Scientific Report:

Beneficial Reuse of Excess Soil at Aggregate Pits and Quarries

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Acronyms and Initialisms

AET: Apparent Effects Threshold

APV: Aquatic Protection Value

ARA: Aggregate Resource Act

BMP: Best management practice

BRAT: Beneficial Reuse Assessment Tool

COPC: Contaminant of potential concern

EC: Electrical conductivity

foc: fraction organic carbon

GW: Groundwater

GW1: Exposure pathway due to ingestion of potable groundwater

GW2: Exposure pathway due to inhalation of indoor air containing soil vapour from groundwater at water table

GW3: Exposure pathway to aquatic biota via groundwater discharge to surface water

I/C/C: Industrial/Commercial/Community

K-S: Kolmogorov-Smirnov

MECP: Ministry of Environment Conservation and Parks

MNRF: Ministry of Natural Resources and Forestry

OTR: Ontario Typical Range

PHCs: Petroleum Hydrocarbons

Q-Q: Quantile-quantile

QP: Qualified Person as defined by *O. Reg153/04*

R/P/I: Residential/Parkland/Institutional

RL: Reporting Limit

S1: Component for direct exposure to soil via soil ingestion and dermal contact appropriate for a residential scenario

S2: Component for direct exposure to soil via soil ingestion and dermal contact appropriate for a commercial/industrial scenario

S3: Component for direct exposure to soil via soil ingestion and dermal contact appropriate for the subsurface soil in a commercial/industrial scenario

S-IA: Exposure pathway due to inhalation of indoor air containing soil vapour

S-GW1: Exposure pathway due to movement of a substance from the soil to groundwater then to a human receptor via drinking water.

S-GW2: Exposure pathway due to the movement of vapour from soil to groundwater and through groundwater to indoor air.

S-GW3: Exposure pathway due to movement of a substance from soil to groundwater then to aquatic receptors in a surface water body.

SS-GW1: Exposure pathway due to movement of a substance from the saturated soil to groundwater then to a human receptor via drinking water.

SS-GW2: Exposure pathway due to the movement of vapour from saturated soil to groundwater and through groundwater to indoor air.

SS-GW3: Exposure pathway due to movement of a substance from saturated soil to groundwater then to aquatic receptors in a surface water body.

S-O: Exposure pathway due to odour from surface soil

S-OA: Exposure pathway due to inhalation of soil vapour in outdoor air

SAR: Sodium adsorption ratio

SLC: Screening Level Concentration

SQG: Sediment Quality Guidelines

Executive Summary

This document was developed by the staff and members of the Ontario Society of Professional Engineers (OSPE), with support from the OSPE Excess Soil Project Steering Committee, and was funded by the Ontario Ministry of Environment, Conservation and Parks (MECP), through a Transfer Payment Agreement (TPA), however the MECP or the province of Ontario does not endorse any content, recommendation or opinion found in this document.

The purpose of this document is to identify best practices for rehabilitating aggregate pit and quarry sites with beneficially reused excess soils, and to consider how elements of the *On-Site and Excess Soil Management Regulation (O. Reg. 406/19)*, the associated rules, and Beneficial Reuse Assessment Tool (BRAT) may be applied to licenced and unlicenced aggregate sites. The intention of this document is to assist Qualified Persons (QPs) and aggregate licensees and operators in evaluating options for using excess soils to rehabilitate pits and quarries in a manner that is safe, economically viable, climate positive, and facilitates sustainable land use practices.

Rehabilitation of aggregate pits and quarries may require large quantities of soil. Therefore, pit and quarry sites are potential reuse sites for the significant volume of excess soil that is generated in Ontario each year. Pit and quarry site plans have traditionally referenced the use of 'inert fill' for rehabilitation, which has been interpreted as soil meeting the *O. Reg. 153/04* Table 1 background site condition standards. However, reliance on the *O. Reg. 153/04* Table 1 standards may not be practical in all circumstances and may limit opportunities to beneficially reuse excess soil in a manner that is safe, preserves landfill capacity for waste, and reduces the generation of greenhouse gas emissions and wear on road infrastructure. Conversely, many pit and quarry sites are located in rural areas that rely on groundwater as their main source of drinking water and/or where agricultural land use is occurring, and importation of material (if not managed appropriately) can present risks. In other cases, communities have grown around abandoned pits and quarries, and this may contribute to additional concerns associated with increased truck traffic contributing to road congestion, noise, dust, and ground vibration. This report investigates these and other issues by studying work conducted in Ontario, other jurisdictions, and the scientific literature.

The primary objective of this report is to examine whether *O. Reg. 406/19* and its associated generic standards are protective of common receptors and pathways in a typical pit or quarry setting. The second objective is to assess the suitability of other tools such as the Beneficial Reuse Assessment Tool (BRAT) for pit and quarry rehabilitation. Finally, potential adverse impacts that are not addressed by *O. Reg. 406/19* but may commonly arise in a pit or quarry setting are considered.

Most sites undergoing rehabilitation will require more than 350 m^3 of soil, therefore, the small volume soil standards (consistent with those found in *O. Reg. 153/04*) were not considered, and the focus was on volume independent standards. Following our review of *O. Reg. 406/19* and *the Rules* it was concluded that when a site is less than 30 m from a surface body of water, Tables 8.1 and 9.1 may be appropriate for use in potable and non-potable groundwater conditions, respectively. While Tables 6.1 and 7.1 may be appropriate for backfilling pits or quarries below the water table in some circumstances, this Scientific Report recommends the application of Table 1. This is due to the high level of uncertainty associated with metal fate and transport in saturated conditions – which is not contemplated in the generic models. QPs may consider using the leaching models discussed in Appendix 6 to derive site-specific standards that are less stringent than Table 1 but remain protective of all potential receptors. Tables 2.1 and 3.1 are appropriate for most cases of placing fill in a pit or quarry above the water table, in potable and non-potable conditions, respectively. Similarly, Tables 4.1 and 5.1 subsurface values may be appropriate when placing soil above the water table and below 1.5 m of the surface if Stratified Conditions are satisfied, in potable and non-potable conditions, respectively. It is generally recommended that the selection of appropriate MECP tables of standards for a given reuse site be completed by QPs who are aware of their underlying assumptions and the limitations of the generic model from which these tables are derived. Table 1 standards remain appropriate as a default reference standard and are required to be used in situations described by the regulations (e.g., sites located in environmentally sensitive areas).

The BRAT is considered an appropriate tool for deriving tailored site-specific standards for many pits and quarries. However, QPs must be aware of the assumptions behind the BRAT and be vigilant of those circumstances in which the BRAT may not be adequately conservative. The range of hydraulic conductivity for the underlying aquifer, which varies between 10^{-3} to 10^{-6} m/s and is anticipated to be protective of pits and quarries in most settings, may not be conservative of pits and quarries with higher hydraulic conductivity (e.g., coarse gravel and fractured rock). Another assumption of the BRAT that is not clearly stated is the pH of groundwater. While the ministry's Synthetic Precipitation Leaching Procedure (mSPLP) method is based on a slightly acidic pH (intended to model precipitation percolating through soil), the pH of groundwater can vary from acidic to alkaline, and will commonly be buffered with dissolved metals complexes, and therefore may not adequately model how potential contaminants (e.g., metals) will behave if soil is placed directly into groundwater.

While the regulations consider common chemical contaminants of concern, QPs must remain vigilant about emerging contaminants of concern and adverse impacts arising from non-chemical contaminants not specifically addressed by the *O. Reg. 406/19* or the *Rules*. This may include biological contaminants, invasive species, physical impacts to groundwater (e.g., turbidity), soil erosion, noise, and dust. These issues are discussed in detail in this report, and some best practices are identified for consideration. Furthermore, the potential impacts of climate change on pits and quarries operation and rehabilitation are discussed. At the end, two case studies of rehabilitated pits and quarries in Ontario are presented.

1. Introduction

This chapter provides a synthesis of the existing literature on excess soil management with emphasis on pits and quarries. The sources for this report are categorized into three classes:

1. Regulations, standards, and best practices in Ontario.
2. Regulations, standards, and best practices in other jurisdictions.
3. Academic literature, including books and peer-reviewed articles.

Policies and protocols developed by the Ontario Ministry of Natural Resources and Forestry (MNRF) generally define acceptable backfill materials as materials meeting the *Records of Site Condition (O. Reg. 153/04)* Table 1 full depth background site condition standards. However, these standards may be overly conservative in some circumstances, particularly considering that in some areas of the province the typical range of chemical concentrations may naturally exceed Table 1 specifications. This may lead to importation of material from distant locations, and/or use of high-quality soil resources in a manner which does not constitute their highest and best use.

O. Reg. 153/04 established generic standards (Tables 2 through 9) for the remediation of brownfield sites, considering different site settings and uses, and to limit the risk of adverse impact to human and ecological receptors. However, these standards were modeled on a relatively small (350 m^3) quantity of soil.

The *On-Site and Excess Soil Management regulation (O. Reg. 406/19)* was developed by the MECP to provide greater clarity around the management and beneficial reuse of excess soil, with the recognition that soil is a valuable resource, and effective reuse of this resource is beneficial to our economy, and the health and safety of our communities and natural environment. As a component of this regulation, new generic soil quality standards were developed, contemplating the placement of large quantities (>350 m^3) of soil in different settings and applications. The excess soil standards complement the pre-existing generic standards for brownfields and are represented by Tables 2 to 9 (small volume; <350 m^3) and Tables 2.1 through 9.1 (volume independent; >350 m^3).

It is recognized that backfill of aggregate sites may be a beneficial reuse of excess soil and can include the adoption of alternate soil quality standards. However, aggregate sites operate and are governed under their own regulatory regime, and given the nature and setting of such operations, elements of the generic model may be invalidated. Therefore, there is a need to review the underlying assumptions of the standards put forward by the MECP and to benchmark them against conceptual models relevant to pit and quarry scenarios.

1.1. Pits and Quarries

Construction aggregate (e.g., sand, gravel, and crushed stone) is extracted from pits and quarries. The difference between pits and quarries lies in the type of material extracted and the associated extraction method. A pit is an area from which unconsolidated aggregate, such as sand and gravel, is excavated. The product of a quarry is crushed stone or building stone aggregate derived from bedrock such as limestone and granite (Environmental Commissioner of Ontario 2007; MNRF 1990). Unlike a pit, it is a common practice to use blasting for material extraction in a crushed stone quarry. In this document pits and quarries are differentiated by licenced (active) sites and unlicenced (typically inactive)[1] sites.

1.2. Licenced Pits and Quarries

There are more than 5,000 active pits and quarries in Ontario (Association of Citizens Together In Our Nassagaweya 2019; MNRF 2020a; Savanta Inc. 2008). Approximately, 3,600 of these sites are on private land in designated areas under a licence, and 2,500 are located on Crown land and are operating under a permit (Environmental Commissioner of Ontario 2007; The Ontario Aggregate Resources Corporation 2020a). The annual consumption of aggregates in Ontario is estimated to be approximately 170 million tonnes (Ontario Stone Sand & Gravel Association 2020). Almost all construction projects are dependent on sand and gravel extracted from pits and quarries. For example, one kilometre of a four-lane highway requires 1,760 truckloads of aggregate, and one kilometre of subway consumes 4,560 truckloads (MNRF 2020b). The volume of material exported from some pits or quarries is not small and, in some cases, could reach up to one million cubic metres (Ecometrix Inc. 2020).

The locations of pits and quarries are typically close to urban areas to reduce transportation costs. If not well operated, gravel pits and quarries may negatively impact neighbouring ecosystems and communities: contributing to erosion and loss of topsoil, increasing greenhouse emissions, causing light and noise pollution, causing blast contamination, and introducing invasive species (Berry and Pistocchi 2003; Gulia 2012; Markvart 2015; NSW Government 2020). These issues, especially groundwater protection, require attention as groundwater is a significant source of potable water for many communities in Ontario. These are all reasons why aggregate operations have been regulated in many jurisdictions.

Regulations require aggregate operation owners to minimize adverse effects during their operation and commit to a rehabilitation plan which defines how a pit or quarry will be rehabilitated by the end of its useful life. While there are many rehabilitation options, the focus of this document is licenced and unlicenced aggregate sites where backfill is identified as a

[11] Unlicenced sites can also be fully active where they are not regulated under the ARA (see Table a for a more detailed categorization).

preferred means of rehabilitation. Given the volume of material imported, the rehabilitation process can pose short- and long-term impacts to human and ecological health.

Most short-term impacts are associated with trucking backfill material (Pal and Mandal 2019; Shotyk 2020) and typically limited to the time of operation or rehabilitation of the aggregate site. Among the most important operational issues are the following:

- Noise caused by trucks and movement of material (e.g., tailgate slamming, heavy machinery)
- Muddy roadways
- Increase in traffic or road congestion
- Dust emissions
- Impacts to surface water and/or groundwater resources arising from poor sediment and/or erosion control
- Ground vibration

Long-term issues can extend beyond the final aggregate site closure if soil and/or water become contaminated (Mollema and Antonellini 2016). Among the more significant potential long-term issues are:

- Surface water quality interference
- Groundwater water quality interference
- Air emissions and/or vapour intrusion
- Contamination of soil
- Contamination of flora and fauna (i.e., bioaccumulation and/or biotransformation)
- Introduction of invasive species

1.3. Rehabilitation of Licenced Pits and Quarries

Active pits and quarries are under the jurisdiction of the MNRF. These sites are regulated by the *Aggregate Resources Act* or *ARA* (MNRF 1990). A site plan is prepared as part of an *ARA* licence application and, when the licence is approved, the site plan becomes a legally binding requirement on the licensee and the site operator(s). Aggregate extraction impacts the human health and/or the natural environment. Therefore, each site plan prescribes how an aggregate site will be developed, operated, and monitored to ensure that impacts are mitigated. The site plan also prescribes how the aggregate extraction site will be rehabilitated by the end of its useful life.

Under the definition proposed by the *ARA* for rehabilitation, the land must be treated in such a way that it is either restored to its original condition or its condition is changed but still compatible with neighbouring land use.

Rehabilitation does not necessarily begin at the end of an aggregate operation's useful life. The *ARA* recognizes the need for progressive rehabilitation and states that "*every licensee and every permittee shall perform progressive rehabilitation and final rehabilitation on the site*."

While rehabilitation strategies are diverse, there are general requirements. For example, slopes cannot be steeper than 3:1 (H:V) for pits or 2:1 (H:V) for quarries. Generally, pits and quarries below the water table will be predominantly converted to ponds and lakes, whereas those above the water table will have more opportunities for commercial, residential, recreational or agricultural use or naturalized upland habitats (Ontario Stone Sand & Gravel Association 2018).

Between 1990 and 2008, more than 450 hectares of pits and quarries were rehabilitated to different final uses in Ontario under the *Management of Abandoned Aggregate Properties (MAAP)* program (Savanta Inc. 2008). Rehabilitation of licenced sites is higher and reaches over 15,000 ha between 1998 and 2018 (The Ontario Aggregate Resources Corporation 2021). The most common final reuse covers include agricultural land and natural areas (e.g., wetlands or alvars). The post-rehabilitation land use and final cover are indicated in the site plan and developed in consultation with the public and conservation authorities. Pits and quarries to be rehabilitated by backfill will typically identify the quantity and/or quality of the backfill material to be used in the site plan[2].

1.4. Unlicenced Pits and Quarries

Unlicenced pits and quarries are sites that have surrendered their licence and are no longer regulated by the MNRF or sites that have never been licenced under the *ARA*. These types of sites fall into two categories: formerly licenced and abandoned or legacy sites (See Table a). Since the *ARA* is not applicable to unlicenced pits and quarries, the land use activity that occurs is the governed by the local municipality, commonly through a zoning bylaw. For

[2] This is only the case for more recent (post-1997) site plans, and there will be more emphasis on it in the future.

instance, when a pit or quarry owner wants to change the land use of their unlicenced pit or quarry they would typically work through the municipality for a (re-)zoning review[3].

Another category of pits and quarries is abandoned pits and quarries, also called legacy pits and quarries. This group of unlicenced pits and quarries include sites for which a licence was never in force at any time after December 31, 1989, or possibly even prior to that. In other words, they have never been licenced under the *ARA*. There are approximately 8,000 abandoned pits and quarries in Ontario (The Ontario Aggregate Resources Corporation 2020b). Table a summarizes these different types of pits and quarries and where and under which instrument, if any, they are operating.

The Ontario Aggregate Resources Corporation (TOARC), which derives its authority from the *ARA*, is responsible for the selective rehabilitation of abandoned pits and quarries through the *Management of Abandoned Aggregate Properties (MAAP)* program, and rehabilitation costs are paid via the *Abandoned Pits & Quarries Rehabilitation Fund*. *MAAP* is funded by the aggregate industry through a portion of the annual licence levy as prescribed in the *ARA* regulations. Rehabilitation of abandoned pits and quarries can be challenging given that information regarding these sites is often limited and/or unreliable. Another challenge of rehabilitating abandoned sites is lack of enough onsite topsoil that may limit the reuse options. Some unrehabilitated abandoned sites may present a liability to the owner due to the presence of steep embankments or deep holes or present a danger to neighbouring land uses and users. Moreover, some of these sites could become a location for illegal aggregate extraction or waste dumping (MNRF 2013). Proper communication and public engagement are important for the rehabilitation of legacy pits and quarries. This is because residents may come to accept them in their current state (i.e., after many years of dormancy/abandonment).

[3] Note that if the future land use is more sensitive than current use (for example if you change the land use from industrial to agricultural) a record of site condition (RSC) is generally required, especially for an unlicenced aggregate site.

Table a. A summary of different types of pits and quarries in Ontario

Land Tenure	Legal Authority	Status of Pit/Quarry Site	Regulation Instrument Type or Status	Regulation Instrument Sub-Type
Private Land	ARA - designated parts of Ontario	Current	Licence	Site Plan (Operations and Rehabilitation Plan)
		Surrendered (former)	Surrendered Licence	Municipal Bylaw – rezoned from ‘extractive’ zoning at discretion of landowner or municipality
		Abandoned	N/A –never under licence Revoked sites	Municipal Bylaw – rezoned from ‘extractive’ zoning at discretion of landowner or municipality OR never under ‘extractive’ zoning
	Planning Act - non-ARA designated parts of Ontario	Current	Municipal Bylaw – ‘extractive’ zoning	
		Former	Municipal Bylaw – re-zoned from ‘extractive’ zoning at discretion of landowner or municipality	
		Abandoned	Municipal Bylaw (never under ‘extractive’ zoning)	
Crown Land	ARA	Current, Surrendered or Abandoned	Permit except N/A for Abandoned	Site Plan except N/A for Abandoned

1.5. Excess Soil Management

It is estimated that 25 million m^3 of excess soil is generated in Ontario annually (MECP 2020a; OSPE 2016). Prior to the *On-Site and Excess Soil Management regulation (O. Reg. 406/19),* excess soil management in Ontario has been conducted under vague policies, regulations and standards, and soil often has been treated as a waste rather than a resource, or in some cases deposited without adequate consideration of potential adverse impacts. The management of excess soil has been frequently perceived as an ad hoc task associated with construction projects, with limited advance characterization or planning for how soil will be managed. A lack of a proactive plan to deal with excess soil often results in an increase in project time and cost. In fact, the cost of disposing excess soil in Ontario has increased over the past decade, an issue partly associated with a scarcity of reuse sites. In the absence of clear provincial regulation, some municipalities have been reluctant about receiving excess soil from beyond their boundaries. This reluctance is understandable given the large number of municipalities in Ontario and that many of them, especially relatively small ones, may not have the resources or expertise to create bylaws to limit the potential liabilities associated with poorly managed excess soil and/or to audit the incoming soil to ensure that it will not create a liability for the community as a result of adverse impacts arising from improper placement.

2. Literature Review

This section provides a synthesis of the technical literature regarding excess soil management with emphasis on pits and quarries as a reuse site. This section summarizes the key findings, and a more detailed discussion of some subsections is presented in the Appendices 1 to 5.

The content of this section is taken from three main sources:

1. Works developed in Ontario, which include regulations, guidelines and best management practices developed in Ontario by different bodies of government or others.
2. Works developed in other jurisdictions.
3. Technical literature, which includes books and peer reviewed articles.

These three categories and some examples of each are shown in Table b.

The literature review concludes with a discussion of potential gaps when considering the application of O. Reg. 406/19 and the Rules to a pit and/or quarry setting.

Table b. A summary of main sources reviewed during preparation of this Scientific Report.

Category	Subcategory	Works studied
Works developed in Ontario	Regulations and other legal requirements	• On-Site and Excess Soil Management (*O. Reg. 406/19*) • Rules for Soil Management and Excess Soil Quality Standards • Importation of Inert Fill for the Purpose of Rehabilitation (A.R. 6.00.03) • *Aggregate Resource Act* (*ARA*) • Records of Site Condition (*O. Reg. 153/04*) • Application Standards for Proposed Pits and Quarries
	Best practices and tools	• Beneficial Reuse Assessment Tool (BRAT) • The Canadian Urban Institute (CUI) Excess Soil Bylaw Tool • Aurora District Off-Site Fill Acceptance Protocol • MECP Best Management Practice for Excess Soil Management • Fill Quality Guide and Good Management Practices for Shore Infilling in Ontario • TOARC Best Practice Guidelines
	Scientific reports	• Rationale Document for Development of Excess Soil Quality Standards • Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario

		• Rationale Behind Criteria for Sediment Quality Guidelines • Ontario Typical Ranges Soil Chemistry Data
Works developed in other jurisdictions (jurisdictional overview)	Alberta	• Alberta Tier 1 Soil and Groundwater Remediation Guidelines • *User Guide to Pit and Quarry Rehabilitation in Alberta*
	British Columbia	• Reclamation and Environmental Protection Handbook for Sand, Gravel and Quarry Operations in British Columbia • Prevention of Site Contamination from Soil Relocation – Final Policy Direction Paper • Hydrogeological Assessment Tools for Modeling Transport of Metals in Groundwater
	Massachusetts	• Reuse and Disposal of Street Sweepings (Policy # BAW-18-001) • WSC 13-500 – Similar Soils Provision (310 CMR 40.0032(3)) Guidance • Interim Policy on the Re-Use of Soil for Large Reclamation Projects (Policy # COMM-15-01)
	Minnesota	• A Handbook for Reclaiming Sand and Gravel Pits in Minnesota • Best Management Practices for the Off-Site Reuse of Unregulated Fill • Draft Guidelines Risk-Based Site Characterization and Sampling Guidance • Soil Sample Collection and Analysis Procedures, Petroleum Remediation Program
	New Jersey	• Fill Material Guidance for SRP Sites • New Jersey Department of Environmental Protection. Site Remediation Program: Monitored Natural Attenuation Technical Guidance.
Technical literature	-	• Books, peer review articles and technical reports presented in the reference list (Section 7.0)

2.1. Works Conducted in Ontario

This section is devoted to reviewing works concerning excess soil and pit and quarry rehabilitation in Ontario. These works include regulations, standards, best practices, and research projects. This section highlights The *On-Site and Excess Soil Management Regulation (O. Reg. 406/19)*, also referred to as the Excess Soil Regulation, and the *ARA*. These regulations are enforced, respectively, by the MECP and MNRF. The implementation of excess soil regulations is not possible without understanding other related regulations and standards. Therefore, a part of this section is devoted to standards and regulations cited by *O. Reg. 406/19*. Similarly, discussion of regulations, standards, and protocols for the rehabilitation of pits and quarries that complement the *ARA* are also provided.

