in a rural area far outside of the City of Waterloo. Waste disposal operations in the early years of the landfill’s operation were haphazard, and were certainly not carried out with the goal of preventing groundwater contamination. If the goal had been to protect regional groundwater supplies then a landfill would never have been built at this location.

In the early years of the site’s operation, a mix of waste streams which included municipal waste but also liquid and solid industrial wastes (including what would later be considered hazardous wastes) were dumped at the landfill. There was no liner to contain the potentially hazardous liquids leaching out of the wastes, and there was no provision made to collect these liquids. This was not because of ill intent on anyone’s part - people simply didn’t know better.

The solid wastes including industrial wastes (which may have contained small amounts of liquid industrial wastes) coming into the landfill will have gone onto the approved waste footprint, which is shown on maps of the landfill such as Figure B.1 of the 2018 Report.

But larger amounts of liquid industrial waste and in particular highly flammable waste liquids, will likely have been disposed of outside of the waste footprint in the early years of the landfill's history - in order to prevent operational problems such as landfill fires or explosions. Based on groundwater monitoring information which is now available, it seems likely that prior to 1990 potentially hazardous liquid wastes were at least occasionally dumped into one or more depressions on the northwest side of the original landfill area (OLA) - outside of the landfill footprint and outside of the contained area within the landfill's leachate collection system.

Ontario's environmental legislation was overhauled in 1990 - since then the dumping of hazardous wastes in municipal landfills has been against the law - but by that time the damage was done. There were industrial wastes containing smaller amounts of hazardous chemicals within the OLA (which was not designed to properly contain those chemicals), and it seems likely that there were also larger quantities of liquid wastes containing hazardous chemicals dumped outside of the landfill footprint on the northwest side of the original landfill.

Dealing with the impacts and effects of this legacy is the main challenge facing the Region in its efforts to contain water contamination on the landfill property, and in its monitoring of groundwater and surface water in the vicinity of the landfill.

2) Landfill Leachate Mounding and Leachate Collection

"Leachate" is the technical term for the contaminated liquid which is produced at a landfill when precipitation falling onto the landfill leaches chemicals out of the wastes, and then leaks out of the landfill. Every landfill produces leachate, and every landfill leaks in one way or another.

If leachate liquid levels within the landfill rise to above the elevation of the surrounding water table, then "leachate mounding" is said to be occurring. The mounding of leachate can lead to leachate seeps and springs on the sides of the landfill, and the increased hydraulic pressure from a leachate mound increases the rate of leakage into the groundwater system through the bottom and sides of the landfill.

At the Waterloo Landfill, the older parts of the landfill have different designs and thus different levels of leachate mounding from the newer parts of the landfill as discussed below.

a) Newer Parts of the Landfill - SEA and NEA

The newer parts of the landfill are known as the North Expansion Area (NEA) and South Expansion Area (SEA). Cells in both the NEA and the SEA have been designed and constructed with leachate underdrains such that little mounding is expected, and the liner and leachate underdrain system in these areas are expected to contain and collect any downward moving leachate. Any leakage from the NEA and SEA will be very much less than from the older parts of the landfill (ie. the OLA).

b) Oldest Parts of the Landfill - The OLA

The original landfill area (OLA) was built without a proper containment liner and without a leachate collection underdrain system, although a perimeter leachate collection system was retrofitted between 1987 and 1994. The lack of an underdrain system has led to mounding of leachate within the OLA, with leachate heads up to 20 meters (m) or more above the base of the waste in some parts of the OLA.

I am unaware of any remedial measures which can be cost-effectively used to significantly reduce the overall mounding in the older parts of the landfill. As a result of the leachate mounding, the older parts of the landfill will continue to be a source of leachate contamination to local groundwater and/or surface water systems for the foreseeable future.

Figures B.2A, B.2B, B.2C and B.2D of the 2018 Report show leachate level hydrographs for various leachate wells at the site. The thing I look for in these figures is any sign of a sustained upward trend in leachate levels, which would indicate that increasing leachate mounding (which may eventually lead to leachate breakouts) is occurring.

A map showing leachate wells and leachate elevations is also provided in Figure B.3, which indicates very significant leachate mounding is long-established across much of the OLA.

c) Leachate Leakage and Outbreaks

The original landfill area (OLA) was built without a leachate collection underdrain system, and in places there was also no protective clay layer separating the base of the landfill from the underlying groundwater flow system. As a result, there is ongoing leakage of contamination into the groundwater flow system occurring from at least 2 areas of the OLA:

- there is lateral leakage of contaminated groundwater to the west from the northwest corner of the OLA, followed by vertical downward migration of the contamination downward into the underlying aquifer;
- there is vertical leakage downward through the landfill base into the underlying aquifer, which is showing signs of contamination all along the east side of the landfill.

These problems are discussed in more detail in **Section 5 and Section 6** of this review.

Due to the leachate mounding in the OLA, leachate springs/outbreaks from the landfill sideslopes remain an ever-present threat to surface water quality. For example, the 2017 Operations Report noted in the second paragraph on page 52 that: *"… the Region did complete work along the western side of the OLA to repair a leachate outbreak in mid-2015."* The 2018 Report (in Section 4.3) notes however that there were *"no reported leachate outbreaks in 2018"*.

4) Leachate Contamination and Critical Contaminants

Many leachate-derived chemicals are present in the contamination which has made its way into the groundwater system. A series of indicator parameters have been developed by the Region's consultants for use in interpreting groundwater monitoring results for the landfill.

Of these parameters the **“critical contaminants”** (the ones most likely to cause regulatory issues at the property boundary, and thus the ones most important to track) are **vinyl chloride, trichloroethylene (TCE),** and **1,4-dioxane**.

Vinyl chloride is the fastest/farthest moving organic contaminant in the groundwater flow system at this site. It has very low acceptable limits in groundwater (because it is a carcinogen). There are many monitoring wells near the landfill where the only real sign of leachate contamination is the presence of vinyl chloride. Vinyl chloride has an Ontario Drinking Water Quality Standard or ODWQS of 1 ug/L (micrograms per Litre), and a Reasonable Use Limit for groundwater quality at the landfill site property boundaries of 0.25 ug/L.

Trichloroethylene (TCE) is an industrial chemical which was widely used and disposed of at the time the OLA was being filled. The ODWQS for TCE is 5 ug/L. Like vinyl chloride, TCE is in the landfill leachate which has leaked out of the landfill, and has therefore become widespread in the groundwater system. TCE is not quite as mobile in the groundwater system as vinyl chloride, but it is a second critical contaminant for this site. TCE’s low ODWQS (of 5 ug/L) means that it also has a low Reasonable Use Limit (1.25 ug/L) at the landfill property boundaries.

It is worth noting that vinyl chloride is a breakdown product of TCE. I expect that the original vinyl chloride contaminant sources within the landfill were hazardous wastes (which in some cases contained pure phase TCE), and that this TCE has been breaking down to form vinyl chloride. The TCE-bearing wastes would have been deposited in the original landfill area decades ago when oversight and regulations were not nearly as stringent as they are today.

1,4-Dioxane is also a very fast moving organic contaminant, which can travel far in the groundwater flow system (making it a good leachate indicator parameter). The Region has only in recent years become aware of the presence of 1,4-dioxane at this landfill.