2.1.1. On-Site and Excess Soil Management

On-Site and Excess Soil Management (*O. Reg. 406/19*), is a regulation under the *Environmental Protection Act (EPA)* (Government of Ontario 2019). This regulation defines excess soil as "*soil, or soil mixed with rock, that has been excavated as part of a project and removed from the project area for the project*."

Section 2 of the regulation lists conditions for non-application of the regulation. One of these conditions is the excavation of consolidated or unconsolidated aggregate within the meaning of the Aggregate Resources Act, including the use and production of recycled aggregate in the pit or quarry. The regulation applies when an aggregate site will be a reuse site, and will be accepting excess soil for beneficial reuse, not a source site.

On-Site and Excess Soil Management Regulation designates excess soil as waste and outlines criteria in Section 3 of the regulation that if met, will lift the waste designation. One of the conditions is placement of excess soil for beneficial reuse at a reuse site governed by instruments such as a licence or a permit under the *ARA*, a bylaw passed under Section 142 of the *Municipal Act*, or a site-specific instrument under an Act of Ontario or Canada that may regulate the quality or quantity of the soil. The regulation defines a reuse site as *"a site at which excess soil is used for a beneficial purpose…"*. The regulation defines beneficial purposes under subsection 5(1), paragraph 3, including *"achieving the grade necessary, for… a project governed by an instrument issued by a public body"* or *"the placement of fill to assist in the rehabilitation of the reuse site"*. In circumstances where reuse sites are governed by an instrument, Section 4 of *O. Reg. 406/19* must be reviewed to determine where soil quality and/or quantity specifications in the instrument (and its governing authority) may take precedence over the excess soil regulations.

Section 4 of the regulation allows for other instruments to define quality standards that are different from the regulation standards, and/or to specify limits on the quantity of soil a site can accept. When an instrument imposes a less stringent requirement than the excess soil standards, the instrument quality requirement must be met. If the instrument imposes a quality standard that is equivalent to, or more stringent than, the excess soil quality standards, the MECP will enforce to the *O. Reg. 406/19* generic quality standards or site-specific standards developed through the BRAT (subsection 5(1)). Therefore, the instrument authority (e.g., the MNRF or a municipality) may still enforce to a more stringent standard when specified by an instrument under their jurisdiction. Furthermore, when an existing site instrument (e. g., a site plan) defines a more stringent soil standard, the existing instrument takes precedence (i.e., O. Reg. 406/19 does not supersede existing instruments). Similarly, where an instrument specifies a maximum amount of excess soil, this takes precedence over the *O. Reg. 406/19* default, which is that material deposited must not exceed the quantity necessary for the beneficial purpose identified.

2.1.2. Rules for Soil Management and Excess Soil Quality Standards

The *Rules for Soil Management and Excess Soil Quality Standards* document (MECP 2020b) is adopted by reference under *O. Reg. 406/19*. This document includes Part I, *Rules for Soil Management* also known as *Soil Rules,* and Part II, *Excess Soil Quality Standards* or *Excess Soil Standards*.

Reviewing the rules document may be informative to someone receiving soil at a pit or a quarry for beneficial reuse during rehabilitation, to become familiar with the minimum level of detail that should be provided by the source site. The Rules document may also be referenced to identify/derive applicable soil quality standards and/or placement requirements (e.g., salt impacted soil) for material to be beneficially reused (see Section 8.1.1), if not specified elsewhere in a site instrument.

The Rules place emphasis on the source site, and while they do not specify minimum requirements for testing or sampling at the reuse site, some understanding of baseline conditions at the receiving site is required when applying reuse rules for specific circumstances (e.g., determining if a site is environmentally sensitive, or for determining whether an excess soil quality standard is deemed to be met due to the local background concentration). An overview of *Rules for Soil Management and Excess Soil Quality Standards* is provided in Appendix 1.

2.1.3. Rationale Document

The *Rationale Document* is a document prepared by the MECP that discusses the underlying assumptions for deriving the soil quality standards. The document discusses the differences between assumptions used for developing *O. Reg. 406/19* and *O. Reg. 153/04* and their associated standards. It explains the risk assessment approach used and pathways analyzed to derive the generic standard tables.

One of the main differences between *O. Reg. 153/04* (also known as the *Brownfields Regulation* and associated site condition standards) and the excess soil quality standards is the consideration of the potential effects of larger volumes of impacted soil (MECP 2020c). The excess soil quality standards account for this by developing volume independent standards. The brownfield site condition standard assumes a spill to a 13 x 13 x 2 m (<350 m^3) volume of soil, but volume independent standards are not limited to this volume. Therefore, two sets of standards are available: small volume, which is the same as *O. Reg. 153/04* (for coarse soils), and volume independent (for quantities >350 m^3). Some other important differences are as follows:

- Soil to Groundwater to Indoor Air Pathway (S-GW2)
    - Unlike the brownfield scenario, in excess soils, the soil indoor air (S-IA) component value may not be protective of the S-GW2 component value. This means that the threshold for the latter might be lower and needs to be evaluated. In addition, groundwater sampling may not be available, and therefore cannot be used as a direct line of evidence to address this concern. Otherwise, contaminants may migrate through this pathway and adversely affect building occupants living above ground as a result of vapour inhalation.
- Soil Texture
    - While some human health component values (e.g., S1, S2 and S3) are independent from soil texture, others that include vapour transport or leaching are affected by this factor. The component values for some of these pathways, such as S-IA or S-OA, may be reduced by more than 50 per cent for coarse textured soil compared with medium and fine textured counterparts. Given that excess soil is a disturbed soil and has a larger vapour permeability and porosity, the generic excess soil quality standards were developed based on coarse textured soil.
- Changes to Methods of Component Value Derivation
    - All odour-based components were rederived for excess soil given that the approach for the development of the brownfield soil standard included some simplifying assumptions.
    - In the excess soil standards, electrical conductivity (EC) and sodium adsorption ratio (SAR) are considered for soil below 1.5 metres. The reason is that, unlike the brownfield redevelopment, groundwater samples may not be available to be used as a direct line of evidence to address this concern. The standards can be deemed to be met if the conditions of page 37 (or Section D.1.(3) of Part I) of *Soil Rules* are satisfied.
- Leachate Analysis
    - Leachate analysis is not mandatory for excess soil when the volume is less than 350 m^3. However, leachate analyses and comparison to leachate

screening levels is generally required when (1) the volume independent standards as prescribed by the standards with a superscript 'a' are applied and (2) excess soil contains a chemical that is identified as a contaminant of potential concern. Additional requirements as to when leachate is (or is not) required are provided in Section A.1.(7) of Part II of the Rules Document (MECP 2020b).

The *Rationale Document* recognizes that there are pathways not considered in the development of excess soil quality standards and these are consistent with the rationale for the development of the *O. Reg. 153/04* standards as follows:

1. Consumption of garden products grown at a reuse site[4].
2. Exposure associated with several agricultural land use scenarios including irrigation water, livestock watering, dust inhalation, consumption of dairy products made at a reuse site and consumption of livestock or plants cultivated at a reuse site.
3. Protection of reptiles and amphibians.

Consistent with *O. Reg. 153/04*, pathways not considered in the development of the generic excess soil standards may be incorporated into a site-specific risk assessment exposure assessment, based on the conceptual site model for a specific property.

2.1.4. Beneficial Reuse Assessment Tool (BRAT)

The *BRAT* is an Excel-based spreadsheet model developed by the MECP, which may be used when a QP determines that generic conceptual model assumptions are applicable. The BRAT allows the user to adjust default inputs based on site specific characteristics to develop e site-specific excess soil quality standards by considering the physical characteristics of the excess soil, the reuse site and the soil-to-groundwater exposure pathways through leachate analysis (MECP 2020d). In such cases, practitioners may deviate from MECP generic standard tables and develop site-specific standards that are protective of human health and the environment. Some of the important physical attributes that can be modified in the BRAT input are:

- Hydraulic conductivity of the aquifer
- Soil texture of the reuse site
- Soil texture of the excess soil
- Soil fraction organic carbon (foc) and aquifer foc
- Site specific layout of excess soil
- Depth of water table

[4] Consistent with *O. Reg. 153/04*.

- Number of frozen ground days per year
- Distance from surface water body

2.1.5. Aggregate Resource Act (ARA)

Aggregate pits and quarries on Private Land in designated parts of Ontario and all Provincial Crown Land in Ontario are regulated under the *ARA* (MNRF 1990). The MNRF summarizes the purpose of this Act in four points: management of the aggregate resources of the province, the regulation of aggregate operations on Crown and designated private lands, the mandate for rehabilitation of land, and the mitigation of adverse environmental effects. Therefore, pit and quarry rehabilitation is one of the main purposes of this Act.

Passed in 1990, the *ARA* replaced a series of Acts and regulations, most notably the *Pits and Quarries Control Act* or *PQCA* (Government of Ontario 1980). The *PQCA* shifted the regulation authority from municipalities to the Province, and this was continued under the *ARA* and made applicable to more private land in Ontario. Under the *ARA*, a pit or quarry owner is required to apply for a licence. All applications must include a site plan that details the operations and plans for rehabilitation of the site. Different types of pits and quarries may have different requirements for a site plan. The *ARA* includes two main types of pit and quarry licences depending on their annual production: Class A refers to a site that removes more than 20,000 tonnes of aggregate annually and Class B removes 20,000 tonnes or less of aggregate annually. The requirements for the application of each category are different and are summarized in Section 2.1.7 of this report.

Following rehabilitation of a pit or quarry in accordance with the site plan and regulations, the licensee can request the MNRF to accept a 'surrender' of the licence. The pit or quarry becomes 'surrendered'[5] after the MNRF accepts the surrender of its licence. Once the licence is surrendered, the MNRF has no authority over the pit or quarry. If fill placement is contemplated after the licence has been surrendered, then approvals must be obtained through a Site Alteration By-Law permit or planning approval process. All fill operations and site alterations of an unlicenced quarry must comply with the existing municipal bylaws.

2.1.6. Importation of Inert Fill for the Purpose of Rehabilitation (A.R. 6.00.03)

A.R. 6.00.03 is a policy developed by MNRF for using inert material in the rehabilitation of ARA-licensed pits and quarries. The policy cites *Regulation 347* of the *Environmental Protection Act* (*EPA*) (Government of Ontario 1990), which defines inert fill as "earth or rock

[5] Also called unlicenced

fill or waste of a similar nature that contains no putrescible material or soluble or decomposable chemical substance" (Government of Ontario 1990).[6] The policy indicates that soil meeting *O. Reg. 153/04* Table 1 standards is deemed to meet the definition of inert fill.

Prior to 1997, the regulations under the *ARA* allowed the importation of soil for rehabilitation without requiring a site plan amendment where the availability of material for rehabilitation at the site was insufficient. The policy notes that because of the earlier regulation remaining silent on importation of material, many site plans remained silent on the importation of material. However, the regulation was revised in 1997 and subsequent licence applications were required to follow the site plan standards of the Aggregate Resources of Ontario Provincial Standards (AROPS) which requires the site plan to identify whether topsoil or inert fill is to be imported for the purpose of rehabilitation (MNRF 2014).

The policy notes that if an existing site plan does not discuss the importation of inert fill to achieve necessary slopes defined in the site plan, a minor site plan amendment can be made to facilitate the importation of inert fill providing that there is insufficient topsoil and/or overburden available at the site.

If an existing site plan has been approved to backfill the entire site, or a portion of the site to original grade, the licensee has the authority to proceed provided that the material meets *O. Reg. 153/04*, with exceptions for EC and SAR standards as follows:

- The surface soil (i.e., soil within 1.5 m of the natural terrain) should meet the standards for SAR and EC, as prescribed by *O. Reg. 153/04* Table 1 standards. These requirements are not mandatory for subsurface soil (>1.5 metres beneath the soil surface), because soil at this depth is not anticipated to result in an adverse impact to plants.
- Proper monitoring or sampling of truck loads or the source occurs.

If backfilling to the original grade is not identified in a previously approved site plan, and the licensee wishes to backfill the entire site or a portion of it, they must complete a major site plan amendment. The new site plan must reflect the change in the rehabilitation process and describe the importation of material.

The policy provides sample wording for site plan conditions which reference material testing at the source and/or random sampling of imported material, with the results being available to the MNR upon request.

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[6] The regulation continues: On January 1, 2021, the definition of "inert fill" in subsection 1 (1) of the Regulation will be amended by adding "but does not include excess soil".

2.1.7. Application Standards for Proposed Pits and Quarries

The MNRF defines eight categories of pits and quarries depending on their annual production and excavation depth (whether it is above or below the water table). These eight categories are shown in Figure a. Pit and quarry owners must develop their site plan according to these categorizations, as the site plan for each category has its own requirements.

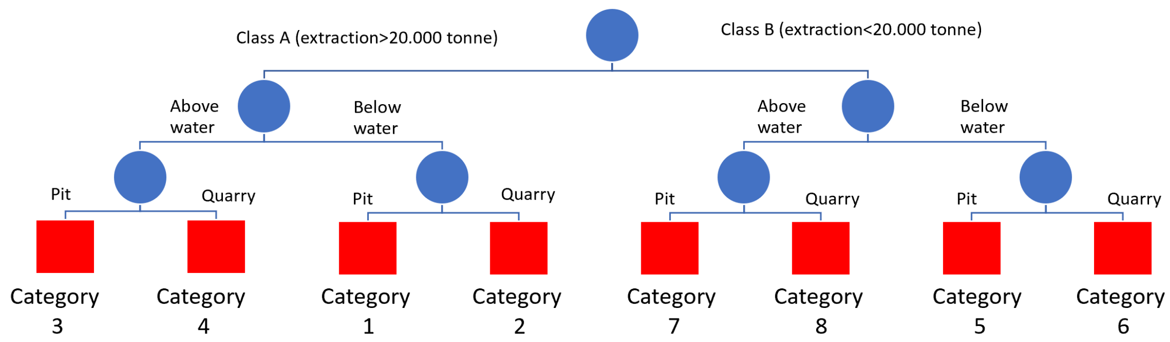

Figure a. Categories of applications for pits and quarries developed by the MNRF

The requirements for the rehabilitation of pits and quarries in these categories are similar with some minor differences. The most important difference is imposed by the water table. For categories where excavation is permitted to go below the water table, being categories 1, 2, 5 and 6, there is a need to show the *"maximum predicted groundwater table* in the drawings submitted along with the application. Sites within categories 3 and 7 are pits, which are restricted to extracting aggregate material 1.5 metres above the water table, and sites within categories 4 and 8 are quarries, which are restricted to extracting aggregate material 2.0 metres above the established water table. For these sites, the site plan must show that operations will occur above the water table (1.5 metres for pits and 2 metres for quarries), but not necessarily indicate where the water table is. Recognizing this difference can be helpful in developing tailored guidelines for the rehabilitation of each category.

2.1.8. The Canadian Urban Institute (CUI) Excess Soil Bylaw Tool

The Canadian Urban Institute (CUI) has prepared an online tool to help municipalities regulate the use of excess soils through alteration or fill bylaws (Canadian Urban Institute 2016). The tool was developed based on the MECP (2016) *Guide for Best Management Practices* and updated according to *O. Reg. 406/19*. It provides municipalities with example language to develop or change bylaws related to excess soil management. In this tool, the main issues of excess soil management are discussed, and examples of the 15 most common sections of the bylaw are presented for each issue (if applicable).

This tool may be considered by municipalities in how they regulate unlicenced pits and quarries. This would assist owners of unlicenced pits and quarries to identify potential bylaw requirements that may apply to their sites. The bylaw tool was developed before *O. Reg. 406/19* was released, but its current version (Excess Soil By-Law Tool 2.0) incorporates the new regulation.

2.1.9. Aurora District Off-Site Fill Acceptance Protocol

The *Aurora District Off-Site Fill Acceptance Protocol* was developed by the MNRF (2007) according to the framework of the *ARA* and A.R. 6.00.03 to address concerns related to the rehabilitation of pits and quarries, including illegal dumping, in the Aurora District.

According to the *Aurora District Off-Site Fill Acceptance Protocol*, the licensee is mandated to place only "*acceptable fill*" at a licenced aggregate site. Topsoil may be imported for the final cover. This protocol requires the licensee to have a QP (called a reviewing professional in the protocol) on site to assess whether the incoming material is acceptable. The protocol defines *acceptable fill* as materials without any putrescible content that meet the following conditions (MNRF 2007):

a) *"Soil/earth that meets Table 1 standards and passes a slump test, as outlined in the General Waste Management Regulation (O. Reg. 347 pursuant to the EPA), as may be amended; or"*

b) *"Rock; brick (without coating and free from contamination); and concrete (without coating or exposed rebar or containing cement fines and free from contamination)."*

The protocol dictates that anyone who wants to ship off-site material from a "*generating location*" to a licenced aggregate site must submit an application and have written approval from the licensee that confirms the material's compliance with the protocol. The *generating location* application must include: the name and location of the generating site; one or more reports prepared by a QP detailing the history of the generating location and its past and present use; description of the material to be shipped and the processes involved in its generation; the results of a comprehensive soil sampling and testing program and a rationale for the sampling locations and parameters selected; a statement from the QP confirming that the shipped material satisfies the requirements of the protocol and is suitable for placement at the aggregate site; the expected volume of material and the estimated time frame in which the material will be shipped.

The QP at the reuse site, "the Reviewing Professional", must consider the results of the sampling program and whether the application should be accepted. Among the criteria upon which the decision should be made are the validity of sampling and analyzed parameters and the suitability of the QA/QC program for the generating location. The QP must communicate their conclusion to the licensee in writing, informing them of their decision to approve or reject acceptance of the material at the aggregate site. The licensee must issue bills of lading to approved generating locations and track them through a master list linking the generating locations to haulage companies and site assessment reports. All documentation detailing the approval and tracking of material must be maintained at the aggregate site.

The protocol also describes required site controls. The licensee must fence the site to prevent unauthorized access and must be staffed by persons appropriately trained by the reviewing professional. The licensee is required to identify a location where unloading and filling will occur. The fill locations must be tracked and documented daily using a locational grid tracking system and records made available to the MNRF if requested. Arriving trucks are allowed to enter after they present a complete and authorized bill of lading that has been cross-referenced against the master list of issued bills of lading. Untested or undocumented loads must be rejected at the gate. In addition to checking documents, the gatekeeper must conduct a visual inspection for unacceptable material or evidence of chemical impact, such as unusual odours or staining. Loads with such issues must not be permitted access. Repeated rejections must lead to an investigation of the generating site, and its results must be shared with the MNRF. After accepting the load, the gatekeeper must direct the truck to a determined location for placing the fill. Records of arriving trucks, including rejected loads, must be retained. Once a load is approved, the driver must be directed to a specific fill placement location and the assigned location noted on the bill of lading. The protocol prescribes requirements for daily logging of trucks and loads accepted/rejected and where soil was placed in accordance with the tracking grid. Retention of all documents is required until the licence is rehabilitated and surrendered.

QA/QC samples of the received materials should be collected by the Reviewing Professional for every 10,000 m^3 of fill. Collected samples must be sent to a laboratory for further analysis. Inorganic parameters, volatile organic compounds, polycyclic aromatic hydrocarbons, and petroleum hydrocarbons are among the parameters that must be tested. The Reviewing Professional can add parameters deemed necessary based on the information provided by the generating site. Should any unacceptable materials be found at the site, the licensee must locate and stockpile them for further action, including analysis and removal. All actions and information must be recorded and reported to the MNRF.

The protocol also explains the requirements for groundwater monitoring and topsoil importation. The MNRF, in consultation with the licensee, decides if a groundwater monitoring program is required. The groundwater program scope will identify the frequency of sampling, wells to be sampled, parameters to be assessed for, standards to be referenced, criteria for confirmatory testing when an exceedance is identified and reporting to the MNRF. Implementation of the groundwater sampling program is to be completed under the supervision of the Reviewing Professional.

Regarding topsoil, topsoil importation requests must be accompanied by sufficient evidence to demonstrate the need for topsoil for rehabilitation purposes along with site sketches showing the exact location in which the topsoil will be placed. Other necessary pieces of information are the description of the generating site, the volume of topsoil anticipated, anticipated timeframe and sufficient proof of compliance with the site plan. The imported topsoil must be used as quickly as possible for final cover. If deemed by the MNRF, additional testing may be required for topsoil.

The protocol notes that it was developed for larger scale fill importation operations and may be altered in co-operation with the MNR where special circumstances exist, or the importation of fill operation is smaller in size.

2.1.10. MECP Best Management Practice for Excess Soil Management

The MECP developed a best management practice (BMP) for excess soil management (MECP 2016), which preceded *O. Reg. 406/19*. The BMP provides brief guidance about handling of excess soil at the generating site, during transportation, during temporary storage, and at the reuse site. It does not apply to the products of pits and quarries, but pit and quarry owners may reference the BMP for soil importation during rehabilitation. The BMP encourages contractors and site owners to reuse the excess soil at the generating site, if possible. Also, those who require soil are encouraged to use excess soil from neighbouring projects to minimize greenhouse gas (GHG) emissions and impact on virgin soil sources.

The BMP encourages site owners to hire QPs, as defined by *O. Reg. 153/04*, and emphasizes the important role of QPs in beneficial reuse. Soil importation must be performed after considering the history of the source site, the quality of the soil at the reuse site, and the purpose of reuse.

Generally, the imported soil should not degrade the quality of the reuse site. For example, a new contaminant should not be introduced to the reuse site because of importation. The BMP explains the necessary sampling and analysis by making references to *O. Reg. 153/04*.

The BMP recommends that reuse site owners/operators engage in public consultation prior to placement of soil to ensure that the community is aware of the proposal to import soil, and to ensure that community comments are received and considered in the final design and operation of the receiving site. These communications may be made along with other public communication activities (e.g., activities required for the purpose of zoning or permitting through municipal bylaws). Furthermore, the BMP recommends early and proactive engagement with First Nations and Métis communities, especially those potentially impacted by soil importation.

The BMP recognizes that soil management activities may contribute to the introduction of invasive species and gives several examples of such species that can be spread or moved with excess soil: European fire ants, Japanese knotweed, phragmites, giant hogweed, garlic mustard and dog-strangling vine. It also reiterates that excess soil may contain plant parts (e.g., roots), seeds, and invertebrates (e.g., European fire ants). According to the *Invasive Species Act* (Government of Ontario 2015), invasive species are defined as *"a species that is not native to Ontario, or to a part of Ontario".* Knowing that pit and quarry rehabilitation usually entails moving large volumes of soil over long distances, it is important to consider the risk of invasive species during the rehabilitation phase.

In addition to these requirements and recommendations, the BMP puts forward a set of best management practices for management of excess soil. It also encourages those who are involved in the management of excess soil consider applicable industry codes of practice. Some of the most important best practices outlined by the BMP are as follows.

- Transportation: It is recommended that owners/operators of excess soil sites have a *Traffic and Transportation Management Plan.* This plan should include the location and configuration of site entrances, logistics of truck queuing and parking, dust control and mud-tracking prevention, truck cleaning considerations, and haul routes between the source site and the reuse site (and temporary storage sites if applicable). This plan must be prepared in consultation with local upper-tier and lower-tier municipalities.

- Municipalities and Conservation Authorities: Municipalities should proactively evaluate whether there are areas within their jurisdiction not suitable for receiving excess soils. Such information must be built into their site-alteration bylaws. Furthermore, they are encouraged to establish a soil tracking system, in partnership with Conservation Authorities, to identify sources of excess soil creation and possible reuses sites.

- Reuse site: Before the reuse site is established, the owner should hold pre-consultation with local municipalities, Conservation Authorities and local First Nations and Métis communities. This should be followed by a public consultation to ensure that local community and landowners are aware of the proposal and have an opportunity to voice their comments. Next, the owner should hire a QP to assess the suitability of the location as a reuse site. After this assessment, the QP must prepare a *Fill Management Plan*, which includes the following information:

- Procedures to preclude the introduction of invasive species
- Copies of any documentation about municipal/provincial permits or those issued by Conservation Authorities
- Identification of appropriate soil quality and soil types for excess soil importation
- Dust and noise control measures
- Site security measures
- Preparation of *Traffic and Transportation Management Plan*
- Protocol for incoming loads: Each incoming load must have documentation signed by the QP at the source site (the requirements for sampling at the source site was explained above in the section about *Soil Rules*). All incoming loads must go through a visual and olfactory inspections checking for evidence of odour, staining, or debris. The plan must include contingency measures for load rejections.
- A record retention system: This system may record all the following information about each incoming load: date and time of arrival of the load; name and location of the source site; the volume of excess soil received; information about documentation received from the source site QP, including soil analytical results; confirmation by the reuse site QP; information of rejected loads; and documentation to the source site owner and QP when excess soil is received.
- Clear signage at the site (containing a contact name and hours of operation)
- Stormwater Management Plan
- Erosion control and run-off control measures
- Sampling protocols: This includes developing audit sampling protocols based on soil volume and source site history and a clear action plan for rejected loads.
- Soil placement/segregation protocol: Soil from each source site should be placed separately, such that it can be assessed easily if required.

2.1.11. Fill Quality Guide and Good Management Practices for Shore Infilling in Ontario

The *Fill Quality Guide and Good Management Practices for Shore Infilling in Ontario* is a set of optional guidelines developed by the MECP to protect aquatic ecosystems by protecting the quality of the sediment and water in areas in the vicinity of shore-infilling activities. These guidelines are discussed here because they are used in the development of excess soil standards (specifically in the development of Tables 8.1 and 9.1[7] for the protection of aquatic life), and they could be potentially applied to a pit or quarry setting. These guidelines, which are also known as lakefilling guidelines, divide the material used for shore infilling projects into Contaminated and Uncontaminated Fill. Uncontaminated Fill may be placed directly into the open water, but contaminated material must be confined within a geological (or artificial) impermeable barrier such as a dyke (such structures must be able to withstand a one-in-one hundred year's storm). To assure the quality of the receiving material the guidelines prescribe the following set of tests:

- Bulk chemical tests for 8 metals and organic compounds including polychlorinated biphenyls (PCBs), arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, total organic carbon, and total phosphorus.
- A Receiving Water Simulation Test which determines whether or not organic compounds, such as PCBs, leach from the fill.
- Further tests which may be requested by a regulatory agency on a case-by-case basis. The tests may include additional chemical analyses for nutrients, other metals, and organic compounds listed in the *Provincial Sediment Quality Guidelines.*

The document enumerates the conditions for determining that fill material is “uncontaminated”. Such material must satisfy the *Lowest Effect Level of the Provincial Sediment Quality Guidelines* for organic parameters and either the Lowest Effect Level or the background level of the sediment for metals and for organics (Tables 3 and 4 in Fletcher et al.(2008)). Furthermore, Unconfined Fill must be free of substances which could bioaccumulate in organisms over time and of substances which could form unpleasant deposits (e.g., scums). Material that fails the foregoing tests may qualify as Confined Fill if it satisfies the requirements for Confined Fill.

During the infilling operation, all necessary measures must be taken to minimize turbidity and to reduce the loss of fill. Such necessary actions may include placing fill only during calm/low

[7] Table 8.1 and 9.1 considered brownfield sediment standards as part of its derivation to address concerns regarding movement of soil to a nearby surface water.

flow periods and protecting exposed areas of the shore infill project from severe storms by dykes and enclosures to preclude erosion.

When developing the *Good Management Practices* the intention was that their criteria will address aquatic environmental concerns sufficiently so that the quality of fill and its placement method will also satisfy additional criteria, which are set to be protective of aquatic life across the province, including:

- The 1994 Ontario Ministry of the Environment and Energy water quality management goal; "To ensure that the surface waters of the province are of a quality which is satisfactory for aquatic life and recreation", and
- The 1993 Ministry of the Environment (Persaud, D., R. Jaagumagi, and A. Hayton) goal for the protection and management of aquatic sediment quality in Ontario; "to protect the aquatic environment by setting safe levels for metals, nutrients (substances which promote the growth of algae) and organic compounds".

Regarding the use of the *Fill Quality Guide and Good Management Practices for Shore Infilling,* it was intended to be used in the following types of projects (there is no mention of pits and quarries):

- Shore stabilization
- Construction of piers, groynes, docks and causeways
- Construction of breakwaters and Confined Disposal Facility perimeter walls/structures
- Large-scale projects for recreational purposes (e.g., Bluffers Park)
- Beach nourishment, enhancement or creation

The document provides some best practices regarding the time and method of fill placement. For standing water in areas subject to storms, waves, and flooding, shore filling should only take place during June to August as that is known as the calm period in Ontario. For running water, filling should be carried out during periods of low flow.

To reduce the risk of loss of material due to erosion the exposed face of the placed fill must be as small as possible. When Confined Fill is used, the outer layer must be covered with a structure made of inert material such as concrete or stone.

2.1.12. Methods Used for Establishing Sediment Quality Guidelines in Ontario

The *Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario* (Fletcher et al. 2008) states that a combination of the approaches discussed in Appendix 4 were used rather than a single method. Since there is currently a significant lack of data for use in the development of sediment quality guidelines based on the Spiked Bioassay

Approach, the Screening Level Concentration (SLC) Approach offers the best means of developing such guidelines for the protection of the benthic biota. Based on the discussed advantages and disadvantages of different approaches to sediment guideline development, these approaches were used as follows:

- Partitioning approaches have been used to establish no-effect levels for the protection of water quality and uses, as well as health risks associated with humans and wildlife through the consumption of fish.
- The effects-based methods (e.g., AET, SLC and bioassay) are being used to develop guidelines for the protection of benthic communities. Based on the currently existing data in Ontario, only the SLC approach is of immediate use.
- Background concentrations have been used as quality criteria where adequate data do not exist for other approaches or where the methods used are inappropriate for the type of chemicals. Background concentrations provide a practical safe lower limit for management decisions.

In the future, when more information about standardized sediment bioassay techniques become available, the protocol may need to be revised to accommodate these approaches. However, it is unlikely that these techniques will ever replace field-based approaches (e.g., the SLC) because they always require some field validation of laboratory results.

2.1.13. Ontario Typical Ranges Soil Chemistry Data

The *O. Reg. 153/04* Table 1 background standards were developed based on the *Ontario Typical Ranges (OTR) Soil Chemistry Data* (Ontario Ministry of Environment and Climate Change 2016).

The data for this project was mostly collected in two studies: inorganic matters in 1991 and volatile organic compounds in 2009. This project was an effort to address the limitations in a previous guideline named Upper Limit Normal (ULN), which was established in 1989 (Ontario Ministry of Environment and Climate Change 2016; Ontario Ministry of the Environment 1989). Guidelines developed prior to the 1980s were deemed to be less than satisfactory, as they were too subjective and could not be represented by a statistical model (Ontario Ministry of Environment and Energy 1994; Ontario Ministry of the Environment 1989).

The *OTR* uses the word ‘typical’ instead of ‘normal’, which does not imply acceptable. It also uses the word ‘range’ instead of ‘upper limit’. The differences between *OTR* and ULN are not limited to naming though. The ULN uses the mean plus three standard deviations to determine 99.9 per cent of the population, but this is only valid when the data is normally distributed. The data used for establishing the ULN guidelines was not necessarily normal, and thus the determined values do not represent 99.9 per cent of the population. The normality claim is addressed in this report for a few chemicals (see Appendix 3). Furthermore, this ULN guideline was developed using a minimum of 30 samples (Ontario Ministry of the Environment 1989). This number is not sufficient for normality because, based on experience, for soils in Ontario the number of samples required to be within 10 per cent of the mean 90 per cent of the time ranges between 100 and 200 samples (Ontario Ministry of Environment and Energy 1994).

Knowing that the data is not necessarily normally distributed, the *OTR* guidelines rely on the real distribution of the data instead of a parametric statistical analysis. The *OTR* method uses a variable called OTR_{98}, which represents the 97.5th percentile of the data (which corresponds to mean plus two standard deviations in a normal distribution). The upper 2.5 per cent are excluded to account for outliers.

The later versions of the *OTR* data and method are more comprehensive. The current dataset includes 485 samples for inorganic material. Furthermore, in the later versions the MECP recognizes the diversity in Ontario's geology. For example, the Rationale Document developed for *O. Reg. 153/04* (Ontario Ministry of the Environment 2011) states that:

> *"…public consultation process for the Guidelines in 1994 resulted in the recommendation that background numbers should take into account the natural occurring sampling variability. This is accounted for through adding two within site standard deviations of the replicated samples between the upper and lower confidence limits of the OTR_{98} (highest OTR_{98} value if there OTR values were different for different regions.) to the OTR_{98} to produce the background numbers in Table 1. However, this allowance for sampling variability is not permitted to increase a background number to beyond an effects-based number."*

It further adds that:

> *"Although for the present update, MOE is using the same methodology that was used previously, consideration should be given in future updates to using geo-regional approaches and matching statistical methods if sufficient data exists at that time."*

The *Soil Rules* and *O. Reg. 406/19* allow the reuse of soil with naturally elevated parameters in areas with similar levels. Subsection 2(3) of Section D of *Soil Rules* (MECP 2020b) provides the rules and conditions under which soil is deemed to meet an excess soil quality standard when the parameter is naturally occurring at the reuse site and within the naturally occurring range of concentrations typically found in soil within the area of the reuse site. However, some challenges remain:

1) The MECP and District Offices review requests by proponents for demonstration of naturally occurring elevated concentrations on a case-by-case basis. However, proponents often lack the ability to survey the range of locations required to adequately demonstrate regional background range and the objectivity of this data is open to question by the MECP.
2) Rock, particularly weathered rock that can end up being more like soil when it is excavated (e.g., shale, sandstone, and limestone). The excess soil regulations clarify that excess soil includes soil mixed with rock, and/or crushed rock. The *OTR* background values were based on relatively shallow, near surface soils. Therefore, further data collection to characterize the chemical properties of crushed rock, and education about these differences are required. QPs typically understand regional variability in soil because, unlike rock, soil is commonly compared to reference standards.

2.1.14. Regional Variability in Background Concentrations

The distribution of *OTR* data, discussed in Appendix 3, suggests that background concentrations in Ontario may be more variable than currently modelled. The findings of Sterling et al. (2017) confirm this statement and suggest that the concentration of multiple metals in Eastern Ontario are naturally higher than the Table 1 reference standards. Other examples of similar studies are presented in this section. In a study conducted by Knight et al. (2012) on the geochemistry of a Champlain Sea aquitard, the mean of barium concentration is 364 ppm, which exceeds the Table 1 agricultural and RPI reference standards.

Studies on geological formation of Southern Ontario are available as well. Coffin et al. (2017) studied the litho-stratigraphic and sedimentological data collected from a 151.8 metres deep borehole sunk near Rice Lake, in Southeastern Ontario. They reported naturally occurring concentrations of multiple elements including barium, calcium, copper, nickel, zinc, and vanadium from multiple samples exceeding the Table 1 standards. For example, the concentration of barium exceeded the Table 1 limit for all land uses throughout the entire borehole with some concentrations exceeding 600 ppm. The concentration of nickel varied between 30 to 90 ppm, which generally exceeded the Table 1 agricultural land use standard and, in some cases, the RPI land use standard.

Another study in Southern Ontario, conducted by Knight et al. (2016), analyzed the geochemical properties of 96 samples from a 127 m borehole drilled near Oshawa. The average concentrations they reported (in ppm) were barium, 839; arsenic, 24; vanadium, 164; and nickel, 84. All these concentrations exceed Table 1.

The example studies discussed in this section were completed with support from the Geological Survey of Canada, which recently published more data in this regard (Sharpe et al. 2019). The availability of such studies can contribute to an improved regional understanding of background conditions and perhaps lead to the eventual development of Table 1 standards that are region specific.

2.1.15. TOARC Best Practice Guidelines

The Ontario Aggregate Resources Corporation (TOARC) has prepared a set of best practice guidelines for the rehabilitation of pits and quarries in Ontario (Savanta Inc. 2008). These guidelines primarily focus on minimizing the impact of pit and quarry rehabilitation on animals and plants, especially species at risk. Therefore, it includes a discussion on regionally and provincially rare species and threats posed to them by the aggregate industry. Examples of these threats include the destruction or degradation of habitats, the introduction of invasive species, direct or indirect harm or disturbance, and alteration of ecological dynamics.

Another part of the TOARC best practice document is devoted to the activities that could be carried out to benefit species at risk during rehabilitation. Examples of such activities are proactive inclusion of the needs for species at risk in rehabilitation plans, the creation of temporary habitats during the extraction phase, and consultations with experts, such as local MNRF staff.

The guidelines enumerate the different types of habitats that have potential for rehabilitation in pits and quarries. The list includes alvars, cliffs and talus, caves and cracks, cultural meadows and thickets, fens, forests, marshes and open waters, rock barrens, sand barrens and dunes, swamps, and tallgrass prairies and woodlands. For each type of potential habitat, its physical and biological characteristics (e.g., type of soil, vegetation, and hydrology) are discussed. In addition, some general guidelines are given to determine how these vegetation types may be rehabilitated. The guidelines provide suggestions about potential candidate species at risk for each habitat. These species must be attracted to restored sites whether by passively allowing them to colonize or by active introduction.

The guideline includes the steps that must be taken to ensure post-rehabilitation sustainability. These actions are mostly around monitoring and reporting the outcomes of rehabilitation, which includes the survival of species and the overall diversity (and density) of native species. Some of the methods for monitoring performance indicators include:

- Photographic inventory (for before, during and after rehabilitation)

- Surveying of the topography and checking its compliance with design
- Surface and groundwater monitoring
- Measuring vegetation characteristics such as distribution, density, and diversity using methods such as the *Floristic Quality Index* (Oldham et al. 1995)
- Monitoring and management of invasive species

2.2. Jurisdictional Overview

This section includes a summary of the findings of a jurisdictional scan of the existing regulations, standards and best practices about excess soil and aggregate pits and quarries. Details for each jurisdiction are presented in Appendix 2. The studied jurisdictions include Ontario, New Jersey, Minnesota, Massachusetts, British Columbia, and Alberta. The last three have best practices for operation and rehabilitation of pits and quarries that can be insightful for Ontario. The following are the main themes identified:

- Most jurisdictions have a flexible framework for the assessment of soil quality rather than one table or one set of values. This framework includes a general conservative standard and a more tailored set of standards with site-specific inputs.
- All jurisdictions recognize the issue of regional variability in background concentrations.
- In most jurisdictions, the excess soil regulations and standards are more current than existing BMPs for pit and quarry rehabilitation. Most regulations and BMPs regarding aggregate sites reviewed for the development of this report were developed in the 1990s.

2.3. Discussion of Literature Review

The MECP has nine standard volume-independent tables to assess the quality of excess soil, however, the MNRF policies and guidelines reference Table 1. This is largely due to the relative naissance of the excess soil standards, and partly due to Table 1 becoming the de facto reference standard for importing fill for pits and quarries, evolving from earlier criteria which permitted importation of “inert fill” for site rehabilitation.

The Table 1 standards are not universally achievable given that naturally occurring concentrations of some parameters exceed the Table 1 standards in some regions of Ontario, and/or due to variability in concentrations of soil parameters by depth. This may limit opportunities to beneficially reuse excess soil locally and lead to soil movement across greater distances, which contributes to increased GHG emissions, road congestion, project costs, and an increased risk of distributing invasive species.

While the excess soil regulation and rules acknowledge the occurrence of naturally elevated regional background concentrations, gaps remain in building consensus about regionally accepted ranges of values.

The excess soil standards were developed considering that a typical site would result in the placement of soil on some volume of pre-existing soil with a degree of separation from the groundwater table. Excess soil standards are distinct from those developed for contaminated sites, with the understanding that evaluation of contaminated sites is reactive, and assessment of groundwater is a viable method for assessing whether transfer of contamination from soil presents an adverse impact. The excess soil rules and standards recognize that measurement of a groundwater contaminant after the placement of excess soil is an unacceptable risk. Therefore, excess soil standards were developed to identify concentrations that would not impair groundwater, and incorporate leachate testing and leachate screening criteria as a means of proactively evaluating the potential for contaminant transfer to water. Many pit and quarry sites are deep excavations which:

- Are more likely to disturb groundwater and may result in the placement of backfill in groundwater during rehabilitation
- May excavate material with a high conductivity or elevated concentrations of metals.

Reuse sites accepting less than 10,000 m^3 are not required to retain a QP. Some pit and quarry specific protocols, such as *Aurora Fill Acceptance Protocol*, require pits and quarries to retain the service of a QP to evaluate the suitability of material for reuse and to develop and oversee procedures and protocols for the beneficial reuse of excess soil at aggregate sites.

The excess soil standards and rules evolve from models used to evaluate contaminated sites and common contaminants arising from anthropogenic activities (chemical parameters). However, movement of excess soil may introduce other contaminants/hazards (e.g., biological and physical) that may cause adverse impacts in settings commonly associated with pits and quarries (e.g., rural land use, potable conditions, deep excavation, and backfill) and requiring the consideration of QPs.

The findings of the literature review generated the following questions that are the focus of subsequent sections (Sections 3 and 4):

(1) Can the generic excess soil standards be used as an alternative to Table 1 at pits and quarries?

(2) If yes, which tables are the most appropriate? Also, is there a table that can be applied to all pits and quarries? Are there certain settings where the MECP's conceptual model is invalidated?

(3) Can the BRAT be used at pits and quarries? Are there missing elements in the BRAT that would allow us to consider a broader set of pit and quarry sites (e. g., below the water table)?

(4) Can salt-impacted material (because of deicing salt) be used in rehabilitation of pits and quarries? If yes, what are the most important considerations?

(5) What are best practices for receiving material at aggregate sites (e.g., auditing, groundwater monitoring/sampling, stakeholder consultations)? What do QPs and operators need to consider to mitigate adverse impacts?

(6) What potential contaminants associated with acceptance of excess soil at a pit or quarry are not covered by the MECP standards?

3. Analysis of Options for Choosing Excess Soil Quality Standards

MECP effect-based excess soil tables are not specifically developed for pits and quarries. This section of the report presents a brief overview of the most important assumptions used in development of these tables and whether they are appropriate for pit or quarry rehabilitation. Figure b shows a flowchart that QPs can use to evaluate the potential applicability of generic excess soil quality standards for rehabilitating a site.

The rationale for the flowchart and why specific standards may apply to a particular setting is provided in the subsections which follow. The subsections which follow include a brief discussion of the MECP conceptual model used to develop the excess soil standards and comparison to a typical pit or quarry setting, highlighting assumptions that may not be valid for a pit or quarry. Furthermore, the assumptions behind developing component values for different reference standards are summarized, and the reasons these tables are or are not appropriate to be used in pit or quarry rehabilitation are discussed.