There is no ODWQS for 1,4-dioxane, so clarity is lacking regarding the Reasonable Use Limit which should be applied at the landfill property boundaries. The 1,4-dioxane groundwater/ drinking water criteria in most US jurisdictions are around 3 ug/L, which if applied here would imply a Reasonable Use Limit at about the detection limit of 1 ug/L at the landfill property boundaries. In the absence of an ODWQS for 1,4-dioxane it can not be considered a critical contaminant for <u>groundwater</u> at this time.

There is however an Ontario Provincial Water Quality Objective of 20 ug/L for 1,4-dioxane, which applies to the Region’s surface water discharges from the landfill property. 1,4-dioxane is a critical contaminant for the landfill’s <u>surface water</u> discharges.

5) Groundwater Impacts on the Perched Water Table Unit (PWTU)

The Perched Water Table Unit (PWTU) extends from the ground surface down to the top of the regional aquifer, and typically includes both coarser grained, permeable sand horizons and lower permeability till layers.

The Ontario Geologic Survey has adopted new names for the geologic units beneath the landfill, with the new terminology for the PWTU being "Aquitard ATB1". I will stick to the older, more descriptive PWTU terminology for the purposes of this review.

Where there is some horizontal continuity to the sand horizons of the PWTU, these can serve as pathways for the horizontal movement of groundwater (and contaminants) outward from the landfill. And in places where the lower permeability till layers are absent from the PWTU, there will be a "window" through which contaminants can leak downward into the underlying aquifer.

Monitoring results over the past few years have shown that degradation of water quality in the PWTU has occurred at a number of locations around the Waterloo Landfill site.

Contamination of the PWTU is of concern/interest for three reasons:

- PWTU contamination can be an indication that the landfill leachate collection system is not functioning properly in the affected area, allowing leachate to escape from the landfill;

- the locations of PWTU contamination are potential source areas from which contamination of the regional aquifer might occur (such as the landfill's northwest corner);

- remediation/containment of "source" contamination in the PWTU is likely the most effective way to remediate the contamination of the regional aquifer, in areas (such as in the northwest corner of the OLA) where there a known window through the PWTU to the regional aquifer.

<u>a) Northwest Corner of the Landfill</u>

Numerous VOCs are present in groundwater in the PWTU in the northwest area of the site, including the following:

- 1,4-dioxane; 1,1,1 trichloroethane; 1,1 dichloroethane; trichloroethylene (TCE);
- cis 1,2 dichloroethylene (DCE); vinyl chloride.

Interestingly, **in this area of the site in the PWTU the critical contaminant is TCE rather than vinyl chloride - due to much higher TCE groundwater concentrations**. As a result, in the following discussion I will be focussing on the TCE levels in different wells.

At my request the Region has provided a map in the Annual Report showing vinyl chloride and TCE levels in the PWTU (Figure B.8). Highest TCE levels are in the vicinity of a depression in the PWTU surface near monitoring wells OW334-03 and OW317-01, which were situated in the vicinity of a "hot spot" where vinyl chloride and TCE levels were and still are high.

A groundwater extraction sump well (EW 347-06) was installed in this hot spot in 2006, and is being pumped on an ongoing basis. I believe that pure phase TCE (the "parent product" of vinyl chloride) is likely present in the immediate area, and this is supported by the very high levels of TCE in the contaminated water being pumped from the sump well. 2018 TCE levels in EW347-06 were as high as **8,200** ug/L.

It should be noted that this TCE hot spot is in a depression well to the west of the landfill footprint, on the northwest side of the OLA. The depression is outside of the leachate collection system, and as discussed in the next section of this review, the chemical "fingerprint" of the contamination in the depression does not match that of landfill leachate.

In any event, **Table 1** (below) shows approximate annual extraction volumes for EW347-06 since the well was installed.

Table 1 - Annual Volume of Liquid Extracted from Extraction Well EW347-06

Year	Volume of Liquid Extracted
2008*	186,375 L
2009*	251,627 L
2010	244,925 L
2011	137,546 L
2012	37,555 L
2013	194,716 L
2014	314,518 L
2015	164,329 L
2016	107,717 L
2017	306,905 L
2018	304,528 L

Notes: 1) EW 347-06 began pumping in April 2008.
2) Liquid volumes for 2008 and 2009 are estimated.

As can be seen from Table 1, the 2018 volume of liquid pumped was the third highest since the well was taken into operation in in 2008. I am pleased with this result, which may at least in part be related to the Region's more systematic Performance Management Program (PMP) which includes regular maintenance of the extraction well and its pumping system.

It was calculated (in Section 9.1 of the 2018 Report) that since pumping of EW347-06 started in 2008, about 21.3 kg of chlorinated solvents including about 12.1 kg TCE were removed from the PWTU via the EW347-06 sump well through to the end of 2018.

To give some idea of the effects of removing this amount of contamination through EW347-06, it is worth considering that the Ontario Drinking Water Quality Standard (ODWQS) for TCE is 5 micrograms per litre (or ug/L). The 12.1 kg of TCE which have been removed by the end of 2018 could have contaminated about 2,420,000,000 litres of groundwater to levels exceeding the 5 ug/L ODWQS. This is enough to generate a massive contamination plume in the downgradient groundwater flow system.

It is vital that the Region continue to remove as much contaminated liquid from this area of the PWTU as possible, thus preventing it from reaching the regional aquifer. In response to my recommendations, the Region has commissioned an evaluation of alternatives for enhancing PWTU remediation in the northwest corner of the OLA. My comments on the resulting report are provided in **Section 15** of this review below.

<u>b) Sources of Contamination in the Northwest Corner PWTU</u>

I have carefully evaluated the possible source(s) of the contamination in the PWTU adjacent to the northwest corner of the OLA which was discussed in the previous section. This contamination is at its peak in the area of the leachate extraction sump (EW347-06).

Review of the monitoring results in the 2018 Report shows that the chemical "fingerprint" of the contamination in EW347-06 does not match that of landfill leachate. I have prepared **Table 2** which is presented on the following page of this review, to show the remarkable differences between the chemical composition of the landfill leachate (as determined from testing of the leachate in the nearest leachate well - LW162-92) and the contaminated liquid being pumped from EW347-06.

As can be seen from **Table 2** (on the next page of this review), the leachate at LW162-92 is heavy in various inorganic "leachate indicator" parameters (such as chloride, TKN and alkalinity) as well as BTEX parameters (such as benzene, ethylbenzene and xylenes) and 1,4-dioxane - but with no TCE or vinyl chloride detected at all. The opposite is true for the liquid being extracted from EW347-06.

What **Table 2** confirms for me is that the contaminated liquid which is present in the depression on the northwest side of the OLA (well to the west of the landfill footprint, and outside of the leachate collection system) is <u>not</u> landfill leachate. It is simply groundwater which happens to have been badly contaminated by chlorinated organic solvents which were disposed of there in liquid form at some time in the distant past.