The reader is encouraged to review the MECP *Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario* as well as the MECP *Rationale Document for Development of Excess Soil Quality Standards* to fully understand the limitations, and assumptions made in the development, of the excess soil standards to determine the applicability of the generic standards to a given reuse site setting.

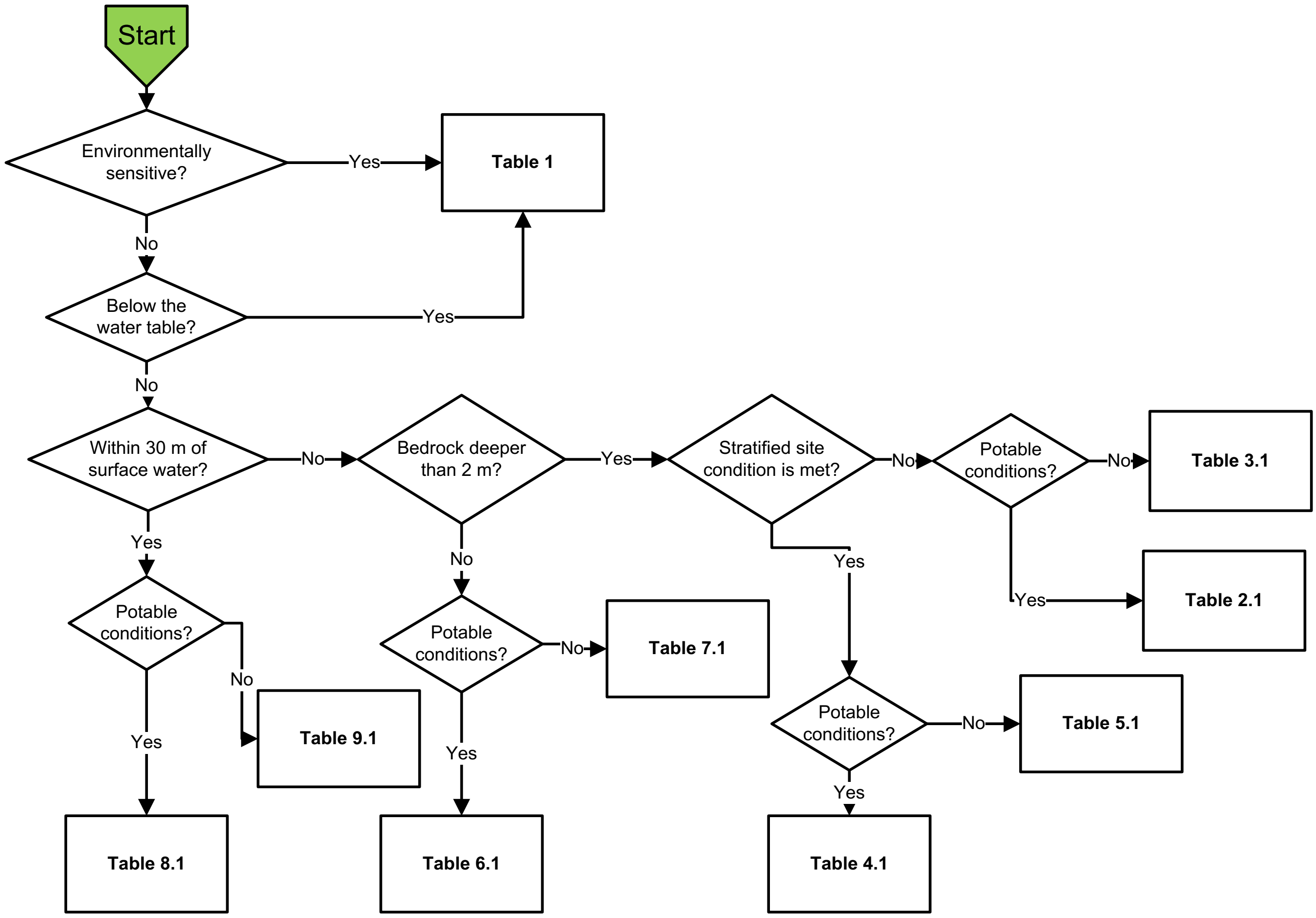

Figure b. Flowchart for choosing appropriate standards for placing fill at a pit or quarry[8]

3.1. Elements of MECP Excess Soil and Brownfield Models Applicable to Pits and Quarries

The *O. Reg. 153/04* generic models were developed to protect 'typical' receptors at contaminated sites. One of these assumptions was that a typical contaminant source zone has a volume of approximately 350 m^3. The *O. Reg. 406/19* standards are based on the model that was used to develop the *O. Reg. 153/04* standards; however, excess soil standards consider that a larger (infinite) volume of a contaminant may be introduced to a reuse site. The generic conceptual site models (and associated component value pathways) developed for *O. Reg. 153/04* were the basis for the new volume independent soil standards, developed for excess soil reuse sites accepting volumes of soil greater than 350 m^3 (volume independent standards). The volume independent standards were developed by assuming that the excess soil volume was sufficiently large to negate the effects of both dilution and source depletion

[8] Also, where excess soil contains volatile compounds and the groundwater table at the reuse site is at close proximity to buildings of concerns Table 6.1 and 7.1 may be used.

(MECP 2020c). In addition, excess soil quality standards are developed to be protective of on-site as well as off-site receptors.

The generic models are based on assumptions described in the *Rationale Documents*. Therefore, QPs must consider each site to determine if the parameters and receptors are appropriately modeled. However, they may not provide adequate protection for 'potentially sensitive' sites[9]. In circumstances where a QP determines that the generic model is not an appropriate representation of the site in question, the QP may consider using the BRAT or undertake a risk assessment to develop site-specific excess soil standards.

The MECP (2020c) *Rationale Document for the Development of Excess Soil Quality Standards*, states that:

> *"The excess soil quality standards are intended to address risks associated with chemical impacts in soil and are not meant to address issues of radioactivity, explosive conditions, soil fertility, or geotechnical considerations."*

The MECP (2020c) document also states that:

> *"A qualified person… shall consider how the excess soil quality standards were derived… if an important assumption in the standard development process is violated for a particular site, the qualified person should evaluate whether the standards are still appropriate for that site."*

Neither the *Rationale Documents* (MECP 2020c) nor the regulations and their associated standards explicitly state which tables are appropriate for rehabilitating pits and quarries. However, based on the assumptions discussed in the *Rationale Documents,* the *O. Reg. 406/19* generic site condition standards may be applicable for pits and quarries. It is assumed that in most circumstances the volume independent standards will be more appropriate for pits and quarries than the small volume standards, due to the anticipated volumes that would be required to meet the definitions of beneficial reuse (e.g., to backfill a pit or quarry). QPs should become acquainted with the factors listed in Section 5.1 of the *Rationale Document* (MECP 2020c), that may alter assumptions made in the generic model for excess soils and may be of specific interest for pit and quarry sites:

- Presence of exposure pathways not considered for the development of excess soil quality standard, including:
    - Consumption of garden products cultivated at a reuse site
    - Agricultural land use specific exposure scenarios such as:

[9] *Soil Rules* requires the imported fill to meet Table 1 for environmentally sensitive sites.

        - Livestock watering
        - Irrigation watering
        - Dust inhalation
        - Consumption of milk or dairy product produced at reuse site
        - Consumption of plants or animals cultivated at a reuse site
    - Protection of reptiles and amphibians.

- Soil with high permeability: This can potentially provide a direct preferential pathway for vapours to migrate quickly to a building. Under such circumstances, the soil properties used in determining some generic component values (e.g., S-IA and S-GW2) may be non-conservative.

- Significant preferential pathways: These pathways are not considered in the generic model. Preferential pathways may be caused by shallow fractured bedrock, gas under pressure/landfill gas, and/or utility conduits that provide a direct connection to the enclosed space of the building. If preferential pathways are present at the reuse site, the S-IA and S-GW2 component values may not be protective.

- Organic content: If the average fraction of organic carbon (foc) of soil above the water table is less than 0.002 g/g, a greater fraction of a chemical may be in the water and gas phases than assumed. This may lead to increased chemical mobility.

- Surface water condition: If there is a surface water body that could be affected as a result of chemical migration via groundwater discharging to surface water, and the surface water has a total hardness level of less than 70 mg/L and/or has pH less than 6.7, the aquatic protection values for some metals and pentachlorophenol may be non-conservative. In such cases, a site-specific estimate of hardness and pH resulting from mixing of groundwater and surface water may be needed to estimate an appropriate aquatic protection value.

If these or other pathways not contemplated in the generic model are present, the generic excess soil quality standards may not be protective.

Although Section 5.1 of *Excess Soil Rationale Document* mentions that consideration is required of chemicals for which generic excess soil quality standards are not derived (MECP 2020c), it also notes that QPs should consider limiting conditions in applying the generic chemical standards (e.g., highly permeable zones in the vadose zone). Placement of fill in pits and quarries may generate physical contaminants (e.g., groundwater turbidity resulting from preferential movement of soil particles through bedrock fractures to neighbouring wells) and biological contaminants (e.g., bacteria) that the QP should consider based on the source of the material and where/how it will be placed within the pit or quarry.

The exposure pathways discussed in the *Rationale Documents* are generally appropriate for a pit or quarry setting (except when placing soil below the water table). However, given that pits and quarries are commonly located in areas where concern of adverse impact to groundwater is significant, and where backfill may be deposited close to or within groundwater, it is anticipated that potential interference with groundwater arising from placement of excess soil will be one of the more commonly encountered concerns. A summary of the components that are used in the development of the groundwater *Site Condition Standards* are as follows[10] (these component values are used in the development of excess soil standards with appropriate modification):

- Potable Groundwater Standard: The lowest of GW1, GW2 and GW3, but not less than the reporting limit (RL) or the background concentration, or more than 50 per cent of solubility limits.
- Non-Potable Groundwater Standard: The lowest of GW2 and GW3, but not less than the RL or the background concentration, or more than 50 per cent of solubility limits.

The soil site condition standards are derived by choosing the minimum of ten component values related to soil: S1, S2, S3, S-IA, S-OA, S-Odour, S-GW1 and S-GW3, component values for protection of plants and soil-dwelling organisms and component values for protection of birds and mammals[11]. The final standards are the lowest of groundwater and soil-related component values, but not less than the Reporting Limit (RL) or the background concentration.

The subsections which follow describe commonly anticipated circumstances that a QP may encounter when considering site condition standards for pits and quarries. A discussion is also included about how generic excess soil quality standards may be applied. Use of the BRAT and/or completion of a risk assessment are discussed as potential alternatives when a QP determines that the generic reference standards may not be appropriate for a specific site setting.

3.2. Conceptual Site Model for Pit and Quarry and Deviation from MECP Model

The conceptual site model provided by the MECP for excess soil is generally applicable to a typical pit or quarry. The main difference is that rehabilitation of pits and quarries may result

[10] For a definition of each component value see the Acronyms and Initialisms in the beginning of this document or refer to MECP rationale documents.
[11] Excess soil standards also include S-GW2 pathway.

in the placement of soil below or in contact with the water table. When large quantities of soil are submerged in water, this may affect how chemicals partition and migrate through a groundwater unit. This pathway, which is not included in the brownfield and excess soil conceptual model, is shown by SS-GW in Figure c, which represents the movement of a substance from the saturated soil to a certain receptor. SS-GW represents the following exposure pathways:

- SS-GW1: Exposure pathway due to movement of a substance from the saturated soil to groundwater then to a human receptor via drinking water.
- SS-GW2: Exposure pathway due to the movement of vapour from saturated soil to groundwater and through groundwater to indoor air.
- SS-GW3: Exposure pathway due to movement of a substance from saturated soil to groundwater then to aquatic receptors in a surface water body.

According to the MNRF (2020a), there are 967 active pits and quarries that go below the water table. This constitutes about 19 per cent of all active sites in Ontario. While this fraction is not negligible, the ratio of soil placed below the water table to the entire volume of soil for rehabilitation in province is small. Although backfilling below the water table constitutes a small fraction of backfilling, a section is devoted to this issue (see Section 3.7) due to the uncertainty associated with contaminant transport (particularly metals) arising from placement of soil in groundwater.

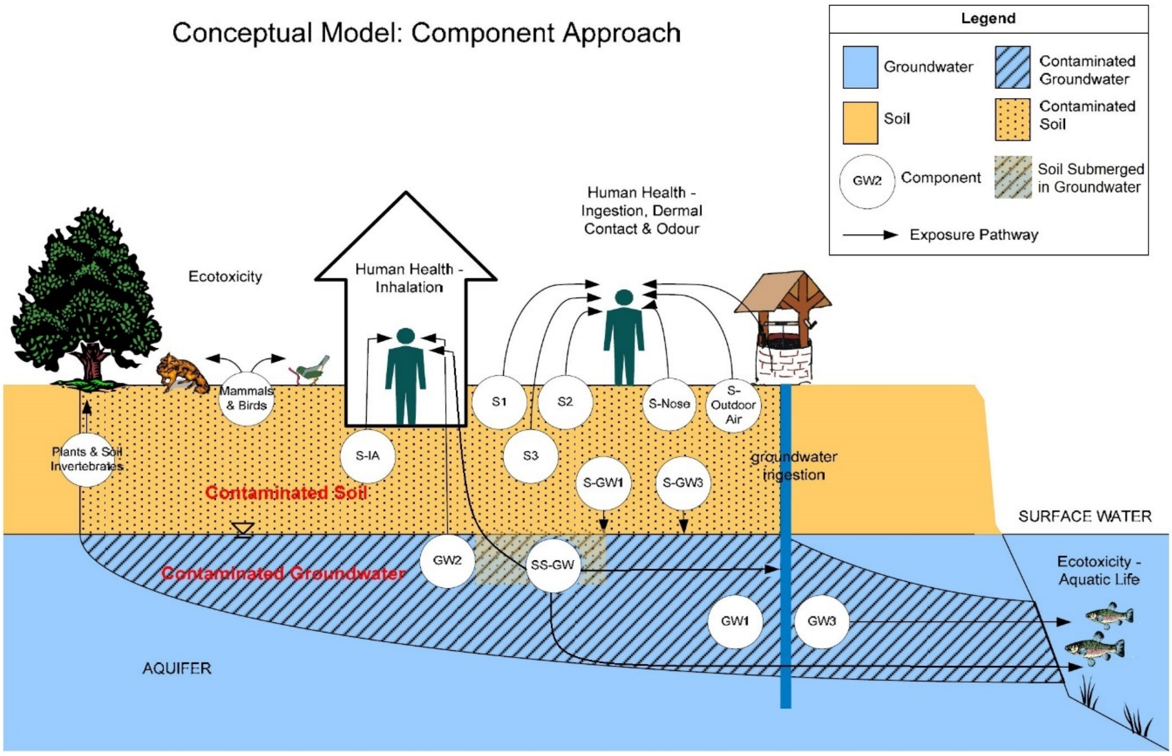

Figure c. Conceptual site model for a pit or quarry.

Other assumptions of the MECP generic model that may not be valid for all pits and quarries are as follows:

- Aquifer recharge rate, used in the calculation of dilution factor in leachate standards, may differ from the 0.28 m/a value (and 0.20 m/a for medium/fine texture) proposed by the MECP. The rate of aquifer recharge not only affects the water table level, which may affect transport of metals (King 2005) but also is a direct input to MECP standard calculations. Aquifer recharge rate may differ from one site to another depending on its location and relation to local groundwater flow. For example, aquifer recharge rate could be different for a recharge site, a discharge site, or a flow-through pit, which are created as a result of changes in hydraulic gradient that cause groundwater to flow towards, away or through a pit (Mollema et al. 2015). Rutledge and Mesko (1996) analyzed discharge records from 89 basins in the eastern US and reported recharge estimates between 0.152 and 1.270 m per year. Studies on Ontario are available as well. In a study by the US Geological Survey, the aquifer recharge rate across the Great Lakes Basin is divided into five categories (in m/yr): less than 0.10, 0.10 to 0.2, 0.2 to 0.3, 0.3 to 0.4 and more than 0.4 (Neff et al. 2006).

- The hydraulic conductivity of the aquifer is set to 3 x 10^{-5} m/s in the brownfield and excess soil standards. However, pits and quarries may be located in areas with higher conductivity and/or with preferential pathways (e.g., fractured rock).

- The pH of the leachate method[12] and the pH of the environment (in this case groundwater and soil pH). While pH is not a direct input to the MECP models, the *Excess Soil Rationale Document* (MECP 2020c) notes that the generic standards are valid for a pH range of 5 to 9 and 5 to 11, respectively, for surface and subsurface soil[13]. The pH for soil matrix in most pits and quarries is anticipated to fall within this range, but groundwater may include more uncertainty. Generally, the water in pits and quarries is depositional rather than corrosive (i.e., it has above-neutral pH values). It is reported that generally lower water pH contributes to increased metal mobility and toxicity (Dave 1985; Sauvé et al. 2000). However, species of some metals (such as aluminum and arsenic) have a higher toxicity as pH becomes more basic (Dave 1985; Fulladosa et al. 2004). The pH of the mSPLP method used to evaluate potential leaching from soil was developed to model percolation of weakly acidic precipitation percolating through unsaturated soils. Therefore, this method of evaluating the potential for leachate generation[14] from soil placed in groundwater may not be conservative, and pH of groundwater should be considered when placing soil in contact with the water table, particularly groundwater that is more basic and/or that has significant dissolved solids. A discussion on metal transport in groundwater is given in Section 3.7.

3.3. Options for Choosing Fill Quality Standards

As a reminder, licenced pits and quarries are regulated by the *ARA* and are assumed to have active site plans detailing whether a pit or quarry may receive fill for the purposes of rehabilitation, and/or specifying the quality of the material that must be used. Site plans frequently specify that imported backfill must meet the Ontario Background Site Condition Standards (Table 1). The excess soil regulations states that where another instrument (e.g., a site plan) defines a more stringent excess soil quality standard or limits the volume of material that can be imported, the existing instrument takes precedence. Therefore, application of alternate standards must first be approved through a site plan amendment.

[12] This value is built into SPLP leachate test method and cannot be modified.
[13] The quality standards for soils out of this pH range are determined to be Table 1 by Section D.1 of the *Soil Rules*.
[14] If a QP is of the opinion that a site-specific feature, such as groundwater pH, may results in higher mobility/toxicity than what considered in the development of generic standards, they may prescribe a risk assessment.

Similarly, unlicensed sites may be regulated under a municipal instrument and the limitations of the instrument must be reviewed.

The *Rationale Document for Excess Soil Regulation* has numerous similarities with the *Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario*, and the considered exposure pathways are generally also appropriate for pits and quarries. Neither rationale document explicitly considers direct contact of fill material with the groundwater, which is a condition that may be commonly encountered at pits and quarries. Both rationale documents consider a mixing zone where contaminants that may leach from soil mix with groundwater.

When considering the appropriateness of generic soil standards for placement of excess soil at pits and quarries, QPs must pay attention to:

- Site end use (i.e., Ag, RPI and ICC)
- Groundwater potability
- Location with respect to closest surface water body
- Whether soil is placed in shallow bedrock
- Whether site is located in environmentally sensitive area
- And other general consideration such as whether an RSC is required

MECP tables are developed for potable and non-potable water conditions. Although aggregate pits in Ontario are commonly situated in areas of potable groundwater use, it is recognized that there are sites that may satisfy the non-potable groundwater condition as prescribed by *O. Reg. 153/04*, and therefore application of the non-potable standards (e.g., Tables 3.1, 7.1, 9.1) may be appropriate, subject to the same requirements of *O. Reg. 153/04*.

Furthermore, QPs should consider the depth of placement in relation to the predicted final water table. For sites where excess soil will be placed above the water table (i.e., where excess soil will be placed at least 2 m above[15] the predicted water table) Table 2.1 is appropriate in a potable groundwater setting, and Table 3.1 is suitable for a non-potable groundwater condition. Note that these tables assume that excess soil will be placed above the saturated zone and will not be in constant contact with groundwater. These tables also assume that there will be contaminant dilution between a potable water supply and/or ecological receptor (i.e., S-GW1 and S-GW2). Tables 4.1 and 5.1 could be used above the

[15] For more details see the layer-cake approach explained in Appendix 1 of the BMP document developed by OSPE, *Best Management Practices for Aggregate Pit and Quarry Rehabilitation in Ontario*

groundwater only when stratified conditions are satisfied. A more detailed discussion of these tables is presented in the following subsections.

3.3.1. Table 1 for Ontario Background Concentrations

Table 1 represents the background concentrations of different chemicals across Ontario. Unlike other tables in the *Soil Rules* document, Table 1 is not derived based on an effect-based approach or risk assessment. Table 1 is useful as a conservative standard when use of generic excess soil standards may be inappropriate (e.g., environmentally sensitive sites and karstic settings). This Scientific Report recommends avoiding the placement of soil in groundwater or, when placement of material in the groundwater is unavoidable, placing soil meeting the Table 1 standards in contact groundwater and extending up to the anticipated maximum groundwater elevation following site rehabilitation.

The MECP soil quality standards and the BRAT do not include S-GW pathways for metals[16]. Furthermore, the behaviour of metals in saturated conditions is highly stochastic and can only be sufficiently modeled upon the availability of site-specific information (see Section 3.7 on metal fate and transport). If a QP would like to evaluate alternatives to Table 1 for placement for fill below the water table, the modeling tools presented in Appendix 6 may be an option for deriving more flexible site-specific risk-based standards.

3.3.2. Tables 2.1 or 3.1

There are reports that some municipalities have applied *O. Reg. 153/04* Table 2 standards for pit and quarry rehabilitation (Conestoga-Rovers & Associates 2015), prior to development of the volume independent standard (Table 2.1). The volume independent standards are suitable for larger quantities (>350 m^3) of material that are anticipated to be required for beneficial reuse at pits and quarries. The values presented in the volume independent tables are protective of multiple typical pathways for pits and quarries. For instance, the Table 2.1 values for industrial/commercial land use considers the following pathways and receptors:

- Direct exposure to soil via soil ingestion and dermal contact appropriate for a commercial/industrial setting
- Direct exposure to soil via soil ingestion and dermal contact appropriate for the subsurface soil in a commercial/industrial setting
- Exposure pathway due to inhalation of indoor air containing soil vapour
- Leachate of a substance from the soil to groundwater then to a human receptor via drinking water

[16] Leachate analysis may be required, where necessary, to address this pathway.