Table 2 - Comparison of Landfill Leachate to Groundwater Contamination at EW347-06

Parameter	Landfill Leachate (from LW162-92)	Contaminated Groundwater (pumped from EW347-06)
chloride (mg/L)	625	106
alkalinity (mg/L)	2300	460
iron (mg/L)	36	4.1
boron (mg/L)	3.3	0.1
TKN (mg/L)	290	6.3
TDS (mg/L)	2357	705
conductivity (uS/cm)	5825	1340
benzene (ug/L)	22	ND
ethylbenzene (ug/L)	34	ND
xylenes - total (ug/L)	540	ND
1,4-dioxane (ug/L)	153	ND
1,1,1-trichloroethane (ug/L)	ND	650
TCE (ug/L)	ND	2249
vinyl chloride (ug/L)	ND	86

Notes: 1) results shown are averages for 2018
2) both levels for 1,4-dioxane from 2013 (most recent test results)
3) ND means parameter not detected

As such, this strongly supports the idea that prior to 1990 liquids containing hazardous wastes chemicals were at least occasionally dumped into one or more depressions on the northwest side of the original landfill area (OLA). This has a number of far-reaching implications, in particular the possibility of implementing targetted additional remedial measures which could build on the success of the contaminated groundwater extraction at EW347-06. The Region has submitted a report on its evaluation of possible remedial measures, and my review of that report can be found in **Section 15** below.

One of the issues assessed in that report is whether the landfill site is adequately contained by the leachate collection system in the area of the northwest corner of the OLA. I will discuss this question in more detail in Section 15, but at this point I can confirm that I agree that the priority issue in the northwest corner of the OLA is remediation of the pure product chlorinated volatile organic chemical (CVOC) contamination found in the vicinity of EW347-06. Of the CVOC's present in the area, TEC is the main and critical contaminant.

c) Stepped Up Monitoring of VOCs Elsewhere in the PWTU

Elsewhere in the PWTU new wells were installed in recent years in several locations and a program of stepped up testing of PWTU wells was carried out by the Region.

Inorganic chemicals and volatile organic chemicals (VOCs) related to landfill leachate impacts were found at the majority of wells tested around the rest of the Original Landfill Area (OLA) - and all of these wells are situated outside the perimeter collection system around the OLA.

The main areas of PWTU contamination are in the northwest side of the OLA, and in the southeast corner of the OLA. In some cases the leachate contamination could be remnant contamination which predates the installation of the perimeter collection system around the OLA, and in some cases it appears possible that leachate is getting past the perimeter leachate collection system (LCS) by overflowing past or flowing beneath the base of the system.

However I don't believe from my review of the PWTU monitoring results that - outside of the TCE/VC hot spot contered on EW347-06 - there are any other areas outside of the landfill footprint where dumping of heavily VOC-contaminated liquids was being carried out. Based on the currently available information it appears that the remaining PWTU contamination appears to be due to landfill leachate - either residual contamination from pre-LCS days, or from leachate escaping and moving past the LCS.

Recent work done in the course of updating the Site Conceptual Model (most recently discussed in a May 2017 report entitled *"Chlorinated Volatile Organic Compounds Investigation Report - ESPA No. 15"*, and in the 2017 Report) has identified that there are quite a few "windows" (ie. areas where the low-permeability aquitards above the regional aquifer (ATB1 and ATB2) are very thin, discontinuous, or absent), and it is through these windows that the observed contamination in the PWTU is likely making its way outward and downward from within or near the landfill into the Regional Aquifer below.

Ever more windows are being found, and the current count includes:

1. the window at the southeast corner of the Original Landfill Area (OLA), which is the main source of the southeast VC plume in the regional aquifer (which is discussed in more detail in **Section 6b** of this review);

2. one or more windows on the east/northeast side of the OLA, which are the source of the VC contamination detected in OW371-13, OW372-13, OW373-13 and OW298-99 (which in turn has caused occasional VC detections in wells in the hydro corridor east of the site);

3. a PWTU window in the northeast corner of the OLA near the OW363 well nest, which is allowing inorganic road salt contamination in nearby surface water ditches to leak downward into the regional aquifer.

4. several windows in the PWTU near the northwest corner of the OLA, which provide the downward pathway and are the source of the west side VC plume in the regional aquifer (which is discussed in more detail in **Section 6c** of this review);

5. a separate window which has facilitated leachate leakage into the regional aquifer of the VOCs detected on the west side of the ESPA at the OW359 and OW345 well nests;

6. a window on the west side of the North Expansion Area (NEA), which is assumed to be the source of the elevated chloride in the regional aquifer at OW2-83 and OW336-05;

7. a possible window between the NEA and the Erb Street Well Field (near the WRESTEC access road), which is assumed to be the source of the elevated chloride in the regional aquifer at OW370A-13;

8. a window in the middle of proposed Cell 5/6 of the South Expansion Area (SEA), which was addressed through improvements to the landfill base design and leachate collection capabilities in this area.

The potential flow paths to and through these windows are numerous and complex, meaning that it will not be possible to gain a full understanding of all of them.

6) The VOC Contamination Plumes in The Regional Aquifer

a) Introduction

In the decades since the Waterloo Landfill began operation, volatile organic chemicals (VOCs) leaking from the OLA into the PWTU moved downward through permeable "windows" in the PWTU into the underlying regional aquifer (AFB2). Once these hit the water table in the regional aquifer, this VOC contamination began spreading as it was carried downgradient in the groundwater flow system.

The critical VOC contaminants in the regional aquifer are **vinyl chloride, TCE,** and **1,4-dioxane**.

Vinyl chloride plumes in Aquifer Unit 1 have developed in at least two separate areas of the Waterloo Landfill (which are each discussed in more detail below):

- an extensive plume emanating from the eastern side of the original landfill area (OLA), and extending downgradient to the southern landfill property boundary and off-site past that property boundary;
- a second, almost as extensive plume originating near the northwest part of the OLA.

b) The Southeast Plume

A major groundwater contamination plume originates beneath the east side of the OLA and extends southwards through the groundwater flow system in the regional aquifer to the southern site boundary. Groundwater extraction wells were installed at the southeast corner of the OLA starting in 2000, with the aim of containing the plume to the landfill property. The network of extraction wells has been steadily expanding along the east side of the OLA, with a second cluster of extraction wells at the south boundary.

The core of the Southeast Plume appears to be situated in the vicinity of well OW296A-99, with average vinyl chloride levels of about **10 ug/L** at this location in 2018 - 10 times higher than the vinyl chloride ODWQS of 1 ug/L, and 40 times its Reasonable Use Limit at the site property boundaries of 0.25 ug/L

A secondary peak in vinyl chloride concentrations is found about 550 meters upgradient of OW296A-99 at well OW372-13, where vinyl chloride levels averaged about **3 ug/L** in 2018. Vinyl chloride has even been detected a further 200 meters north (upgradient) at well OW373-13, with vinyl chloride levels averaging **1 ug/L** in 2018. The northern end of the Southeast Plume at OW372-13 and OW373-13 is currently not contained and the Southeast Plume extends off-site to the east, with sporadic trace level detections as far east as OW301A-00 and OW302B-00 (about 175 meters off-site to the east). The westerly extent of the plume is situated somewhere beneath the landfill. It is likely that the Southeast Plume in the regional aquifer has several windows beneath the OLA as a contaminant source.

From the southeast corner of the OLA the contamination plume extends a further 600 meters to the south property boundary of the landfill, where it is drawn into the South Boundary Extraction Well System. For many years, the Region did not have quite enough high capacity extraction wells at the south boundary of the landfill property and this enabled the leading edge of the Southeast plume to extend off site in the vicinity of OW329-04. However a new, higher yield extraction well (EW382-15) went into service in 2015 doubling pumping rates at the south property boundary, and within a few months vinyl chloride and other contaminant levels in observation wells all along the south property boundary dropped to non detect.