- Leachate of a substance from soil to groundwater then to aquatic receptors in a surface water body
- Off-gassing from soil to ambient air (model check)
- Ecotoxicity (for plants and soil invertebrates)
- Ecotoxicity (for mammals and birds: meadow vole, red fox, red-winged black bird and American woodcock)

Note that different assumptions were made for deriving quality standards depending on the site end use. For instance, the component values considered for R/P/I and agricultural Table 2 (and 2.1) are slightly different than those of I/C/C standards. The I/C/C standards are based on component values S2 and S3 (related to direct exposure to soil via ingestion). Component values S2 and S3 assume that more sensitive receptors (e.g,. children) are not present and that the exposure to a given contaminant is limted to a work day/week, rather than a continuous occupancy. Where the end use of a site will be R/P/I or agricultural, the corresponding standards should be applied because these incorporate the more conservative S1 component value which considers the continous occupancy of a site and/or the presence of sensitive human receptors (e.g., toddlers). Similarly, the ecological component values (i.e., animals considered for ecotoxicity) are different for these land uses. For instance, sheep is included in ecotoxicity analysis of agricultural land use but not in R/PI and I/C/C.

The excess soil standards also consider the S-GW2 pathway, which is discussed in the *O. Reg. 153/04 Rationale Document* but was not considered in the development of the corresponding generic standards because S-IA was considered to be protective of both pathways, and because direct sampling of groundwater (i.e., from monitoring wells at contaminated sites and consideration of the GW2 pathway) was anticipated to be a better indicator of actual impacts. The S-GW2 pathway plays a greater role in the excess soil volume independent standard derivation because for larger volumes the S-IA may no longer be conservative, and because it is anticipated that groundwater sampling will not be a good line of evidence for anticipating the effect soil leaching may have. Therefore, the values in Table 2.1 are protective of most pathways in a pit or quarry setting providing that the leachate screening values are met, where required. However, the direct contact of imported fill with groundwater for an extended period (e.g., in the saturated zone) is not considered in this table. So, other tables in the *Soil Rules* or in other standards/guidelines should be investigated.

Table 3.1 cannot be used in a potable groundwater condition. Unlike Table 2.1, this table does not include the component values and pathways related to drinking water. Therefore,the S-GW1 component values are not considered in the development of Table 3.1 (i.e., the non-potable standard is based on the lower of S-GW2 and S-GW3).

3.3.3. Table 4.1 or 5.1

Tables 4.1 and 5.1, or Stratified Site Condition Tables, may be used for placing soil above the water table and below 1.5 m of the ground surface when stratified site conditions are met. These tables provide a set of more flexible quality standards. However, their application is dependent on satisfying stratified site conditions as prescribed by *Soil Rules*. These conditions are as follows (MECP 2020b):

> *"i. Final placement of the excess soil must achieve a stratified condition such that soil that meets the stratified standards is placed at a depth of 1.5 m or greater below the soil surface and the surface soil placed on top meets the applicable full-depth generic excess soil quality standards,*
>
> *ii. The reuse site is not an agricultural or other property use, is not a shallow soil property, and the final placement is not within 30 m of a water body,*
>
> *iii. The location of final placement, the property use, and the type of beneficial purpose are such that a stratified condition will be maintained into the foreseeable future, and*
>
> *iv. The reuse site owner, occupier, or person who has charge, management or control of the reuse site must ensure that the stratified condition is established and maintained. This responsibility should be communicated to subsequent property owners."*

Another difference of Stratified Tables is that they provide two sets of quality standard values: surface and subsurface soil values (below 1.5 m). Table 4.1 surface soil values are the same as Table 2.1, and Table 5.1 is the same as Table 3.1. Quality standards for subsurface soils are less stringent because several pathways/receptors were excluded. Ecotoxicity for several species (e.g., birds and mammals) and S1 component values were not considered in the development of the Table 4.1 and 5.1 subsurface values. This is because these tables are not intended to be used for placing soil near the surface where those pathways/receptors are usually present. Finally, Table 5.1 is only for non-potable groundwater conditions and does not cover any of the pathways related to drinking water (i.e., S-GW1).

3.3.4. Table 6.1 or 7.1

Tables 6.1 and 7.1 in the *Soil Rules* are developed for shallow soil properties in potable and non-potable groundwater conditions, respectively. These tables are also used in situations in which excess soil contains volatile compounds and the groundwater table at the reuse site is a close proximity to buildings of concerns. The S-GW2 and GW2 component values govern the derivation of groundwater component value for Table 6.1[17], which makes it more stringent than Table 2.1.

Unlike Tables 2.1 to 5.1, Tables 6.1 and 7.1 do not assume the presence of porous media. Assuming the absence of a porous medium is useful when the soil material will be placed within an area where bedrock has been excavated or directly on top of bedrock (e.g., a former quarry) and/or where preferential pathways have been identified. Tables 6.1 and 7.1 assume no dilution of groundwater contaminants over the flowpath, prior to discharge, and the values for protection of the aquatic environment in Tables 6.1 and 7.1 were established by multiplying the Aquatic Protection Value (APV) by two[18] (to account for dilution by the receiving water body at the point of discharge). Both shallow soil and near-water-body tables (i.e., Tables 8.1 and 9.1) share this assumption for the calculation of the S-GW3 (Soil to Groundwater to Surface Water) component values.

Aquatic Protection Values (APVs) are distinct from the MECP Provincial Water Quality Objectives (PWQOs) developed for the protection of aquatic life and recreational uses (MECP 1994). PWQO criteria are conservative values that represent a desirable level of water quality that the Ministry strives to maintain in the surface waters of Ontario. So, when PWQOs are satisfied they are protective of all forms of aquatic life and all aspects of the aquatic life-cycle during indefinite exposure to the water. The PWQOs incorporate assumptions that are not considered appropriate for the assessment of contaminated sites. As a result, unlike the sediment guidelines, these PWQOs were not used in the MECP tables for brownfield site conditions and excess soil (Ontario Ministry of the Environment 2011). The APVs protect most aquatic biota exposed to contaminants from migration of contaminated groundwater to surface water.

Another set of assumptions used for the development of Tables 6.1 and 7.1 was regarding the GW2 pathway, which is accounted for in the volume independent excess soil standards by the S-GW2 component value. The biodegradation component of the GW2 number was turned off, and the empirically-based attenuation coefficient was set at 0.02 for residential and 0.004 for commercial/industrial because, when developing site condition standards, it was assumed that no or little soil might be present between the bedrock and an overlying building, and that there may not be enough separation between groundwater and the point of vapour intrusion for biodegradation to occur within porous media.

---

[17] The component values for Table 6 and 7 are available in Appendix A3 of *Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario*. While the results for different components values for Tables 6.1 and 7.1 are not publicly available, it is expected that they have similarities to brownfield component values.

[18] By 10 for small volume tables

The typical depth of the water table for S-GW2 pathway in a "full depth" setting (e.g. Tables 2.1/3.1) is assumed to be 3 m below ground and the residential building foundation depth is assumed to have a depth of 1.58 m (i.e., a 1.42 m separation distance between the water table and the residential building foundation). The full depth model assumes some biodegradation of volatile contaminants occurs within the separation distance between the water table and receptor, and applies a bioattenuation factor.

Therefore, the S-GW2 component value used for Table 6.1 and 7.1 is generally conservative in a typical pit or quarry setting (with overburden) because it assumes that there is no attenuation caused by biodegradation. However, these assumptions must be taken into consideration on a site by site basis The assumption of no biodegradation for S-GW2[19] for the development Table 6.1 and 7.1 may not be valid for all pits or quarries when rehabilitated by backfill because the depth of soil above the water table may be considerable. In these circumstances, application of Tables 6.1 and 7.1 may be overly conservative and the "full depth" standards may be more appropriate.

3.3.5. Table 8.1 or 9.1

Tables 8.1 and 9.1 are for use within 30 m of a water body (such as a stream or a pond). The main difference between these tables and Tables 2.1 to 5.1 is the travel distance used to model groundwater transport from the centre of pollution zone to edge of surface water is not the typical 36.5 m. In this case the source zone could be adjacent to the water body or less than 30 m away from the water body. As a result, no dilution is assumed for the S-GW3 pathway. Tables 8.1 and 9.1 and shallow soil tables (Tables 6.1 and 7.1) have this attribute in common.

The standards for Tables 8.1 and 9.1 are more stringent than Tables 6.1 and 7.1 because they also consider sediment quality (i.e., there is an assumption that because of erosion, soil will become sediment). The standards also assume that groundwater and sediment discharge to neighbouring surface water bodies with no attenuation[20]. Groundwater component values are the minimum of the GW1, GW2 and GW3 (which is derived by APV times a dilution factor). The soil numbers are determined by finding the lowest of the soil component values and the sediment quality guidelines. In the absence of a sediment quality value, the number is set to Table 1 background concentrations. When the sediment quality standard value is less than Table 1 background concentration, the value is increased to the Table 1 value.

[19] Note also that GW2 (and vapour intrusion pathway in general) will only be relevant if there will be buildings post rehabilitation. So, for example, they are not important to a site with agricultural end use with no buildings on it.

[20] A dilution factor of 2 is considered when calculating S-GW3.

Given that sediment quality guidelines for Unconfined Fill are generally more restrictive than Table 1, this results in having similar component values for Tables 8.1 and 9.1 and Table 1. The Unconfined Fill sediment quality guidelines (see Section 2.1.11) may not be appropriate for all pit or quarry settings as benthic organisms are not usually directly exposed to contaminants. Considering the Unconfined Fill sediment quality guidelines may be appropriate when a pit or quarry rehabilitation will include a water habitat (e.g., a pond) that will cover or include contact with excess soil (e.g., a sloped transition into the water from the sides of the pit or quarry). They also may be relevant if the pit or quarry is within 30m of a water body and/or where future use of site include wetlands, alvars or water bodies.

3.3.6. Lakefilling or Shore Infilling Guidelines

Lakefilling or shore infilling guidelines in Ontario divide imported fill into two categories: Unconfined Fill and Confined Fill. Each category has its own requirements and set of standards when used in a shore infilling project. The tables for assessing quality of candidate fill in such projects are Table C-1 for Confined Fill and Table C-2 for Unconfined Fill. The values of Table C-1 are taken from Table 2, agriculture or other property use, as described in *O. Reg. 153/04*. The criteria in Table C-2 are adopted from *Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario* developed by Fletcher et al. (2008). When compared with MECP Table 1 for background concentrations, as a general observation, Table C-2 contains a smaller number of chemicals, and its values are more restrictive than those of Table 1.

The Table C-2 values are more stringent than Table C-1 because of the considerations in its development. The most important considerations for the development of these standards were:

- Protecting benthic (sediment-dwelling) species, which are directly impacted by the contaminants
- Protecting against biomagnification of contaminants through the food chain
- Meeting the MECP water quality management goals concerning surface waters for aquatic life and recreation

Note that Table C-2 values are derived to protect the quality of surface water and aquatic life. No human health consideration was included when developing these values. Direct exposure of benthic organisms to contaminants is an assumption that is generally not valid for pits and quarries that, following rehabilitation, are not located near to or include surface water bodies or wetlands. Therefore, Table C-2 for Unconfined Fill is anticipated to be too stringent for pit or quarry rehabilitation, where surface water protection is not a primary concern.

3.4. Fill Quality for Backfilling Below the Water Table

In the MECP *Soil Rules* (MECP 2020b), there is no explicit mention of the acceptable criteria for situations in which deposited fill is in direct contact with the groundwater. This issue was investigated using interviews, literature review, and group discussion with the OSPE Excess Soil Project Steering Committee. When placing soil in water table is unavoidable, this Scientific Report recommends using Table 1. If a QP wants alternatives to Table 1, the computer programs presented in Appendix 6 may be an option for deriving more flexible standards.

Other options that QPs can investigate are using tables which assume no contaminant dilution (e.g., S-GW3), such as Tables 6.1. and 7.1, but these tables do not consider the issue of metal behaviour in saturated conditions[21] (see Section 3.7). Table C-2 standards for Unconfined Fill in *Lakefilling or Shore Infilling Guidelines* may be another option, but this table does not include all chemicals listed by *O. Reg. 153/04* and *O. Reg. 406/19* standard tables.

3.5. The BRAT

The Beneficial Reuse Assessment Tool (BRAT) provides QPs with the ability to derive site-specific standards by adjusting some model parameters (e.g., hydraulic conductivity, distance from surface water bodies, soil texture, and depth of building foundation). Therefore, if a QP decides that the assumptions used to develop excess soil standards do not reflect the conditions of their site, they may generate alternative quality standard values using the BRAT. The BRAT provides sufficient options for deriving soil quality standards for pits and quarries. However, consideration should be given to conditions in which the BRAT may not be sufficiently conservative:

1. The range of aquifer hydraulic conductivity in the BRAT varies between 10^{-3} to 10^{-6} m/s. Pits located in highly permeable gravel may have hydraulic conductivities that are orders of magnitude higher (see Section 3.6).
2. The BRAT cannot be used to model placement of soil in groundwater because pH is not an input. pH is known to affect the toxicity and mobility of metals in saturated conditions (Eang et al. 2018; Misra 2013; Pettersson 2009; Sauvé et al. 2000).
3. Aquifer recharge rate, which is used in calculating some component values such as GW2, is not a variable in the BRAT. This parameter may be larger for some recharge or flow-through pits.

3.6. Analyzing the Effect of Hydraulic Conductivity

Excess soil standards are developed based on coarse-textured soil, which is common in pits and quarries. Pits and quarries are usually located in aquifers that have a high hydraulic

[21] Where necessary, leachate analysis will be required to address these pathways for metals.

conductivity. The average value used to develop the MECP excess soil generic standards is based on a horizontal hydraulic conductivity of 3×10^{-5} m/s, while the range of values for aquifer hydraulic conductivity variable in the BRAT is between 10^{-3} to 10^{-6} m/s. As shown in Figure d, adopted from Freeze and Cherry (1979), these are typical conductivity value for a range of silty and/or clean sand materials.

In certain circumstances a pit or quarry may be located in an area with a relatively high hydraulic conductivity (e.g., gravel), exceeding the range of values considered in the development of the generic standards and/or the BRAT model. Similarly, settings that are highly heterogenous with highly conductive zones acting as significant preferential pathways (e.g., karst), are not considered by the generic model and/or the BRAT. Thus, application of the generic standards and/or the BRAT in these circumstances may not be sufficiently conservative and require reconsideration of placement of excess soil or additional hydrogeologic modeling by a qualified individual (e.g., a hydrogeologist) to evaluate the suitability of soil placement. An example showing the influence of hydraulic conductivity on deriving standards using the BRAT is presented in Appendix 5.

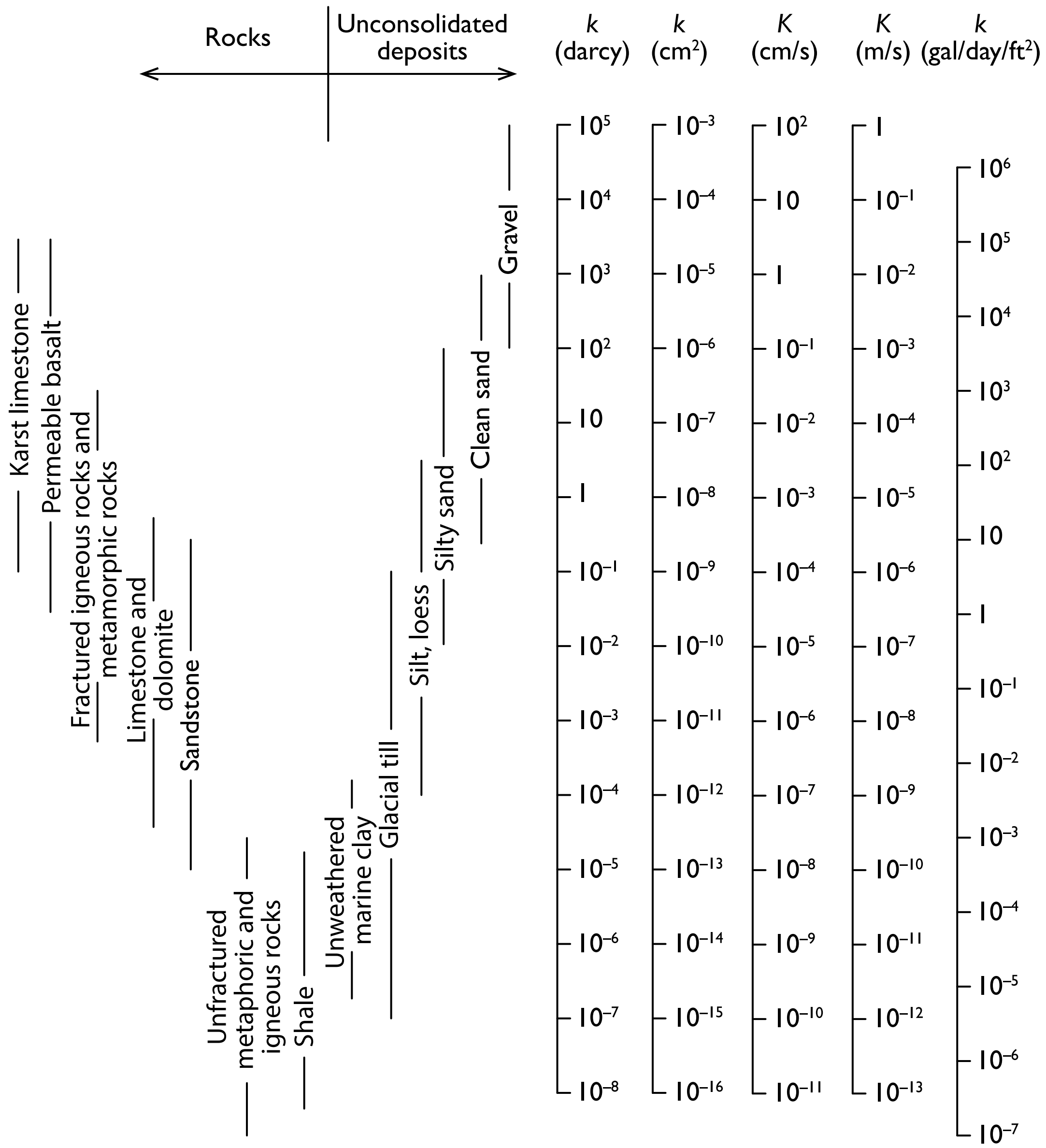

Figure d. Typical range of hydraulic conductivity for different materials, Source: (Freeze and Cherry 1979)

3.7. Fate and Transport of Metals in Saturated Conditions

A pathway that is not included in MECP (2020c) *Excess Soil Rationale Documents* is the transport of contaminants, especially metals, in saturated conditions. This is a potential pathway in pits and quarries as sometimes large quantities of soil are placed below the water table during the rehabilitation of a site. This section provides a brief review of hydrogeological assessment tools/techniques that could be adopted to model the fate and transport of chemicals in groundwater. This includes the description of the types of available geochemical modelling tools and the advantages and disadvantages of each approach.

The 'fate' of a metal includes all the processes that it can undergo after it is released to the environment. These fate processes may leave the chemical's identity unchanged or convert the chemical into a different chemical entity. Therefore, the study of metal fate and transport study is concerned with gaining a quantitative and qualitative understanding of the chemical's behaviour over its entire life-time in the environment, (i.e., from its release until it has reached its final destination) (Wania 2003). In the case of pits and quarries the environment to which the chemicals are released is the groundwater. Metals can dissolve, speciate and migrate in groundwater. Analyses of metal fate and transport go beyond concentrations. The concentration of a metal in groundwater reported by laboratories represents the total concentration of that metal in water (i.e., the sum of all species and complexes formed by the metal). More detail about these species and complexes is needed. The main factors affecting metal speciation and migration in groundwater are (Wania 2003; Zhu and Anderson 2002):

- Groundwater flow in the aquifer and its characteristics (such as pH)
- Chemical reactions that can determine the partitioning of metals to different species and phases
- Transport through advection and dispersion (i.e., moving dissolved species and mixing them further with water)
- Biological processes which affect reactions and transform different compounds
- Heat transport that affects reaction rates

Understanding the fate and transport of metals is possible via geochemical modeling. Geochemical models are either empirical or mechanistic (also known as process-based). These models are developed based on a conceptual model that represents the components present in different phases (solid or aqueous), the main possible reactions, and the factors mentioned above, especially groundwater conditions.

Currently, three main categories of geochemical models are used by practitioners: static models, reaction path models, and coupled reactive transport models. Static models can assess aqueous speciation, complexation, and surface reactions, but cannot incorporate reactive transport of the solution. The other two categories are more sophisticated. A discussion about these three categories, their advantages and disadvantages, as well as examples of freely available software/code for each group is presented in Appendix 6.

4. Potential Adverse Impacts Not Considered by Excess Soil Generic Standards

This section identifies issues not addressed by *O. Reg. 406/19* that may require additional consideration before placement of excess soil in a pit or quarry for rehabilitation purposes. These issues include invasive species, biological contaminants, aesthetic issues, physical impacts on groundwater, slope stability, noise, dust and vibration control, soil erosion, cumulative adverse impacts and climate change.

4.1. Biological Contaminants

Given that microbiological contaminants can travel through groundwater, especially in cases that the pit or quarry is in rock or coarse textured soil, it is important to account for this type of contaminant when rehabilitating pits and quarries. Among the most important biological water contaminants are E. coli and other forms of coliform bacteria. Given that pits and quarries include a large area of exposed groundwater, there is always a risk of accidental or intentional releases of such contaminants to the water. There are reports of contamination of exposed groundwater in a pit by coliform bacteria and E. coli and detection of the same contaminant in neighbouring wells (Welhan 2001). The presence of such bacteria in the water could be the result of fecal waste from birds and other wild or domestic animals. The water, therefore, poses health risk to consumers unless treated accordingly before consumption.