I had been using levels of vinyl chloride at well OW357A-08 (situated midway between the two older south boundary extraction wells) to track whether the south boundary was contained. I also have been watching the one off-site monitoring well (OW329A-04) in which vinyl chloride has been regularly detected. OW329-04 is several hundred meters beyond the property boundary. **Table 3** below shows average vinyl chloride levels for these wells.

Table 3: Average Annual Vinyl Chloride Levels at Wells OW357A-08 and OW329A-04

Year	OW357A-08	OW329A-04
2010	1.1	0.4
2011	1.1	0.6
2012	1.2	1.0
2013	2.5	1.3
2014	1.9	1.1
2015	1.3	1.1
2016	ND	1.1
2017	ND	1.0
2018	ND	0.7

Note:
- all units in micrograms per Liter (ug/L)
- the Reasonable Use Policy limit for vinyl chloride was 0.5 ug/L, dropping to 0.25 ug/L in 2019
- EW382-15 commenced operation in 2015

The pumping at the property boundary extraction wells has now fully contained the south landfill property, but has not yet eliminated the "remnant plume" several hundred meters downgradient at OW329A-04 where average VC levels were **0.7 ug/L** in 2018. The Region has investigated the truncated remnant plume in the vicinity of and downgradient of well OW329A-04 in detail, with the results reported in a February 2018 GHD report entitled "*Evaluation of Off-Site Vinyl Chloride Impact and Action Plan*" which I will briefly summarize below.

The areal extent of the remnant plume and where it has gone from OW329A-04 is now well defined. There does not appear to have been any lateral spread of the remnant plume. One new well (OW398-17) which is situated immediately downgradient of OW329A-04 showed positive for VC, with VC levels at OW398-17 averaging around **0.3 ug/L** in 2018. However OW329A-04 and OW398-17 are satisfactorily "ring-fenced" with clean new observation wells (all showing non-detects for vinyl chloride). In my opinion the Region has done the work needed to confirm that the extent of the off-site remnant VC plume has been satisfactorily defined.

Now that this southern remnant plume is cut off from its source, contaminant levels will be subject to a variety of physical, chemical and biological processes which will act to steadily reduce VC concentrations over time. I expect that within the next few years vinyl chloride levels will drop to below Reasonable Use levels of 0.25 ug/L at OW329A-04, and subsequently at OW398-17.

Modelling presented in the Off-site VC Report concludes that there are no risks to downgradient residents, mainly due to the considerable distance of 600+ meters between OW329A-04 and the nearest downgradient domestic wells. The modelling results are persuasive. The potential threat to downgradient municipal well fields (Mannheim, Greenbrook, and Strange Street and Peaking well fields) was also evaluated. These well fields are not at risk from the remnant plume.
The Region will track the remnant plume until monitoring confirms that it has dissipated.

c) The West Plume

A second contaminant plume is present in the regional aquifer on the landfill's west side. Its primary source is the heavy TCE/VC contamination of the PWTU near the northwest corner of the OLA (outside the leachate collection system), as discussed in earlier sections of this review.

In the OLA's northwest corner in extraction sump well (EW347-06) levels of TCE (the "parent product" of vinyl chloride) were as high as **8,200 ug/L** in 2018. These TCE levels confirm the presence of pure product TCE nearby. This area is the second main source of contamination of the regional aquifer at the Waterloo Landfill. TCE and/or its breakdown product vinyl chloride from this area have made their way downward to the regional aquifer from this area.

Wells OW316A-01 and OW324B-02 (drilled into the regional aquifer downgradient of the northwest area of PWTU TCE/VC contamination) had average vinyl chloride levels of about **5.2 ug/L** and **1.2 ug/L** respectively in 2018, and thus may not represent the core of the plume. Traces of vinyl chloride (at levels generally less than 1 ug/L) are now also being detected in the regional aquifer downgradient all along the west side of the OLA at OW338B-05, OW78B-89, OW352B-08, OW351A/B-08, and OW325B-02. Trace levels of vinyl chloride (which were averaging **0.22 ug/L** in 2018) have been detected at OW294-05, about 200 meters further south from the OLA since 2011.

Alarmingly, groundwater flow directions in the regional aquifer in the vicinity of the West Plume are inconsistent with leachate leaking directly downward from the landfill itself - because groundwater in the regional aquifer is flowing from the known position of the West Plume toward the landfill. It appears that some rather unusual things are happening here.

As outlined previously. DNAPL-containing liquids were dumped outside of the landfill footprint in one or more depressions in the area of OW 317-01 and EW347-06, and these have badly contaminated the otherwise relatively clean groundwater with chlorinated solvents TCE and VC. PWTU contamination in this area then leaked downward into the regional aquifer through one or more windows somewhere upgradient of the known position of the plume at OW316A-01 and OW358B-08.

The contamination moving southward in the West Plume in the regional aquifer has been detected in OW294-95 (about 500 m from the landfill's south property boundary) since 2011. There is no reason to believe that OW294-95 happened by chance to hit the core of the plume, in fact the very steady low vinyl chloride levels suggest that OW294-95 may be on the lateral margins of a plume which is moving past that location.

It is quite possible that the West Plume's reaching the south property boundary is imminent. Fortunately the Region has responded to my urgent recommendations and is now in a much better position to deal with this possibility than it was a few years ago.

<u>d) New Areas of Contamination (West of the OLA) within ESPA 15</u>

Aside from the main West Plume discussed above, it seems that there has been additional outward migration of leachate-derived contamination through the discontinuous sand layers of the PWTU together with downward leakage through windows in the ATB1 and ATB2 aquitard layers - with the resulting leachate contamination showing up in the regional aquifer on the west side of the ESPA.

Two new locations with VOCs being detected in the regional aquifer on the west side of ESPA No. 15 are well OW359B-08 (where traces of VC and other VOCs have been detected), and well OW345A-06 (where traces of VC and other VOCs have also been detected) - raising many questions about how they are getting there.

Volatile organic chemical (VOC) contaminants detected at OW345A-06 in 2016/2018 include chloroethane, toluene, xylenes, and vinyl chloride. Volatile organic chemical (VOC) contaminants detected at OW359B-08 in 2016/2018 include acetone, benzene, chloroethane, toluene, and xylenes (but no VC since 2015).

An investigation of the ESPA area was reported on in a May 2017 report entitled *"Chlorinated Volatile Organic Compounds Investigation Report - ESPA No. 15"*. In a nutshell the results of the investigation indicate that the area of the ESPA has an extraordinarily complex geology and hydrogeology (as does the rest of the site), which combined have made it possible for landfill-related groundwater contamination in the PWTU near the northwest corner of the OLA to "stair-step" downward and westward by travelling laterally through discontinuous PWTU sand layers and then downward through windows in ATB1 and ATB2 (see Figure B.26 of the 2018 Report).

The combinations of contaminant sources and possible flow paths to individual wells are so numerous and so complex that they will never be fully understood. Suffice it to say that in my opinion there is considerable groundwater contamination beneath the ESPA which has not been found through the investigations done to date. I do not consider it practical for the Region to spend more time or funding trying to understand what exactly is happening.

The bottom line is that the contamination under the ESPA will in the long run end up in the regional aquifer, and from there it will flow back to the south and east toward the southern landfill property boundary. It is important for the Region to be ready to install extraction wells as needed when the various component lobes of the West Plume break through at the property boundary.

7) Water Quality in Residents' Wells

There are a few of the original homes to the east of the landfill which are still on domestic wells. Residents' well water quality was good in 2018, and there is no sign of landfill-related impacts.

Hardness, iron, manganese, and arsenic levels are sometimes (naturally) elevated in some of the residential wells.

I should note that the ODWQS for arsenic has been reduced from 25 ug/L to 10 ug/L effective January 1, 2018. All (naturally occurring) arsenic levels from 2017 tests on residential wells were below this new ODWQS. Only one well (WPW49) has ever had an exceedence of the new arsenic criterion, and that was a one-time occurrence in 2012.

It is my understanding that residences and institutions immediately south (downgradient) of the vinyl chloride plume at the southern landfill property are now on a piped municipal water supply, thus the landfill currently does not pose an immediate risk to any private well water supplies. The addition of those former private water supply wells to the landfill's monitoring network some years back has augmented the landfill's groundwater monitoring network.

Many of the residents' wells east of the landfill had not been tested for VOCs - and I had recommended to the Region that it would be good to conduct precautionary testing in 2016. This testing has been done starting in 2016, and no VOCs were found.

The testing program for residential wells near the site is winding down (with only 3 wells needing testing at this point), as the original large properties get sold and homes are torn down and replaced with more intensive developments which are on municipal water supplies.

8) Trigger Level Assessment

The trigger level assessment for the site is found in Section 10 of the 2018 Report. New trigger levels are presented for the site, and I am in general agreement with these.

In addition the Region commissioned 2 reviews of the implications for changes in various criteria in the Ontario Drinking Water Quality Standards which came into effect in 2019. The reviews were presented in memoranda dated December 23, 2016 and May 23, 2018 - both entitled *"Implications of Changes to Ontario Drinking Water Quality Standards, Waterloo Landfill Site"*.

Good work was done in the work on the trigger level assessment in these two memoranda. Considerably more information on the Trigger Level Program for the site is presented in the January 2019 GHD report entitled "*South Boundary Groundwater Extraction System - Contingency Plan*". My review comments and conclusions regarding the information presented in that new report were provided in **Section 15** of last year's review. I can summarize by saying that I am comfortable with the work done by the Region and with the current Trigger Level Program for the landfill.

9) Potential Landfill Effects on the Erb Street Well Field

a) Introduction

The Waterloo Landfill Site has caused extensive contamination of the regional aquifer, which is mostly contained on-site or on other lands owned or controlled by the Region - although there is the truncated lobe of the Southeast Plume now mapped but well off-site beyond the south property boundary of the landfill, and a second portion of the Southeast Plume off-site to the east. The Southeast Plume and West Plume are both moving southward or southeastward, carried in this direction by the regional groundwater flow (influenced locally by regional extraction wells).

The Ministry of the Environment, Conservation and Parks (MECP) hydrogeologist has expressed ongoing concern about the potential for groundwater contamination from the Waterloo Landfill to impact the Erb Street Well Field (ESWF). The ESWF draws its water from the regional aquifer and is situated about 1 km west of the landfill (which is cross-gradient to the landfill given the observed southward to southeastward groundwater flow in the area).

I do not share those concerns, based on currently available information. The reasons for my views on this subject are provided in the following section of this review.

b) Review of Erb Street Well Field Evaluation in 2018 Report

Section 8.0 of the 2018 Report provides an evaluation of the potential impacts of the Waterloo Landfill on the Erb Street Well Field (ESWF).

The foundation for this evaluation was a major hydrogeological investigation of the ESWF commissioned by the Region, which had been completed in September 2009. The results of that investigation by Stantec Consulting Ltd. are entitled *"Hydrogeological Investigations Erb Street Water Supply System Study"*, and hereafter referred to as the 2009 Stantec Report.

The 2018 Report's evaluation of the ESWF considers the following:

i) responses to pumping;
ii) groundwater contours;
iii) chloride distribution.

i) Responses to Pumping

There is clearly a water level response to pumping at the ESWF, which results in a drawdown cone affecting the wells closest to the well field - the greater the pumping of the ESWF, the deeper and more extensive that drawdown cone will become.

Pumping records (in Figure B.6 of the 2018 Report) show that pumping of the ESWF has decreased by about 25% over the past 15 years, and this would cause the drawdown cone of the ESWF to shrink back toward the well field. I see no evidence to suggest that the current drawdown cone of the ESWF extends to the area of the Waterloo Landfill or its contamination plumes in the regional aquifer.

ii) Groundwater Contours

Groundwater contour maps are shown on Figures B.4A, B.4B, and B.4C of the 2018 Report. They are also shown for a much broader area in Figure No. 6 of the 2009 Stantec Report. My interpretation of these figures is that the ESWF is cross-gradient from the landfill, and that there is no direct flow path from the landfill to the well field.

Also evident from Figure No. 6 of the Stantec Report is that the former Sanico Landfill is directly upgradient of the well field (about 1 to 1.5 km away). So there is in fact a landfill which poses a threat to the ESWF - in my professional opinion the landfill posing the threat is the Sanico Landfill (discussed in **Section 9c** below).

iii) Chloride Distribution

Chloride levels in the well field have been slowly rising for decades. Chloride distribution maps are provided in Figure B.17 of the 2018 Report and in Figure No. 37 of the 2009 Stantec Report.

Figure B.17 maps chloride levels in the regional aquifer in the area of the landfill and the ESWF. Figure B.17 shows an area of elevated chloride levels (with readings as high as **92 mg/L**) near the southwestern end of the NEA at well OW336-05 (and nearby well OW2-83). As discussed previously these wells are situated beside landfill access roads and there is a window through the PWTU nearby. The groundwater chemistry of the wells is consistent with a road salt source for the chloride seen in the wells.

With the exceptions of these two wells and several wells on the southeast side of the OLA, levels of chloride in proximity to the landfill are generally lower than in the well field - making a landfill source of the chloride levels at the ESWF highly unlikely.

Chloride distributions are discussed in Section 8.4 of the 2018 Report, and on pages 9.1 to 9.6 of the 2009 Stantec Report. The primary source of the slowly rising chloride levels in the ESWF appears to be application of road salt on Erb Street, which is up-gradient of the ESWF. Experience at the landfill has shown that there are windows in the PWTU, which will allow flow of groundwater carrying contaminants (such as chloride from road salting) from the water table downward into the underlying regional aquifer.

In my opinion a possible secondary chloride source which should be investigated in much more detail is the Sanico Landfill, which is directly upgradient of the well field. I have expressed this concern repeatedly over the past decade.

By comparison, the Waterloo Landfill is cross-gradient to the ESWF and there are wells with low chloride levels between the landfill and the well field - I do not consider the Waterloo Landfill to be a likely source of the chloride being picked up in the ESWF.