Some ancillary land-use activities on aggregate sites are reported to qualify as potential significant drinking water threats as per MECP *Clean Water Act* Source Water Protection regulations. For instance, having a septic wastewater system on-site for the use of the workers, which is considered a potential source of biological contaminants such as E. coli (Hussain and Hamdy 2013).

Regarding rehabilitation, it is important to know the history of the source site. The source sites that have the highest risk for bacterial contaminants are farms, feedlot, rural areas with a history of livestock farming, sewage sludge (biosolids), and areas in the vicinity of sewer systems such as sewer pipes or septic tanks. Note that farms can reduce pathogens in the manure by composting it. A study in Alberta suggests that 99.9 per cent of total coliforms (TC) and E. coli are eliminated after seven days of composting (Larney et al. 2003). However, precautions must be still taken when dealing with above-mentioned sites because the speed and extent of attenuating pathogens varies with temperature and quality of composting practices. During rehabilitation, consideration should be given to screening for biological contaminants (e.g., soils containing biosolids) in areas with potable groundwater conditions, and prohibition of acceptance of soil that is of high risk of containing biological contaminants is recommended.

4.2. Invasive Species

In some jurisdictions the regulations and guidelines differentiate between exotic species and invasive species. Species that have been introduced or moved because of anthropogenic activities to a new location where they do not naturally occur are called ‘exotic’. All exotic species are not necessarily harmful. In fact, some have beneficial purposes. When a non-native or exotic species invades lands, waters or native species causing ecological or economic problems, it is termed ‘invasive’ (Minnesota DNR 2020). However, the *Invasive Species Act* (Government of Ontario 2015) in Ontario defines invasive species as “a species that is not native to Ontario, or to a part of Ontario”.

Many introduced species are aggressive and invasive and difficult to control compared to native species. They can displace native species in undisturbed habitats and take over disturbed areas. For example, in Minnesota, 20 per cent of non-cultivated plants species are invasive (Buttleman 1992).

The risk of introducing invasive species should be considered when rehabilitating pits and quarries. This is not only because exotic or invasive species could be introduced when importing soil but also because pit and quarry conditions are usually relatively more hostile than those in the surrounding area (Buttleman 1992). Only plants or species tolerant to harsh conditions can survive. So, weeds and other invasive species may invade aggressively and outcompete native desirable species. This is especially an issue when natural revegetation is the preferred rehabilitation approach.

Some of the most important invasive species in Ontario enumerated by *MECP Best Management Practice for Excess Soil Management* (MECP 2016) are:

- European fire ants
- Japanese knotweed
- Phragmites
- Giant hogweed
- Garlic mustard
- Dog-strangling vine

Nematodes are also known as a common species introduced to new locations in Ontario because of earthworks. Some nematode species are known to be invasive and parasitic to plants (Celetti and Potter 2016; Singh et al. 2013) and other species such as reptiles and amphibians (Baker 1986). Therefore, soils with a history of nematode problem should be sampled when imported to reuse sites for agricultural purposes. Ontario Ministry of Agriculture, Food and Rural Affairs has guidelines about best times, locations and methods of sampling soils for nematodes (Celetti and Potter 2016). Parasitic species of nematodes in Ontario include:

- Soybean cyst nematode (*Heterodera glycines*)
- Oat cyst nematode (*Heterodera avenae*)
- The sugar beet cyst nematode (*Heterodera schachtii*)
- The northern rootknot nematode (*Meloidogyne hapla*)
- Bulb and stem nematode (*Ditylenchus dipsaci*)
- Dagger nematode (*Xyphinema sp*.)
- The root lesion nematode (*Pratylenchus penetrans*)
- Some Falcaustra species such as *F. inglisi, F. chelydrae, F. wardi, F. affinis and F. catesbeianae*

Plants are another important category of invasive species. The *TOARC Best Practice Guidelines*, discussed in Section 2.1.15, includes some recommendations about plants monitoring and control. In addition, the following actions are recommended:

- Before beginning any expansion of the operations, such as tree removal or movement of brushes or soil, identify any occurrences of invasive species and discuss the management implications with the operational staff and report them to the MNRF (MNRF 2012).
- An annual invasive species assessment must be conducted, and invasive plants must be removed.

4.3. Impact on Groundwater Flow

Chemical contamination and turbidity are not the only potential impact to groundwater from pit and quarry operations and rehabilitation. Another potential impact is disruption of the natural flow of groundwater resulting from:

- Lowering the water table because of dewatering during extraction or rehabilitation and disturbing the natural flow backfilling using material with low permeability. In some rare situations, these intrusions could have positive outcomes for the neighbouring communities. For instance, in an area with agricultural land use where the soil is water-logged, continuous pumping may lower the water table and make the soil conditions more favourable (BCMEMPR et al. 1995). However, because of the serious potential impacts on groundwater and surface water, it is usually recommended that pits and quarries be designed and operated in a manner that does not alter groundwater flow.

- Dewatering of pits and quarries sometimes may cause neighbouring shallow wells to yield less water (or even dry up).
- The reduction in flows in local watercourses during periods of low recharge may potentially impact aquatic habitats. In cases where either of these problems are likely, the pit or quarry should be operated in a manner that will not require lowering the water table levels by pumping.

If it is necessary to extract or place material below the water table, the following approaches could be used to minimize potential physical impacts on groundwater flow (BCMEMPR et al. 1995; Green et al. 1992):

- Excavating or backfilling the portion of the site below the water table during seasonal low elevations.
- Backfilling with free draining granular material prior to the peak water table season. This approach may not be attractive because granular material are the product of pits and quarries that are commercially valuable. However, owners/operators can always use salvaged native material, which do not satisfy the quality standards of construction aggregate material but have suitable permeability. Furthermore, the materials may be relatively consistent with the permeability of the surrounding, unexcavated areas.
- Building impoundment berms across the pit or quarry at multiple locations. The space between these berms will be filled with water and they will act as small dams and regulate the water table level.
- Lowering the final depth of the pit or quarry to less than 1m below the high winter water table level.

Usually quarries within impermeable rocks are less likely to affect the level of water table or affect the neighbouring wells (BCMEMPR et al. 1995). However, in situations that the rock is permeable (because of being cracked or porous) or when domestic wells are dug in the same aquifer and are close by, they could be affected by quarry dewatering. This is also true of other physical issues such as turbidity.

4.4. Cumulative Adverse Effect

Most MECP standard tables are developed for a single contamination source. Limited research is available from a system perspective. This may be important in Southern Ontario which has a relatively high density of pits and quarries compared to northern areas of the province. The cumulative adverse impact of multiple sites in a municipality needs to be studied. This is important to aggregate-rich municipalities, which contain a larger number of active aggregate developments in a relatively small geographic area compared to their counterparts. This notion of cumulative impact could be integrated into all stages including planning, operation, and rehabilitation.

Although this issue was mentioned by the then Environmental Commissioner of Ontario (ECO)[22], their approach is focused on landscaping and societal choices about land uses rather than hydrological and ecological aspects (Environmental Commissioner of Ontario 2007). This system aspect of pits and quarries, on a regional or broader scale (e.g., watershed), is largely understudied and still includes scientific unknowns (Port 2013). The *Rationale Documents* for brownfield and excess soil standards assume a single contamination source located on the property. So, there is a need to study the cumulative impacts on ground water sources and associated surface waters and ecosystems, resulting from multiple aggregate rehabilitation/operations. While this cumulative impact may have been considered when issuing the aggregate licence for sites opened after 2010, its implementation for rehabilitation may be more complicated. This is because there are 8,000 abandoned pits and quarries, with minimal amount of documented information, that need to be rehabilitated and are co-located within the same region/watershed with active sites.

4.5. Slope Stability

Detailed methods of slope stability analysis or slope design is beyond the scope of this report. Such methods are sufficiently discussed in the literature of soil and rock mechanics (Craig 2004). However, several points about slope stability in pit or quarry rehabilitation must be pointed out here.

First, groundwater has a significant impact on slope stability. The presence of groundwater especially affects fine-grained soils, but granular soils are affected too. A slope composed of uniform sand that has a frictional strength of 1.5H:1V will stand at a 1.5H: 1V slope if dry. However, when groundwater pressure is present it reduces the effective stress in the slope, thus, the frictional strength will be reduced, and the slope may not stand at angles smaller than 1.5H:1V (BCMEMPR et al. 1995). Therefore, only granular soil should be placed below the water table or in a perched aquifer (perched water table). Having granular soil under the water table protects the site against slope instability or unwanted settlements. Such issues could be caused because of placing saturated fine-grained soil below the water table or in the

[22] ECO described the situation as ‘swiss cheese syndrome’.

lower layers. This is especially common in Ontario because the soil may remain frozen for several months in winter and become unstable after melting in spring. In addition to geotechnical issues, placing fine-grained soil may also negatively impede the natural flow of the groundwater.

4.6. Noise

The process of rehabilitation is not anticipated to be as noisy as the extraction phase. This should be communicated to the public. Most sources of noise production are absent during rehabilitation (e.g., rock drilling, blasting, and dumping rock into steel hoppers). When rehabilitating a site by backfilling, most noise is anticipated to be the result of trucking activity. However, since in active pits and quarries, rehabilitation and extraction are conducted simultaneously, some of the principles of noise reduction are reviewed here.

Choosing the quietest set of equipment can be more practical than noise reduction (BCMEMPR et al. 1995). For example, it is known that hydraulic drills are usually quieter than their pneumatic counterparts (BCMEMPR et al. 1995; Marshall 1975). When such choices are not possible, noise reduction techniques can help. Stationary equipment noise is usually the easiest to reduce because the noise source is in the same location. Providing barriers can reduce noise for both mobile and stationary equipment. However, barriers are only effective if they are long and high enough to cover all possible equipment locations. Blasting noise can be significantly reduced through proper design of the blasting process.

For trucks and other material transfer equipment, barriers, enclosures, and impact absorbing linings are effective noise control approaches. Barriers must be built out of relatively heavy, non-porous materials (e.g., earth, rock, sand, 18-gauge steel and wood). Sometimes stockpiles of sand or gravel can be placed so that they act as barriers. A barrier must be tall enough to interrupt the line of sight between the top of the noise source and the neighbours. It also should be long enough to preclude the noise from leaking from the ends. It is reported that effective barriers can reduce noise intensity up to 10 dBA (BCMEMPR et al. 1995). Another consideration is modification of the equipment. For example, standard engine exhaust mufflers can be replaced with more powerful models that offer additional silencing. Some equipment manufacturers produce engine enclosure kits. Finally, skilled and well-trained drivers and operators who operate equipment to limit the generation of noise (e.g., by reducing tailgate slamming) are an important contributor to noise reduction. The *MECP Best Management Practice for Excess Soil Management* recommends the development of noise control measures in compliance with local bylaws (MECP 2016). The BMP notes that noise may represent an adverse effect or impact under the *Environmental Protection Act* and importation of soil may be limited until the adverse effect or impact is sufficiently mitigated (MECP 2016).

4.7. Dust

The MECP *Best Management Practices for Excess Soil Management* notes that dust may represent an adverse effect or impact under the *Environmental Protection Act* and importation of soil may be limited until the adverse effect or impact is sufficiently mitigated (MECP 2016). The development and implementation of dust control measures at reuse sites is recommended (MECP 2016).

Roadways inside and near the site are a common source of dust emission, and every effort must be made to keep these surfaces free of loose material. Paved roads should be washed or swept regularly. Water should be regularly applied to unpaved roads. There are various approved dust suppressant products on the market that may be effective in controlling dust. However, these products may have an adverse environmental effect on the quality of air, surface water and groundwaters and should be used cautiously (Foley et al. 1996; Piechota et al. 2004). Outgoing trucks should pass through mud mats or a tire wash to limit tracking of dirt onto road surfaces.

During extraction and rehabilitation, materials handling and processing activities (loading and unloading of gravel trucks and conveyor systems) are a common source of dust emissions. Operational measures, such as limiting the height from which material is dropped can reduce the generation of dust.

Planting vegetation or placing mulch on topsoil stockpiles or slopes that are exposed will significantly reduce erosion and windblown dust. In windy areas, stockpiles of production material should be kept small to reduce the chance of wind erosion (Government of Canada 2020; US EPA 2020).

4.8. Vibration

Vibration generated by hauling trucks and other heavy equipment may be of concern to pit or quarry neighbours. These vibrations are not expected to damage neighbouring structures, but rather prompt nuisance complaints. To reduce truck vibration, roads leading to the site should be paved, regularly monitored, and maintained in a good state of repair. Truck speed should be minimized when approaching the site.

The *MECP Best Management Practice for Management of Excess Soil* recommends that reuse sites consider local traffic bylaws and prepare a traffic and transportation management plan in consultation with upper and lower tier municipalities to identify appropriate transportation routes (MECP 2016).

4.9. Soil Erosion

Soil erosion should be avoided at all stages of operation and rehabilitation of pits and quarries. Soil erosion may be caused by wind, water, and destruction of permafrost. Silt and fine sand with small quantities of organic content or clay, are the most susceptible to wind and water erosion. Erosion arising from wind is largely addressed by dust control and mitigation measures (Section 4.7). However, water erosion should be considered during the placement of excess soils to limit adverse impact to surface water receptors and/or groundwater via preferential pathways.

The *MECP Best Management Practice for Management of Excess Soil* recommends that reuse sites consider local municipal and conservation authority fill bylaws. The best management practices also recommends that reuse sites develop and implement, sediment and erosion control plans and measures to ensure that materials remain where placed and prevent discharge from the site to sensitive receptors (MECP 2016).

Most activities resulting in soil erosion occur during the extraction phase. However, since extraction and progressive rehabilitation are undertaken simultaneously some important considerations for reducing erosion during this phase are presented here. These considerations are useful to those dormant unlicensed sites that may require site preparation before the beginning of the rehabilitation.

To minimize the potential for water erosion and impact on neighbouring surface water all perimeter interception ditches, creek diversions and treatment facilities should be constructed prior to, during, or immediately after the stripping of the site. This way the operator/owner can minimize the window during which uncontrolled runoff from the site can cause an impact on neighbouring water bodies or adjacent properties. Overburden removal and grubbing should be undertaken in the warm and dry season (early summer to early fall). In this window, the ground is usually not frozen or excessively wet. If the initial site work is to be completed during the wet season, there is a higher risk that uncontrolled runoff will affect adjacent water bodies. Furthermore, handing and stockpiling wet soil materials is difficult.

However, if overburden removal or surface finishing is likely to occur during periods of intensive rainfall, care should be given to implementing temporary or permanent measures to contain and treat surface runoff from the disturbed areas or recently backfilled areas.

4.10. Climate change

Local reuse of excess soil can contribute to climate change mitigation by lowering GHG emission levels because it reduces the distance that excess soil is hauled.

Another important facet of climate change is adaptation, defined by the Intergovernmental Panel on Climate Change (IPCC) as "*the process of adjustment to actual or expected climate and its effects*" (IPCC 2014).

Ontario has a relatively large geographical area, and the impact of climate change on different parts of the province is anticipated to be varied. However, the following general patterns will be common across the province over the next decades: an increase in annual precipitation level and an increase in annual average temperature (Deng et al. 2018; Piryonesi 2019). The increase in precipitation levels and number of days of precipitation, as well as an anticipated increase in the frequency of high intensity precipitation events may increase surface runoff and increase erosion across the province. Furthermore, it is suggested that climate change will increase groundwater recharge as a result of the overall increase in precipitation and increased water infiltration due to an earlier spring melt (Jyrkama and Sykes 2007). The changes in temperature and precipitation in Northern Ontario may result in a shift from continuous permafrost to discontinuous or sporadic permafrost (Tam 2009, 2014). The destruction of permafrost is one the factors contributing to soil erosion in these areas.

Wind may also be affected by climate change. Some studies suggest that frequencies of future wind gust events are projected to increase by the end of the century. For example, two studies in Ontario by Cheng et al. (2012, 2014) predicted the annual mean frequency of future wind gust events with a speed above 70 km/h will increase by 20 per cent by the end of the century. Such increase in the frequency of strong winds can contribute to the erosion of soil.

Finally, climate change is known to impact the balance of invasive and native species in an area. This is true of both aquatic and terrestrial wildlife and plants (Van Zuiden and Sharma 2016). Therefore, these changes must be considered when making policies and strategies to manage invasive species. Regarding the impact of climate change on aquatic species, typical impacts are higher water temperatures, shorter duration of ice cover, change in streamflow patterns and increased salinization. Such changes can modify the ecological impacts of invasive species by enhancing the virulence of some diseases or by boosting their competitive or predatory effects on native species. Climate change will also change the pathways by which invasive species reach aquatic systems by facilitating the spread of species during floods, which will have higher frequencies, and by expanding fish-culture facilities and water gardens (Rahel and Olden 2008). Similar evidence is available about the influence of climate change on the introduction of invasive or parasitic terrestrial species in Canada and Ontario. For example, newly introduced pests will increase in range and relative abundance as a result of increase in average temperature (Olfert and Weiss 2006).

4.11. Aesthetic Issues

Some reports have indicated that the rate of rehabilitation of pits and quarries (area of land that is restored to original state or a beneficial non-disturbed state) in Ontario has been inadequate (Port 2013). The practice of not rehabilitating pits and quarries prior to 1970s has left an estimated 8,000 abandoned aggregate sites in Ontario (some of which are already rehabilitated after the 1990s), which are aesthetically displeasing and environmentally degrading. They are a concern because of their steep slopes (safety hazards), erosion and slower natural regeneration. The presence of these sites has damaged the public image of the aggregate industry, which is sometimes perceived by the public as a risk to property value and water resources.

5. Conclusions and Recommendations

The current definition of 'inert fill' in *Policy A.R. 6.00.03* which is based on Ontario background site condition values, limits opportunities for beneficial reuse of excess soil in the rehabilitation of pits and quarries and may be overly conservative for several common scenarios, particularly considering new excess soil regulations, rules and associated volume independent reference standards.

The MECP excess soil tables may be used as an appropriate alternative to background site condition values for a typical pit or quarry setting as follows.

1. Tables 2.1 and 3.1 may be used in a pit or quarry above the water table in potable and non-potable groundwater conditions, respectively.
2. Tables 4.1 and 5.1 may be used to place fill above the water table and below 1.5 m of the surface when Stratified Conditions are met.
3. When a site is less than 30 m from a surface body of water (e.g., a stream or pond) and/or if the rehabilitated site will include water body, Tables 8.1 and 9.1 must be used to protect the aquatic life.
4. While Tables 6.1 and 7.1, also known as shallow soil tables, may be appropriate options for placing soil below the water table, this Scientific Report prescribes Table 1 due to the high uncertainty in metal and fate and transport under the water table. Note that component values related to vapour intrusion via groundwater (i.e., GW2 and S-GW2) may be overly conservative for pits and quarries where the water table is around 3 m below ground or deeper given that the standards assume a limited soil thickness and no biodegradation of a contaminant between source and receptor.
5. Tables 8.1 and 9.1 values are anticipated to be overly stringent in some situations because they were developed to protect benthic organisms. Since benthic organisms are typically not directly exposed to contaminants when rehabilitating a pit or quarry (except within a 30 m distance of a water body or wetland), Tables 8.1 and 9.1 and *Shore Infilling Guidelines* are expected to be conservative.
6. Appropriate application of generic standards is dependent upon a QP developing a conceptual site model, evaluating the specific reuse site setting and considering the assumptions and limitations of the models used to develop the generic site condition standards.

In circumstances where generic standards are considered overly conservative, application of the BRAT may provide greater flexibility in modeling the site-specific conditions of a pit or quarry. While many elements of the BRAT are relevant to pit and/or quarry sites, QPs must be aware of some of the limitations of the BRAT when working with it:

1. The range of hydraulic conductivity does not cover highly permeable material as gravel as well as fractured or dissolved rocks such as karst limestone. Preliminary analysis of existing ranges of hydraulic conductivity in the BRAT suggest that some chemicals are not sensitive to hydraulic conductivity. Further analysis of the influence of conductivity on contaminant transport may allow pit and quarry sites with potential preferential pathways (e.g., fractured rock, faults, conductive soil seams) to better evaluate risk of adverse impacts to offsite receptors. However, given the uncertainties in modelling groundwater flow through this type of material, presence of preferential pathways, this is a higher risk activity within BRAT and likely well beyond the original modelling domain of the Domenico model that is built into the standard tables and the BRAT. This Scientific Report prescribes Table 1 for such situations, but QPs may consider to using Tables 6.1 and 7.1 as their GW3 component value is not based on Domenico equation.
2. Further consideration should be given to modeling the soil to groundwater leaching pathway in circumstances where the water deviates from neutral pH, particularly for soils that will be placed, or anticipated to be in contact with groundwater. The mSPLP method was developed to model precipitation leaching and is based on an unbuffered slightly acidic water (pH of 5), while groundwater can have more varied pH. Groundwater pH is anticipated to affect contaminant solubility and toxicity, and the mSPLP may not adequately represent the mobility of parameters (particularly metals) in circumstances where soil is placed into groundwater. This is an area that may require further research in future.

This report also investigated potential impacts arising from non-chemical contaminants that are not addressed by *O. Reg. 406/19* and the *Soil Rules*, including biological contaminants, invasive species and physical impacts to groundwater (e.g., turbidity). QPs should consider these issues and consider the additional testing or implementation of risk mitigation measures to limit impacts arising from these non-chemical contaminants.

6. Acknowledgements

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8. Appendix

8.1. Appendix 1: Overview of Rules for Soil Management and Excess Soil Quality Standards

8.1.1. Part I: Rules for Soil Management

The rules identify required activities (the items listed below are not required for all sites): that must be completed prior to the transfer of excess soil to a reuse site including:

- **Assessment of past uses:** This includes investigating the history of the site[23] and evaluating contaminants of potential concern (COPCs) that may contribute to areas of potential environmental concern (APECs). The *QP* can use different tools to achieve this goal: examining past records, existing environmental assessment reports, publicly available documents such as from ERIS[24], site reconnaissance and interviewing others. The findings must be presented in a conceptual model consisting of figures and information about all necessary pieces, including neighbouring properties, roads, and information about potentially contaminated areas.