To date I have seen little evidence to suggest that there is a significant risk of Waterloo Landfill derived contamination of the ESWF occurring, provided that pumping rates from the ESWF are not significantly increased from current levels. If the Region wished to substantially increase pumping rates at the ESWF, then this could be problematic and should be carefully evaluated.

c) The Sanico Landfill

When considering potential threats to the ESWF, it is in my opinion critical to consider the Sanico Landfill. In my professional opinion the Sanico Landfill poses a much greater threat to the ESWF than the Waterloo Landfill. While I realize that this is not the focus of my work for the Waterloo Landfill Liaison Committee, the issue requires continued attention because of the ongoing MECP concerns about the potential for landfill contamination of the ESWF - with the landfill in question being the Waterloo Landfill. I agree that there is a landfill posing a threat to the ESWF, but in my opinion the main threat is posed by the upgradient Sanico Landfill.

My earlier reviews of the Waterloo Landfill annual reports included a detailed discussion of the Sanico Landfill. I have removed that information from this review, but it can still be found in my 2017 review (esp. in **Attachment A** of that review). I would encourage those seeking a better understanding of the Sanico Landfill to review this background information.

The Sanico Landfill is situated on the south side of Wilby Road about 1-1.5 km upgradient of Well 6A of the ESWF. The Sanico Landfill contains various potentially hazardous organic chemicals, including 1,4-dioxane. 1,4-dioxane is likely the critical contaminant for that landfill, and there is 1,4-dioxane contamination of the regional aquifer beneath the Sanico Landfill.

1,4-dioxane has turned up in Production Well 6A of the ESWF - in my professional opinion the Sanico Landfill is the most likely source of the 1,4-dioxane. Unfortunately the Region was not able to conduct a thorough investigation of the Sanico Landfill and the threat it poses to the ESWF, because the owner of the majority of the property on which the landfill is situated denied access to the property.

The MECP has the power to require that access be provided for an investigation - and it should make full use of those powers. The MECP needs to do all that is needed to facilitate the proper investigation of the Sanico Landfill and protection of the Erb Street Well Field.

Recommendation 1

a) The MECP should use its powers to deal promptly and firmly with the threat which the Sanico Landfill poses to the Erb Street Well Field.

b) A thorough investigation is needed in the main part of the Sanico Landfill (to which access has been denied) and downgradient areas between the landfill and the Erb Street well field, and it is up to the MECP to use its powers as needed to ensure that these areas are properly investigated.

c) The Region should provide the Waterloo Landfill Liaison Committee with an update presentation on the Sanico Landfill and its groundwater impacts in 2020. The MECP's hydrogeologist should be invited to the meeting at which the presentation is made.

d) The possibility of contamination from the Sanico Landfill reaching the Waterloo Landfill property should be discussed in the next Annual Report.

10) A New Critical Contaminant - 1,4-Dioxane

a) Introduction

1,4-dioxane is an "emerging contaminant" - that is, it is a contaminant which has been around for many years but whose hazardous nature is only now being recognized by regulatory authorities.

1,4-dioxane is present at significant levels in the landfill's leachate. It is also present at levels of concern in groundwater around the site, and it is present in groundwater being discharged to surface waters from the extraction wells on the south property boundary and on the southeast side of the OLA.

b) 1,4-Dioxane in Groundwater

Sampling for 1,4-dioxane was originally carried out at numerous wells at the Waterloo Landfill in 2013 at the request of the MECP. That sampling has shown that is a very good indicator parameter for the landfill's groundwater impacts, and it may be a better trigger parameter than several of the parameters now being used. If another leachate indicator parameter is needed for the Waterloo Landfill then 1,4-dioxane will be an excellent parameter. 1,4-dioxane may also be a third critical contaminant (beside vinyl chloride and TCE).

The US Environmental Protection Agency (EPA) has classified 1,4 dioxane as a probable human carcinogen. It is classed as an "emerging contaminant" which means that it is a newly identified threat to human health for which the EPA has not yet developed a drinking water standard.

However the EPA's guidance has been revised downwards and various states are following suit. The drinking water standard for 1,4 dioxane in Colorado is 3.2 ug/L. California has established a "public health protective concentration" of 3 ug/L in drinking water, and 3 ug/L is also used in guidelines by Connecticut and New Hampshire. Other states with drinking water guidelines include Michigan (2 ug/L), North Carolina (7 ug/L), and Massachssetts (0.3 ug/L).

Canada and Ontario appear to be lagging far behind from a regulatory perspective. There is currently no Ontario or Canadian drinking water standard for 1,4 dioxane. The matter of an appropriate drinking water criterion for 1,4-dioxane was the subject of considerable discussion and evidence at an Environmental Review Tribunal (ERT) hearing in Belleville in 2015, and in its Decision the ERT recommended that a site specific Reasonable Use Policy Limit of 1 ug/L should be applied to groundwater contamination from the Richmond Landfill.

More recently, Health Canada in 2019 conducted a consultation on a proposed drinking water quality guideline of 50 ug/L for 1,4-dioxane. If it were to be adopted by Health Canada and later by the MECP then it would all but eliminate 1,4-dioxane as a contaminant of regulatory concern at the Waterloo Landfill given the relatively lower concentrations in the aquifer.

In the meantime with a wide spread in guidance and in the absence of a regulatory standard, it seems that there is certainly merit in continuing to sample for 1,4-dioxane, given that it is another excellent tracer of groundwater contamination.

c) 1,4-Dioxane in Groundwater in the Landfill Area

Testing done to date has shown that most 1,4-dioxane detections are occurring in the Southeast Plume in wells which are also contaminated by vinyl chloride. Interestingly, the 1,4-dioxane is appearing to be almost as persistent as vinyl chloride as the plume progresses southward.

Two anomalous areas of 1,4-dioxane contamination are worth noting:

1) Near the northwest corner of the OLA, 1,4-dioxane is present at elevated levels in PWTU well OW334-03 (93 ug/L in 2015, 52 ug/L in 2016, 30 ug/L in 2017, and 42 ug/L in 2018), which has in part been impacted by landfill leachate. But 1,4-dioxane is not found in the nearby PWTU extraction well EW347-06 (just a few meters away).

2) Outside of the southwest corner of the OLA, regional aquifer well O351A-08 had a 2018 1,4-dioxane level of **5.6 ug/L** - the highest level in the West Plume. No other wells in the regional aquifer on the landfill's west side (except OW351B-8, which is a shallower well at the same location) have 1,4-dioxane detections.

This well falls within the West Plume of vinyl chloride contamination, but vinyl chloride levels in the well are pretty low (about **0.3 ug/L** in 2018). Levels of inorganic leachate indicators such as sodium, chloride, alkalinity, iron and DOC are slowly rising and suggestive of low level leachate impacts on the regional aquifer at this location.

It is not clear where the 1,4-dioxane in the well is coming from. There are no upgradient detections of 1,4-dioxane, which suggests that there is a different source of 1,4-dioxane affecting this well. Further investigation is indicated. In response to my recommendation the Region tested nearby Stormwater Management Pond 2 for 1,4-dioxane in 2018 - nothing was detected.

Groundwater being pumped from extraction wells on the eastern property boundary is routinely showing 1,4-dioxane levels between 15 and 35 ug/L. Since the extracted water is discharged to surface water features downstream of the site, there are surface water quality issues to consider.

d) 1,4-Dioxane in Surface Water

There is an Ontario Provincial Water Quality Objective (PWQO) of 20 ug/L for 1,4-dioxane in surface water. 1,4-dioxane is a critical contaminant in surface water because:

- 1,4-dioxane is persistent in surface water - so unlike VOCs (which will evaporate from surface water) 1,4-dioxane can be carried off-site into downstream surface water features.

- There is water being pumped from groundwater extraction wells on the south property boundary and on the southeast side of the OLA. Testing has shown that the water being pumped from these wells often contains 1,4-dioxane, in some cases at levels which can exceed the PWQO for 1,4-dioxane (20 ug/L).

The only SWMP in which 1,4-dioxane was detected in 2018 was SWMP3, which makes sense since the pond received the discharges from the extraction wells which are being used to contain the Southeast Plume (and the plume contains 1,4-dioxane). The 1,4-dioxane levels noted in 2018 were in the range of 2 to 6 ug/L - well below the PWQO of 20 ug/L. The Region is to be commended for carrying out this precautionary testing.

11) Surface Water Monitoring

a) Introduction

Background location WSP 33 is a pond located some distance from the landfill and other potential contaminant sources, and is used to establish background water quality for the landfill's surface water quality monitoring program.

The Region has indicated that monitoring locations Stormwater Management Pond 3 or SWMP 3 (southeast), Stormwater Management Pond 4 or SWMP 4 (northeast), and WSP 15 (southwest) are to be used as site boundary monitoring locations for surface water quality, and that its long-term goal is to achieve surface water discharges from the site at these locations that have the equivalent of background surface water quality.

b) Stormwater Management Ponds (SWMPs)

Table 4 below provides an overview of inorganic surface water quality results for the 4 stormwater management ponds (SWMPs) which receive runoff and discharges from the landfill. My interpretation of the results from **Table 4** is provided in the following discussion.

SWMP 1 on the west side of the OLA has generally good quality water which is comparable to background and I have no concerns. Iron levels are elevated but this is likely due to the high total suspended solid (TSS) load of the water, which is normal in a surface water retention pond.

SWMP 2 on the southwest side of the OLA had a bad year in 2015, when the monitoring data provided in Appendix G of the 2015 Report suggested a landfill influence leading to water quality degradation (which may have been related to a leachate breakout in that year). I have not seen a significant landfill impact on the pond since then.

SWMP 3 is the collective designation for the 3 ponds southeast of the landfill which receive the discharges from the southeast and south groundwater extraction systems. As can be seen from **Table 4,** the quality of the water being discharged from SWMP 3 is excellent. It will be beneficial to the downstream urban surface water system. As an aside, the 1,4-dioxane levels in the discharges from the downstream pond (WSP-3C) were also all far below the PWQO.

SWMP 4 receives surface water flows from the northeast parts of the landfill property, including the recycling drop-off and compost areas. Water quality in SWMP 4 shows the effects of road salt inputs but is otherwise comparable to background levels.

Table 4 - Waterloo Landfill Surface Water Quality Monitoring Results

Parameter	Background (WSP-33)	SWMP1	SWMP2	SWMP3 (WSP3C)	SWMP4	PWQO
sodium	26	23	24	13	330	-
chloride	41	28	30	23	523	-
alkalinity	280	183	247	250	127	-
un-ionized ammonia	ND	ND	0.005	ND	ND	0.02
boron	0.02	0.13	0.11	0.02	0.03	0.2
iron	0.16	**3.3**	**1.7**	**0.24**	**0.66**	0.3
conductivity	775	563	563	821	2609	-
TDS	390	345	351	330	988	-
TSS	5	55	49	1	22	-

Notes:
- unless otherwise noted, all values are 2018 averages (in mg/L)
- ND means parameter not detected;
- PWQO is short for Ontario's Provincial Water Quality Objectives (which have been set to be protective of aquatic life and human use); **bold** values mean PWQO exceeded)

Overall Table 2 presents good news - in 2018 the Region did an excellent job with its surface water quality management program. No organic chemicals were found in the SWMPs except 1,4-dioxane in SWMP3. Levels of heavy metals met PWQO. Levels of landfill indicators were almost all within their respective PWQO, and comparable to background levels.

12) Major Construction Activities and Site Life Estimates

Section 8.6 of the 2018 Annual Operations Report summarizes future site development activities which were to be carried out in 2019. For 2019 the Region's planned activities included:

- confirming extraction well containment at the south end of the landfill property;
- advance the design of pending SWMP2 modifications;
- complete the construction of Cell SE-4B;
- continuing to monitor new leachate wells in southeast corner of OLA, and implementing recommendations from the related pilot assessment;
- assessment of alternatives to improve remediation of the northwest PWTU contamination;
- complete the tie ins which would allow leachate to be sent to the Kitchener Wastewater Treatment Plant;
- maintenance of the landfill gas collection system, and work on odour abatement projects;
- a variety of other site improvement activities.

The 2018 Operations Report's estimates of the remaining site life of 17 to 20.5 years are based on very conservative assumptions and lack credibility - almost identical figures were provided for the past 6 years. All landfilling activity with be in the South Expansion Area (SEA) going forward.

13) Site Operations

Operating conditions at the landfill are observed during my regular site tours, and any concerns arising from the site tours are the subject of separate correspondence to the Region and are discussed at the Site Liaison Committee meetings.

For many years there have been major concerns about landfill odours which have been severely affecting residents and businesses around the landfill. The rate of landfill odour emissions is strongly affected by the accumulation of leachate in the landfill. The "wetter" the waste becomes, the faster the garbage in the landfill decomposes, and the worse the landfill odour problems become. As a result it it critical that at all times as much as possible of the landfill's leachate is being collected and sent to the wastewater treatment plant (WWTP).

The volumes of leachate collected at the site over the past 6 years are as follows:

2013	98,436,000 Litres
2014	77,877,000 Litres
2015	53,868,000 Litres
2016	80,510,000 Litres
2017	90,383,000 Litres
2018	98,436,000 Litres

It is my understanding that at times in the past leachate was allowed to build up in the landfill due to constraints in either forcemain or sewer system capacity, or due to constraints in the ability of the receiving WWTP to actually take in the maximum possible volumes of leachate coming from the landfill. Having leachate build up in the landfill - even on a short-term basis - should be avoided at all costs. It can lead to nasty landfill odour and/or groundwater contamination issues.

The taking into operation of a new leachate forcemain connection to the Kitchener Sewage Treatment Plant should help the Region stay on top of leachate collection issues going forward.

Recommendation 2 (ongoing recommendation)

a) The Region should at all times be collecting as much leachate from the landfill as possible and immediately transferring the collected leachate to local wastewater treatment plants.

b) If there are any impediments to the Region removing as much leachate as possible from the site, then such impediments should be eliminated.

c) Future Annual Reports should include a report on any downtime(s) of any component(s) of the leachate collection system lasting more than 1 day, including when the system component(s) went down and when operations resumed and the reason for the downtime(s).

I should note that in 2018 the number of odour-related complaints (30) dropped significantly from the 58 recorded in 2017 and 53 recorded in 2016.

14) MECP Review Comments and Region Responses

The most recent MECP review of an Annual Report was provided in the January 24, 2018 review by the MECP's hydrogeologist of the 2016 Report. I can say for the record that I see the site hydrogeology very similarly to the MECP hydrogeologist, and am in general agreement with his comments. I look forward to future MECP Annual Report reviews.