Sampling and analysis plan[25]: Sampling is conducted to evaluate APECs identified during the assessment of past uses to determine the concentration of COPCs within the volume of soil anticipated to become "excess" to the site as part of the construction project. The sampling plan should determine the areas requiring sampling and provide a rationale for why soil in other areas may not require sampling. The sampling and analysis plan must be developed and implemented under the supervision of the QP. Cross-contamination must be avoided. If a contaminant is discovered that does not have a value in standard tables, the QP can ask a laboratory for further analysis on that contaminant. The number of samples must be enough to determine the subsurface stratigraphy and the contaminant location, and the samples must be collected from representative depths. Moreover, samples must be collected from the areas with maximum contamination concentrations, with field logs recorded for all sampling locations. The representative pH of the soil must be determined as well. Soil samples must be analyzed for the following parameters: petroleum hydrocarbons; metals and hydride-forming metals (e.g., barium, arsenic and lead); SAR and EC; leachate analysis (if required); and any contaminant identified in the assessment of past uses. For stormwater management pond

[23] Numerous studies have shown the importance of knowing the history of a site. Hutchinson and Whitby (1974) collected soil samples in the vicinity of a metal smelter near Sudbury and reported that surface soil contaminated by heavy metals was detected up to almost 50 km from the location. Similar results were reported by other researchers (Gratton et al. 2000; Taylor and Crowder 1983).This study highlights the importance of considering regional anthropogenic activities that may alter soil chemistry at sites that would otherwise be considered to be "background" (i.e. non-impacted) by a point source at the site.
[24] Environmental Risk Information Services.
[25] Sampling and analysis plan is not necessarily required for all cases. If a site satisfies the exemption conditions of Schedule 2 of *O. Reg. 406/19*, the requirements of Section 8 of the regulations do not apply.

sediments, samples must be analyzed for the following parameters: petroleum hydrocarbons; metals and hydride-forming metals (e.g., barium, arsenic and lead); polycyclic aromatic hydrocarbons, SAR and EC; cyanide; and leachate analysis for certain contaminants. These parameters are the minimum requirements, and further analysis may be needed.

The standard defines a minimum number of samples for each volume when conducting *in situ* sampling. This starts with a minimum of three samples for less than 600 m^3. If the soil volume is greater than 600m^3, then one sample per every 200 m^3 up to 10,000 m^3, followed by one per 450 m3 up to 40,000 m3 and then one per each additional 2,000 m3 thereafter). It also sets requirements for sampling from a stockpile, such as collecting samples from different depths. Similarly, the number of samples and the parameters required to be analyzed are determined for stormwater management pond sediment. Furthermore, the standard identifies the responsibilities of the QP for handling, storing, and analyzing the samples, which are in line with *O. Reg. 153/04* (Government of Ontario 2004) and its *Protocol for Analytical Methods* (MECP 2011).

If a leachate analysis is required, which is the case for most sampling programs, a minimum of three soil samples must be submitted when the volume is less than 600 m^3. These samples should be collected from areas where 90% (or higher) of the highest contaminant concentrations were found. Furthermore, a leachate analysis must be conducted on 10 per cent of the samples.

If the contaminant concentration exceeds the *O. Reg. 153/04* Table 3 for Residential/Parkland/Institutional (RPI) land use and determining site-specific standards (e.g., by using the BRAT) is not viable, the QP can depart from sampling and testing requirements set out in the *Soil Rules*, however some sampling may still be required by the reuse site. This is only for cases where the QP has decided that the only disposal option for the contaminated material is to transport it to a Class 1 soil management site which include a MECP licenced landfill or dump.

- **Soil characterization report:** This section documents the outcomes from implementing the sampling and analysis plan and includes tables and figures that describe the following: areas of potential concern, areas of sampling and their dimensions and approximate depth to water table. All information with regards to sampling must be included. Examples include number of collected samples, their locations, analyzed parameters and their rationale, date of sampling and analysis as well as a discussion of the analysis results. If the QP decides that a part of the soil should be placed in a MECP licenced landfill, then the border between that contaminated area and the rest of the reusable soil should be delineated. The report must be signed by the QP.

- **Excess soil destination assessment report:** This report must include the estimated volume and quality of soil to be removed from the source site and the anticipated beginning and end date of soil removal. Regarding the destination site[26], information such as the type of reuse site, the regulating authority and the availability of a site management plan should be included as well. A contingency plan must be developed in case the reuse site cannot receive the soil. In such cases, the truck driver must know whether to deposit the soil in another location or return it to the source site.

- **Development and implementation of a tracking system:** Some of the most important information that a tracking system should report include:
    - Locations of the source site where the soil was excavated and the soil quality in those locations
    - The quantity of the load of soil being exported
    - The location of the reuse site as communicated to the truck driver
    - The date and time the soil left the source site and was received at the reuse site
    - The person responsible for investigating the loads at the source site
    - The information of the vehicle transporting the soil, its driver, and the firm
    - The contact information of the person receiving the soil at the reuse site
    - A confirmation that the quantity and quality of the soil is the same as what left the source site.

Furthermore, the tracking must be able to track the accumulative number of trucks and volume of soil leaving the source site and arriving at the reuse site. Moreover, it should be able to produce reports upon request and include procedures to prevent fraud.

- **Qualified person:** A QP must declare that the project leader has provided them with access and information to all parts of the project and that all project documents are developed according to the excess soil regulation.

Another important component of the *Soil Rules* is Section D, which discusses reuse rules for specific circumstances. In this section, rules for specific types of soil (e.g., soil blended with compost, dewatered/solidified soil, and salt-impacted soil) are explained. Of particular importance is the exemption of salt-impacted soil when the chemicals are resulting solely from

[26] A written consent from the receiving site is needed indicating that they have agreed to take the soil.

deicing salt in winter. The standards can be deemed to be met if the conditions of page 37 (or Section D.1.(3) of Part I) of the *Rules* document are met. EC and SAR are among the most common contaminants of soil in Ontario due to road salting. It is important to consider whether soil impacted by such contaminants could be imported to pits and quarries based on the setting and final use.

8.1.2. Part II: Excess Soil Quality Standards

Part II explains the generic and site-specific standards for accepting excess soil. Tables 2 to 9 are for small volumes (<350 m^3) of excess soil and are consistent with *O. Reg. 153/04*. Table 1 and Tables 2.1 to 9.1 are volume independent. Both sets of tables have component values for different land uses. A leachate analysis is necessary for contaminants for which soil-to-ground water component values are not determined (e.g., metals and hydride-forming metals). Contaminants with analytical limitations also require a leachate analysis. There are several consideration that can be considered when determining the requirement of a leachate analysis (including being identified as a COPC that is associated with past uses or whether the bulk soil concentration meets background concentration). The support of a QP is highly recommended when evaluating the applicability of generic soil quality standards to a given setting. Failure to do so may potentially result in an adverse impact to human health and/or the environment.

Table 1 represents background concentrations of parameters in Ontario soil and, thus, may be applied regarding any reuse site and any volume of soil. Small volume tables should be only used when the soil volume is less than or equal to 350 m^3. For volumes larger than this, volume independent tables must be used. When using the tables, note that the 350 m^3 volume does not apply only to the imported soil and should be compared with the sum of the imported soil and the impacted or suspected to be impacted soil at the reuse site. This implies that there is some basal understanding of soil quality at the reuse site, though this is not well parameterized by *O. Reg. 406/19* or the associated rules.

The development of the soil quality standards has been based on a set of assumptions. When these assumptions are invalid for a site, the QP can determine the appropriateness of these standards. Generally, the potable tables should be used unless the conditions of section 35 of *O. Reg. 153/04* (such as the existence of drinking water service offered by a municipality and the absence of wells used for drinking water) are satisfied. Even in such conditions, written consent from the governing municipality is needed. When the location of the final placement of the excess soil is within 30 metres of a water body, Table 8 (or 8.1) and Table 9 (or 9.1) must be used depending on the potability of the groundwater. Shallow soil tables (Table6 and 7 or 6.1 and 7.1) must be used when (1) the depth of soil is less than two metres in more than one-third of the reuse sites or (2) when groundwater is in close proximity to buildings of concern (a separation distance of less than 0.8 metres between the bottom of the gravel crush of an existing or future building and the top of the capillary fringe, or if the depth to the water table is less than 3 metres from the surface of the soil). If the rules require the application of two tables at the same time (e.g., Table 6.1 and Table 8.1), then the lower value of the two must be used. This instruction also applies to property use. If the reuse site has more than one property use, then the standards applicable to the more sensitive property use govern.

If Table 1 or small volume tables are used for excess soil volumes of less than 350 m^3, then leachate analysis is not required. If Table 1 is used for excess soil volumes greater than 350 m^3, the need for leachate analysis is determined according to Section A.1.(7) of Part II of the *Rules for Soil Management and Excess Soil Quality Standards* (MECP 2020b).

Soil quality standards can be met in two ways: the single point compliance method and the statistical method. When using the single point method, all samples must meet the applicable soil quality standard. If two or more *in situ* samples of soil are taken from the same sampling location that are at the same depth and within a radius of less than (or equal to) two metres, then the average of those sampling results must be less than or equal to the applicable excess soil quality standard.

For the statistical method, the following conditions must be met. First, 90 per cent of the samples must be less than or equal to the pertinent soil quality standard. Second, the mean concentration of the samples must be less than (or equal to) the excess soil quality standard at a 95 per cent confidence level. Third, none of the individual samples should exceed the corresponding ceiling value of that contaminant given in Appendix 3 of the *Soil Rules* document. Additional requirements for the use of statistical attainment approach are provided in Section A.1.(10) in Part II of the Rules document, including the minimum number of samples.

The process of deriving ceiling values is explained in the *Rationale Document for Development of Excess Soil Quality Standards (Rationale Document)*, which is discussed in the next section. In short, the ceiling values are the lowest of these three values: 2x the applicable excess soil quality standard, effect-based Cap and Acute Cap. The ceiling value should not be lower than either the analytical reporting limit (RL) or typical soil background concentration found in Ontario. It is worth mentioning that when site-specific standards are developed using the BRAT, site-specific ceiling values are generated for use if the statistical method is deployed.

8.2. Appendix 2: Details of Jurisdictional Overview

8.2.1. Ontario

In addition to the literature discussed above, the soil management approaches used by municipalities in Ontario were studied. This task was conducted via interviewing practitioners and relying on a report by Conestoga-Rovers & Associates (CRA), who conducted a study about the excess soil management approaches adopted by municipalities in Ontario (Conestoga-Rovers & Associates 2015). The CRA was retained by the MECP to assist the Ministry in collecting information about the management of excess soil in Ontario and other jurisdictions. The CRA study included a review of the bylaws developed and the common approaches adopted by 14 municipalities in Ontario.

It was reported that, prior to the development of *O. Reg. 406/19*, there was no clear and widely accepted definition of clean soil across the province, and different municipalities had different criteria. As a result of this lack of clarity, as well as the variance in capacity of different municipalities, they have adopted different approaches in their bylaws. In the absence of clear regulations and lack of capacity to enforce municipal bylaws, some municipalities have taken a more restrictive approach. They have put different restrictions on soil coming out of their jurisdiction. This approach can limit the opportunities for the rehabilitation of pits and quarries. On the other hand, some municipalities have been using MECP *Record of Site Condition* (RSC) standards, instead of Table 1, as fill acceptance criteria. A few municipalities have created bylaws that recognizes the need of some sites, such as pits and quarries, for importing large volumes of fill. Upon completion of the backfilling activities, and prior to the site being utilized for its new purpose, they t require that an RSC to be filed. This requires a QP to confirm that the soil and groundwater quality satisfy the MECP RSC standards. Therefore, it is important for pit and quarry owners/operators to be familiar with *O. Reg. 153/04*. Note that when an aggregate site changes its land use to more sensitive use, a record of site condition (RSC) is generally required.

8.2.2. Alberta

Alberta Ministry of Environment and Parks (AEP) has prepared a framework for the management of contaminated sites (AEP 2019). One of its three main goals is ‘productive use’, which includes encouraging remediation and return of contaminated sites to productive reuse. This framework provides users with three tiers of management options: Tier 1, Tier 2 and Exposure Control. Tier 1 has the most conservative approach, which assumes that all exposure pathways are present. Given its stringent values, it could be applied to all sites, including the more sensitive ones, without any modifications. This level of safety comes with many restrictions. Therefore, in cases that more information about the site is available, Tier 2 could be applied, which is a modified version of Tier 1. Tier 2 allows for more flexibility by considering site-specific conditions and excluding pathways that are not the matter of concern for a certain site. Exposure Control involves risk management through exposure barriers or administrative controls according to site-specific risk assessment.

Both Tier 1 and Tier 2 provide the same level of protection. The difference is simply in the amount of site-specific data used to create each guideline. Tier 1 entails simple tabular values developed using conservative assumptions. If enough evidence is available that the site condition is more sensitive than conservative assumptions of Tier 1, then Tier 2 approach could be used based on site-specific data. In such cases, the resulting Tier 2 guidelines may be more stringent than Tier 1 values. On the other hand, sites that are less sensitive may have Tier 2 guidelines that are less restrictive than Tier 1 numbers delivering the same protection level.

Background concentrations can vary with soil parent material or geological formation, depth, and hydrologic characteristics of a site. These factors can lead to large spatial variations in background concentrations that may or may not be easy to predict. Therefore, assessing background using representative sampling is a must. The Alberta guidelines (AEP 2019) recognize the diversity in background concentration of soil in Alberta. It defines background concentration as “the natural concentration of that substance in the absence of any input from anthropogenic activities” or “the background concentration in the surrounding area because of generalized non-point anthropogenic sources.” In cases that the background concentration is more than Tier 1 guideline values, the remediation level should be set to background or to guidelines developed using Tier 2 methods.

The definition of background should not be applied to any situation in which anthropogenic activities resulted in redistribution of soil or water sources with elevated substance concentrations. For instance, PAHs can be considered a background in urban surface soil because of the emission of automobiles. However, additional PAH contamination caused by industrial activities at a site cannot be considered part of the urban background. Another example is when material with elevated conductivity is brought to the surface from deeper sediments or groundwater because of anthropogenic activities. This should be considered as a contaminant of potential concern even if the surrounding area has a high conductivity.

8.2.2.1. Pit and Quarry Rehabilitation in Alberta

A *User Guide to Pit and Quarry Rehabilitation in Alberta* is a document published by Alberta Environment Land Reclamation Division (Green et al. 1992). A significant portion of the Guide is devoted to rehabilitation of pits and quarries. The Guide is focused on operational aspects of rehabilitation and does not include a discussion on soil quality standards. Different post-rehabilitation land uses are discussed in this document, and considerations for choosing a final cover are enumerated. These categories of reclamation land use include agricultural, forestry, wildlife habitat, fish habitat, recreation, residential, and industrial. The proposed factors, which must be considered for deciding the final cover, are regional limitations, environmental limitations, size and depth of the pit or quarry, surrounding land use, land use zoning, and costing. Finally, the Guide devotes a chapter to the main considerations for reclamation of each land use category, the appropriate methods, and the regulations concerning each category.

Regional factors such as climate, type of soil, landforms, and vegetation cover strongly affect the decision about the final cover. For instance, Alberta can be divided into four regions based on these factors: prairie grassland, aspen parkland, boreal forest, and foothills. In the prairie grassland, high summer temperatures, strong winds, low precipitation, rapid changes in winter temperatures and long periods of sun result in losses of vegetation and water and soil erosion. Consequently, grasslands are the predominant native habitat type, with limited presence of shrub and tree communities. Most common land uses in the grassland area are cattle production and cereal crop production. On irrigated lands, forage and vegetable production are common as well. Due to the extremes of climate in this region, wildlife species are generally restricted. On the other hand, the favourable moisture conditions in aspen parkland can support a diverse mixture of trees, shrubs, and herbs. This region has some of the best quality soil in Alberta and is one of the most productive farming areas. Clearly these environmental differences limit the type of land uses that can be chosen for a successful rehabilitation.

When the site is rehabilitated for agricultural purposes, the following considerations are important: Adjacent land use and zoning, soil type and availability, and shape and size of the pit or quarry. When the pit or quarry is located within a large pastureland area, rehabilitation to a pastureland may be most suitable. However, in a cereal crop area where cattle grazing is uncommon, this choice would not be appropriate. Sites in depressional areas may be too wet for cereal crops. Soil type is another important factor and is closely related to landforms and geological formations.

Soil surveys are usually required for development and reclamation approval of large pit and quarry operations. A soil survey is recommended in agricultural areas with soil of CLI Class 1 to Class 3 (i.e., good soil according to Canada Land Inventory classification). Such surveys can determine the quantity and quality of topsoil and subsoil that are available for rehabilitation, which can determine the best methods of soil replacement and the need for fertilization. Farming efficiency is highest in rectangular fields with no obstructions or severances. So, if the rehabilitation area is too small to be used as a separate field, it can be incorporated into the adjacent fields. Careful consideration must be given to providing suitable access by farming equipment to the rehabilitated site.

The BMP is mostly silent about the quality of imported soil, but one of its references about agricultural rehabilitation includes some guidance (Alberta Soils Advisory Committee 2004). This guideline explains the best practice for sampling agricultural soil and its analytical requirements. Some of its parameters of interest are pH, saturation percentage, electrical conductivity, soluble cations for determining salinity and sodicity (i.e., ions of Ca, Mg, Na, K). There is no mention of concentration of other chemicals in the imported soils.

Another final cover discussed in the BMP is residential or industrial lands use. One of the rehabilitation methods for this category is backfilling. The guidelines briefly discuss the materials that are appropriate for backfilling a pit or quarry that will be used for residential or industrial purposes. Natural inorganic fill material is recommended for backfilling. Ideally, such material should be placed and compacted in thin layers. The BMP allows other materials, such as waste concrete when it is placed at a depth of 1.6 metres or more. But it adds that concrete blocks and similar debris can create installation problems for deep foundation systems such as piles that may be used later. The BMP forbids the use of organic soil, landfill material, or domestic garbage as backfill material under all circumstances. Such material can cause instability in the foundation of future structures. In addition, organic fill may generate methane gas, which can lead to long-term health issues and fire hazards[27].

8.2.3. British Columbia (BC)

The British Columbia Ministry of Energy Mines and Petroleum Resources (BCMEMPR) in collaboration with the provincial Ministry of Transportation and Highways as well as Natural Resources Canada developed *Reclamation and Environmental Protection Handbook for Sand, Gravel and Quarry Operations in British Columbia,* which is a detailed document about the best practices for the rehabilitation of gravel pits and quarries in BC (BCMEMPR et al. 1995). The document is developed based on *Alberta User Guide to Pit and Quarry Rehabilitation* discussed above (Green et al. 1992), and it shares the same structure and even some graphics and portions of texts. These documents precede the current excess soil or contaminated sites regulations in BC and Alberta. Therefore, they almost overlooked the requirements about the quality of imported material for backfilling. The BC handbook

[27] In addition, methane is a considerably more potent greenhouse gas compared carbon dioxide, and its emission is a contributing factor to climate change.

(BCMEMPR et al. 1995) limits its recommendations regarding the quality of imported backfill to characterizing the history of the source site and states that:

> *"Contaminated backfill can inadvertently be backhauled from a contaminated site if strict control is not exercised over all backhaul activity. Backhaul loads should only be accepted if the source of the material is accurately known. If the backhaul soil comes from a site that is known to be contaminated, you must obtain documentation from the shipper that the soil complies with all of the contaminant criteria that are applicable to the planned end use."*

The *BC Handbook* covers the entire life cycle of a pit or quarry. It starts with the legal approvals for establishing a pit or quarry. Next, it delves into the most important considerations during the planning phase followed by a discussion about important requirements for the operation/extraction stage (e.g., site preparation, timing, on-site water management including drainage and dewatering, site clean-up, and closure considerations). It also includes some information about best practices for minimizing the impact of pit and quarry operations and rehabilitation on groundwater, surface water, soil, and neighbouring communities. Where appropriate, some of these best practices are mentioned throughout the current document (see Sections 4.5 to 4.9). Another interesting point about the *BC Handbook* is the presence of four case studies. This section describes the rehabilitation of four different aggregate sites in BC with different end uses (fish habitat, agricultural, and recreational). The handbook describes the following areas for each project: project background (including geological conditions), planning and end use, the adopted rehabilitation techniques, and the assessment of rehabilitation success. The rest of the structure is similar to the *Alberta User Guide* and is devoted to identifying the appropriate end use for a pit or quarry and how the rehabilitation techniques vary depending on end use.

8.2.4. Massachusetts

Massachusetts Department of Environmental Protection (MassDEP) regulates the reuse of excess soil for rehabilitation of aggregate pits and quarries via *Interim Policy on the Re-Use of Soil for Large Reclamation Projects* also known as *Policy # COMM-15-01* (MassDEP 2015). This policy was created in 2015 to allow the reuse of soil in rehabilitation of pits and quarries that require greater than 100,000 cubic yards (76,455 cubic metres) of fill. MassDEP requires the proponents to submit the following information:

- Implementation of a detailed Soil and Fill Management Plan that specifies how material will be sampled, documented, tracked, transported, and managed as well as what materials are permitted and not permitted

- Detailed plans specifying how material will be managed at the rehabilitation project to prevent nuisance conditions, such as noise, odour, litter, and dust
- Detailed Stormwater Management Plan to prevent impacts to sensitive receptors
- Detailed Wetlands Impact provisions, including, as applicable, a requirement to obtain an Order of Conditions, Determination of Applicability, or other approval or permit to proceed with the project as designed
- A plan for communicating with the public and involving interested parties at key points in the implementation of the reclamation project
- Oversight by a Licensed Site Professional (LSP) or other qualified environmental professional and/or Third-Party Inspection program
- Knowledge of and intention to comply with all applicable laws and regulations
- Stipulated penalties for noncompliance with the Administrative Consent Order

Regarding the quality of the imported material, MassDEP requires the fill to meet Table 2 or Table 3 of *Similar Soils Provision Guidance* (MassDEP 2014). Table 2, which is more stringent, is based on an RCS-1 reuse site, and Table 3 is based on RCS-2. Reporting Category RCS-1 applies to locations with the highest potential for exposure, such as residential buildings, playgrounds and schools, or locations within the boundaries of a groundwater resource area. Reporting Category RCS-2 applies to all other locations, which are less sensitive. The standards of Table 2 and Table 3 of *Similar Soils Provision Guidance* are determined by finding the minimum RCS-1 and RCS-2 Reportable Concentrations and background concentration multiplied by a factor (>2.5).