15) Northwest Corner PWTU Remedial Alternatives Assessment

The Region's consultants (GHD) recently issued a comprehensive January 2020 report entitled "Northwest Corner Perched Water Table Unit Remedial Alternatives Assessment". This report looks at the issue of the heavy chlorinated volatile organic chemical (CVOC) contamination near the NW corner of the OLA which was discussed previously in **Section 5** of this review.

The possibility of a landfill connection to the CVOC contamination was thoroughly investigated, with 11 boreholes (10 of which were made into monitoring wells), soils sampling, groundwater sampling and more. The report concludes that there is not a landfill connection to the CVOC contamination which is found in a depression outside of the landfill access road near EW347-06. I share that conclusion.

A series of alternatives for enhanced remediation of the CVOCs in the area are presented in the report (in particular in Table 7.1), and include:
- contaminant removal through excavation;
- contaminant migration control through various barrier options;
- several in-situ contaminant destruction options.

The report concluded that only two of the contaminant destruction options were likely to be successful for a variety of reasons, and I share that conclusion. Those two options were:
- in-site chemical oxidation
- in-situ enhanced anaerobic biodegradation

Bench testing laboratory testing was done using samples of impacted soil and groundwater from the EW347-06 area - with results of this testing provided in Appendix G of the report. Based on the results of that testing, the in-situ enhanced anaerobic biodegradation option was recommended to proceed to the detailed design stage. I agree with this recommendation.

I note that the MECP provided its hydrogeologist's review comments dated December 23, 2019 on the PWTU Remedial Alternatives Assessment. His interpretation of the local hydrogeology of the area differs somewhat from mine, but that does not affect the viability or applicability of remedial options.

With respect to the remedial alternatives, the MECP hydrogeologist is in agreement with the in-situ enhanced anaerobic biodegradation option - but he also offers the suggestion of using prior in-situ thermal treatment as a means of reducing the contaminant mass. There was no description of what exactly was being proposed, its potential effectiveness, or discussion of successful application in other similar settings. I am open to hearing more from the MECP reviewer about his suggestion, but I am concerned about the possibility that heat treatment might mobilize the CVOC contamination allowing it to more effectively migrate downward into the regional aquifer. This concern should be addressed if in-situ thermal treatment is pursued as an option.

16) Action Plan - East Boundary Off-Site Vinyl Chloride

The Region commissioned the East Boundary Off-Site Vinyl Chloride Action Plan (presented in a memo dated September 11, 2019) in response to unexpected detections of vinyl chloride off-site to the east of the Waterloo Landfill. The wells with vinyl chloride detections confirm that there is an uncontained VC plume extending eastward to at least as far as the eastern boundary of the Hydroelectric Power Corridor (HEPC). The Action Plan was presented to the Liaison Committee at its November 2019 meeting.

The Action Plan provides a combination of recommendations for short-term action and longer-term action. Overall it is clear that the Region is taking the issue very seriously, and is pursuing multiple initiatives to get the best possible understanding of the situation before initiating site containment and/or other remedial options.

The Short-Term Actions the Region is considering and/or implementing include the following:

1. **Sample the existing private water supply wells (WPW15 and WPW18) along Ira Needles Boulevard and West Hill Drive.** This has already been done, and the wells are being added to the ongoing site monitoring program.

2. **Survey the newly installed monitoring wells.** Surveying of newly installed monitoring wells was completed on August 30, 2019.

3. **Undertake an expanded well survey to the east of the Site, between the HEPC and the StrangeStreet Well Field** (located approximately 2 km from the east boundary of the Site) - with water level monitoring and sampling of suitable wells for VOCs .

4. **Evaluate detailed stratigraphic sequences obtained from the 2019 HECP drilling program**, to identify possible preferential groundwater pathways between areas of known VC impact along the east of the OLA and the areas of identified VC presence east of the Site.

5. **Revisit the 2013 vertical aquifer sampling results for the OLA east side**. Detailed vertical VOC chemistry profiles were done at that time, and revisiting these profiles may improve the conceptual understanding of the likely pathway(s) from the Site to the off-Site areas of observed VC impact.

6. **Contact Region Water Services regarding pumping rates at the Strange Street Well Field**. This would allow comparison of observed water levels in monitoring wells to well field pumping rates, and review of possible evidence of an eastern component of flow within Aquifer AFB2 as a result of pumping at the Strange Street Well Field.

7. **Increase pumping rates at existing East Boundary GWES extraction wells**, including in particular the northern-most extraction wells (EW376-13 and EW377-13).

The Longer-Term Actions the Region is considering include:

8. **Install additional on-Site Aquifer AFB2 groundwater monitoring wells** to identify the ideal locations for expanded groundwater extraction along East Boundary (as necessary). There are gaps as large as 200 m in the monitoring well network. Filling these data gaps may be necessary in order to ensure the groundwater control strategy properly addresses all potential sources of off-Site migration of VC.

9. **Delineate the northern and eastern extents of the off-Site VC plume (as necessary).** Additional Aquifer AFB2 groundwater monitoring wells may need to be installed to supplement the existing monitoring well network.

10. **Install additional Aquifer AFB2 groundwater extraction wells along the East Boundary.** In light of the significance of the VC concentrations observed off-Site, it will be necessary to expand the existing East Boundary GWES with additional groundwater extraction wells. The location and depths of these extraction wells will be determined based on the results of the short-term tasks and the additional Aquifer AFB2 drilling, sampling and monitoring well installations referenced in Task 8, above (if necessary).

11. **Test the effectiveness of the expanded GWES and develop a monitoring plan for observing the continued effectiveness of the expanded system.**

The MECP hydrogeologist has reviewed this plan and deemed it to be acceptable. I also concur with all aspects of the Action Plan which have been presented. I also have two additional recommendations for the Region to consider.

Recommendation 3

a) The Region should assess the possibility of a large-scale water taking (outside of Regional well fields) to the east of the site. If there is an unknown and possibly unauthorized major off-site water taking nearby, then this could account for the site's vinyl chloride plume being drawn in an easterly direction.

b) The Region should assess the possibility of the vinyl chloride being found in the HEPC to the east of the landfill site coming from an upgradient source to the north of the Waterloo Landfill.

17) 2018 Report Recommendations

The 2018 Report includes (in Section 12) a series of recommendations which were made by the Region's consultants for the site, and I support all of those recommendations. I am also providing 4 Recommendations in this review, and I urge the Region to implement them.

I also request that the 2019 Annual Report (and future reports) should continue to report on the Region's implementation of the published recommendations from the professionals involved with the site.

Recommendation 4 (ongoing recommendation)

a) A copy of this review should be sent to the MECP hydrogeologist who is responsible for reviewing the landfill Annual Reports.

b) The 2019 Report should provide an accounting of the Region's progress in implementing the recommendations provided by their consultants, by the MECP, and by myself with respect to the design, operations and monitoring of the landfill.

This concludes my review of the 2018 Report and other reports related to the Waterloo Landfill. I hope that my comments are helpful and informative to the Liaison Committee and the Region.

APGO Stamp

Yours sincerely,

W Ruland

Wilf Ruland (P. Geo.)

766 Sulphur Springs Road
Dundas, Ontario
L9H 5E3
tel: (905) 648-1296
deerspring1@gmail.com