Since 2018, MassDEP has allowed street sweepings to be reused at pit and quarry rehabilitation projects (MassDEP 2018). *Policy # BAW-18-001,* developed by MassDEP in 2018, explains the rules for reuse and disposal of street sweeping material. According to this policy, sweeping must be inspected, and all solid waste and debris must be removed and disposed in a solid waste site. The number of samples required for analysis is one sample per 100 cubic yards (76 m^3) for urban centres (MassDEP 2018).

8.2.5. New Jersey

The New Jersey Department of Environmental Protection (NJDEP) has included a chapter about quarries/mines in its guidance document about managing fill material (NJDEP 2015). However, it is discussing pits and quarries as a source site rather than a reuse site. The NJDEP document defines licenced quarry material as a class of material distinct from alternative or clean fill and not necessarily clean material. Therefore, it requires the QP (or investigator) to assess the quality of the material received from a quarry. So, the NJDEP requires the QP to check the source of the material. If it is from a quarry with certification the QP may rely on the certification for receiving the material without sampling. This is only for materials delivered from a quarry with a certification that clearly states the source of the material and state that the fact that the quarry has not been exposed to a discharged hazardous substance at any stage of extracting the aggregate. When receiving material (i.e., rock, sand, or gravel) from an unlicenced or without certification quarry, the material needs to be evaluated using proper sampling to ensure compliance with the definition of clean fill. Note that having a certification for a licenced quarry does not preclude the QP from testing the material. In cases that numerical/analytical data are provided with the certificate, this data can be used for assessing the soil if the QP finds it reliable.

Record keeping is a must whether the material is delivered from a licenced or unlicenced quarry. The QP should record the information about the quantity received, source of material and its location, contact information of the people at the source. This is easier for material of licenced quarries with certification as some of this information may be available in the certificate.

8.2.5.1. Sampling the Received Material

The source of the received material is a good measure to determine whether sampling is required before placing the excess soil at the reuse site (the source's location could be inside or outside the state). As mentioned above, the material belonging to unlicenced quarries without certification should be sampled. Furthermore, if the source generates fill based on a blending process, which often includes mulch, composted organic materials, or peat moss, there is a need for sampling and analyzing the material before placing it in the rehabilitation area. Other sources of clean excess soil include construction projects and sites with contaminated material that has been treated, so it meets the designation of clean fill. When the sources are heterogenous, the QP should use professional judgment to sample each component separately before blending and placing the received materials. Soil resulting from a clean cap, and even soil in rootballs of shrubs and trees planted in a cap, do not need analysis or sampling.

Regarding the method of sampling, if QPs have prior knowledge that a part of the soil is more likely to be contaminated, they can use biased sampling. Otherwise, sampling must be conducted randomly to represent the entire load or stockpile. This unbiased sampling should be based on the grid-based method by the US *Environmental Protection Agency (EPA)* (United States Environmental Protection Agency 2002) or other proper statistical sampling techniques (Gilbert 1987). Samples must be taken from all parts of the soil including surface and inner layers. When the size of a stockpile is that large, it makes sampling difficult, it should be regraded to smaller piles to facilitate physical access to interior parts.

8.2.6. Minnesota

The Minnesota Pollution Control Agency (MPCA) framework for excess soil use defines three categories of potential fills: clean fill, unregulated fill, and regulated fill (MPCA 2012a). Clean fill refers to soil that is not affected by any form of spill or release. There are no limitations or restrictions surrounding the use of clean fill. Unregulated fill describes soil that has been affected by a release, but its concentration is less than the conservative values proposed by the MPCA. Note that this type of fill does not necessarily show signs of contamination. The MPCA (2012b) has developed a set of best management practices for using unregulated fill.. Regulated fill includes soil contaminated, to a certain degree, by any of the following contaminants: diesel range organics (DRO) or gasoline range organics (GRO); metals or semi-volatile organic compounds; and volatile organic compounds (VOCs). Note that in all these cases the concentration must be lower than a threshold for the soil to be reusable.

When working with regulated fill, a sampling plan is needed for soil characterization. First, sometimes the naturally occurring concentration of some metals exceed the determined Soil Reference Values (SRVs). Examples of these metals are copper, selenium and arsenic. Such soils should not be considered impacted if there is no evidence of contaminant point sources. Second, sometimes the presence of DRO could be a result of the presence of natural organic material in the soil. Examples of such organic matters are coal tars or other material containing polynuclear aromatic hydrocarbons. Therefore, the history of the property (e.g., the presence of a petroleum source) should be taken into consideration when dealing with DRO data. Averaging of sampling data is only acceptable if the number of collected samples is large enough. Furthermore, hot spots must be excluded anyway. Regulated fill may contain a minimal amount of inert debris (e.g., brick, concrete, metal). Since regulated fill contains historical urban fill, it may be discoloured compared to native soil. If volatile organic matters are present in regulated fill, special placement criteria at the reuse site may apply.

There are several materials that are excluded from the Minnesota fill reuse framework:

- Soil contaminated with agricultural chemicals
- Soil mixed with asbestos-containing material
- Soil containing more than a *de minimis* amount of demolition debris and industrial waste
- Characteristically hazardous soil (or contaminated by a listed hazardous waste)

- Soil exhibiting chemical odours
- Non-soil materials (e.g., crushed concrete and bricks). Such material must be managed according to the requirements of the MPCA's Solid Waste Program
- Dredge material

The MPCA sets several requirements for importation of regulated fill. According to these rules, both generating and reuse sites must be registered (as appropriate for the type of existing contaminants) under related programs. Both source and reuse sites must have Soil Management Plans approved by the MPCA. Furthermore, they both must have completed environmental assessments recommended by the MPCA. Regulated fill can only be reused at restricted sites (commercial or industrial), which have similar contaminants (in terms of type and concentration). For instance, if the regulated fill contains heavy metal, it should only be reused at a site with existing concentrations of heavy metals at a similar level. The placement of regulated fill should not pose any threat to human health. So, the following scenarios must be checked: human health risk via direct exposure; the potential for groundwater impacts because of leaching; the risk of soil vapour migration and intrusion; and the potential for surface water impacts.

Before the beginning of importation/exportation, a regulated fill application must be submitted to the MPCA. This application must include information about both the generating and reuse site and other necessary information for approval. Final placement of imported soil must follow the timeframe and other requirements determined in the regulated fill application. Records of implementation must be retained and submitted to the MPCA. Of course, the reuse site must be locally permitted and must have a legitimate need for fill.

Finally, it is important to point out that the MPCA considers regulated fill to be solid waste. What was mentioned above applies only to cases that their contaminant concentrations are below determined levels. In those cases, the MPCA has developed a Program Management Decision on regulated fill which allows the Voluntary Investigation and Cleanup Program (VIC) and Petroleum Brownfields (PB) to provide supervision for the off-site use of regulated fill without a need for applying for permits from a solid waste management program.

8.2.6.1. Best Management Practice for Unregulated Fill

According to the MPCA's BMP for unregulated fill, sampling is only required if the excess soil originates from a site with potential sources of contamination. If no contamination is discovered during the environmental assessments and subsequent inspections, there is no need for soil characterization at the source site. The BMP excludes the following materials from unregulated fill:

- Characteristically hazardous soil or soil contaminated by hazardous waste
- Waste material proposed to be reused as fill (e.g., salvaged bituminous, crushed concrete, bricks, fly ash).
- Dredged material

On the other hand, unregulated fill must meet all these criteria:

- Not containing solid waste, debris, asbestos-containing material, and staining
- Free from odour
- Organic vapours less than 10 ppm
- Less than 100 ppm DRO/GRO (for petroleum-impacted soil)

The BMP recognizes that naturally occurring concentrations of some chemicals could be more than thresholds determined by the MPCA. Common examples are arsenic, selenium, and copper. Soils containing such metals are not considered impacted, unless they are located near a contaminant point source, or if field or laboratory analyses indicate the existence of contamination. Additional evaluation (about eligibility as unregulated fill) may be required for contaminants that do not have published SRVs.

Regarding the placement of unregulated fill, the BMP recommends industrial or commercial properties as the most suitable reuse sites. Placing unregulated fill at schools, daycares, residential properties, and playgrounds must be avoided. Similarly, gardens where food for human/animal consumption will be grown are not suitable either. Another category of reuse site to which unregulated fill should not be imported are locations where contaminants may be transported by run-off to lakes, rivers, wetlands, and streams.

Decisions about the need for sampling depends on the history of the source site and its neighbouring area. If the potential contamination sources are or have been present in the source site, sampling will be a must. Examples of sites in which such contamination sources exist are all categories of previously developed sites, agricultural properties, or land that may have been subject to dumping, historic filling activities, and spills. If no known or potential sources of contamination are detected during environmental assessment and subsequent field observations, then sampling is not necessary.

Sampling type and frequency must be based on the type of contamination sources, their depth, volume, and heterogeneity. The availability of data and well-maintained records are important as well. Analytical parameters must include VOCs, polycyclic aromatic hydrocarbons (PAHs), RCRA metals[28], DRO and GRO. Other parameters may be included depending on the site history. Even light contaminations by heavy metals have the risk of leaching at concentrations above the Toxicity Characteristic Leaching Procedure (TCLP) regulatory thresholds. Therefore, a TCLP analysis for heavy metals should be conducted when the concentration of a metal is 20 times (or greater than) the TCLP regulatory limit. As for frequency, a typical sampling frequency for using a photoionization detector (PID) is one sample for every 10 cubic yards of soil. More details about analytical sampling and sampling from stockpiles are given in the MPCA (1998) *Site Characterization and Sampling Document*. Similar information for the *Petroleum Remediation Program* are presented in another guidance document (MPCA 2018).

8.2.6.2. Minnesota Handbook for Reclamation of Gravel Pits

The Minnesota Department of Natural Resources prepared *A Handbook for Reclaiming Sand and Gravel Pits in Minnesota* for the rehabilitation of pits and quarries (Buttleman 1992). This handbook explains the environmental regulations for operation of aggregate sites, the steps for the development of a site plan and general guidelines for rehabilitation of pits and quarries. It further explains the requirements for two types of final land use categories: wildlife habitat and forest plantings. Other types of end uses, such as residential, commercial, and agricultural, are excluded.

Wildlife habitat is the most affordable type of rehabilitation. Sometimes animals naturally start to colonize the pit even before the beginning of the rehabilitation process. Although wildlife diversity is one of the objectives of rehabilitation, it is more practical to focus on a few key species, preferably native species, and design the site according to their needs. These species have some basic needs that should be taken into consideration during landscaping. Among the most important requirements of a good habitat are the existence of food, water, shelter, and space. A broad range of food could be provided by planting appropriate plants. Using native plants will be more beneficial to native species. Wildlife seek shelter in different places such as trees, rocks, and cracks. Sometimes artificial structures such as nest boxes or nest platforms could be used as well. The handbook also includes details about creating wetlands as an example of rich wildlife habitat.

Reforestation of aggregate sites is another common method, which could be conducted via natural forestation or direct seeding. In natural forestation, the owner simply leaves the site hoping that trees will be introduced because of natural processes. This approach is slow, and the land can take up to several decades for the site to become similar to neighbouring forests.

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[28] Resource Recovery and Conservation Act (RCRA) metals are eight heavy metals that are extremely toxic: Arsenic(As), Barium (Ba), Cadmium (Cd), Chromium (Cr), Lead (Pb),Mercury (Hg), Selenium (Se), and Silver (Ag).

A faster approach is artificial forestation whether by seeding or seedlings. Jack pine and black spruce are example of species that can be reproduced via direct seeding.

8.3. Appendix 3: Normality Analysis of Ontario Typical Ranges (OTR) Data

In this part of the report the normality of *OTR* data is assessed for two chemicals: barium and cadmium. Two methods were used for the purpose of this assessment: quantile-quantile (Q-Q) plot and Kolmogorov-Smirnov (K-S) normality test (Lilliefors 1967). Since the values of Table 1 are developed based on urban and rural categories (i.e., rural parkland for Ag/RPI and urban parkland for ICC), these analyses were performed for both categories as well as the aggregate data.

Figure e shows the distribution of barium concentration. Like other inorganic matters in the *OTR* dataset, it includes 485 readings for barium, of which 176 are urban and 309 rural. The histogram for rural and urban samples are given, respectively, in figures f and g. It is clear that none of the distributions are symmetric or close to normal. If we take the whole data as reference, there are seven examples that are above Table 1 agricultural threshold and four above residential. However, if we divide the data into rural and urban, the number of rural samples above Table 1 agricultural limit is five and the number of urban samples greater than Table 1 residential value is one. These samples represent a small percentage of the data (1.6 per cent) but still need attention, as outliers usually contain interesting information.

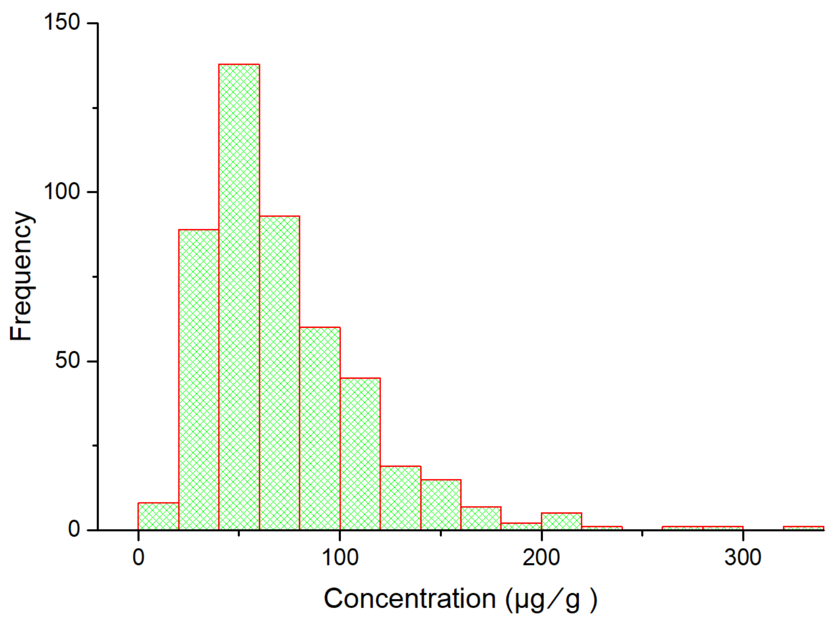

Figure e. Distribution of barium concentration in *OTR* data

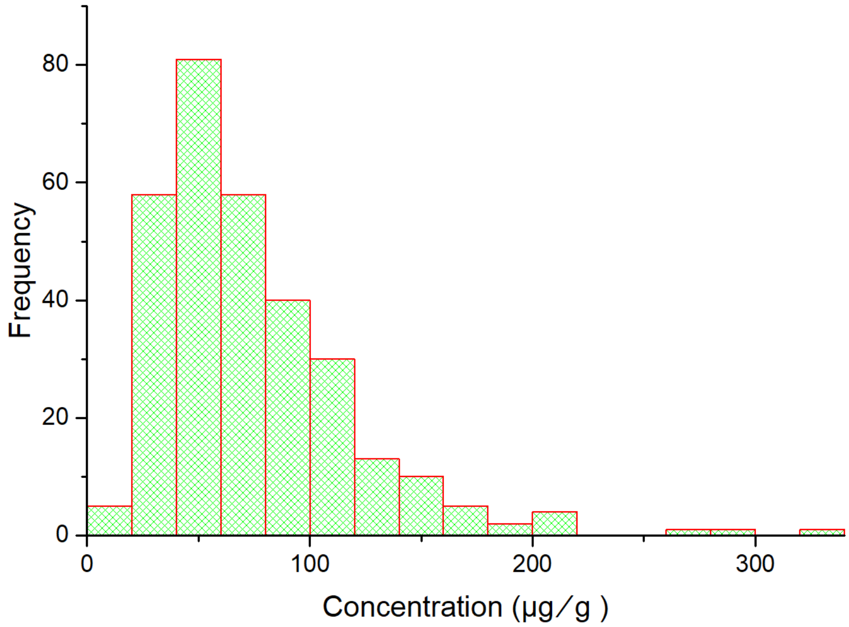

Figure f. Distribution of barium concentration in *OTR* data (rural parkland)

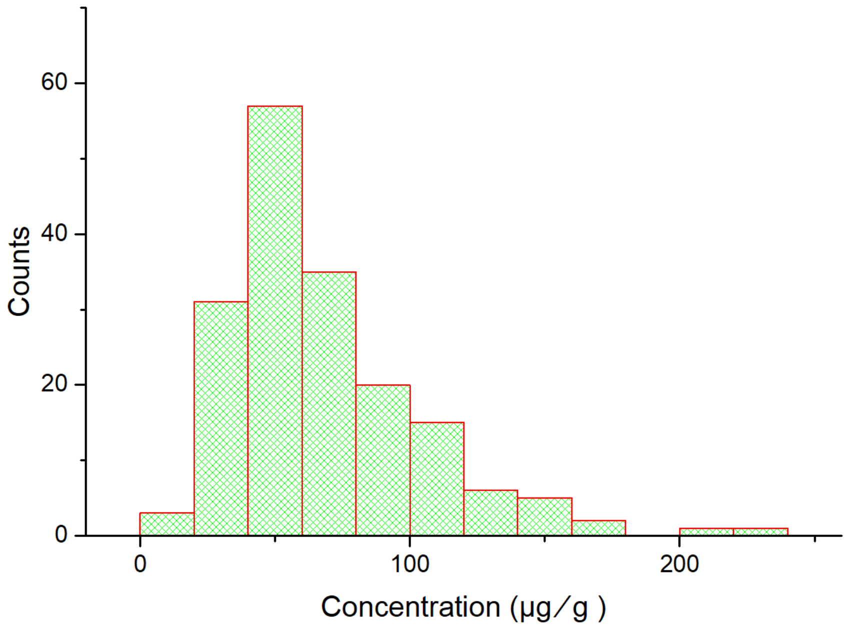

Figure g. Distribution of barium concentration in *OTR* data (urban parkland)

One of the samples exceeding Table 1 values has a concentration of 331 μg/g. This sample was collected in the Town of Perth in the east of Ontario. Such high concentrations in Eastern Ontario can be corroborated by other studies (Arcadis Canada Inc 2019; Knight et al. 2012; Sterling et al. 2017). Multiple practitioners and researchers have reported that the concentration of some metals in the Ottawa region are more than Table 1. Examples of these chemicals with high concentrations are barium, boron, chromium, cobalt, and vanadium.

These metals are often found in native clays associated with the post-glacial Champlain Sea. Sterling et al. (2017) gathered laboratory data from multiple sources and verified this claim. They developed regional standards for Eastern Ontario using an approach similar to the MECP's Table 1. However, not all barium outliers belong to Eastern Ontario. For instance, a sample collected at the Town of Red Lake, which is in the opposite corner in northwest Ontario, has a concentration of 239 µg/g.

Similarly, the histograms for cadmium concentration are presented in figures h to j. Clearly these distributions are not symmetric either. In figures h and i the existence of an outlier has resulted in a long tail. Collected near the town of Thessalon, this outlier shows a concentration of 17.1 µg/g, which is considerably more than Table 1 values for both agricultural and residential land uses (1 and 1.2 µg/g, respectively). Similar large values are cited in the literature[29] (Faroon et al. 2012), but the magnitude of this number raises the question if this sample was collected near a source of contamination or from surficial sediment material.

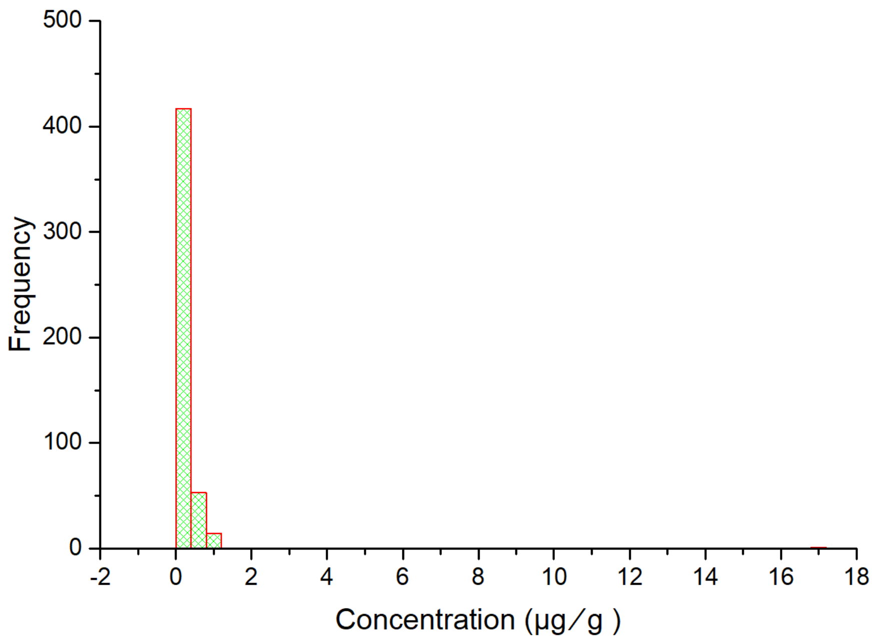

Figure h. Distribution *of cadmium* concentration in *OTR* data

[29] For example, in Newark Bay, New Jersey concentrations in the range of 10±6 mg/kg have been recorded (Faroon et al. 2012).

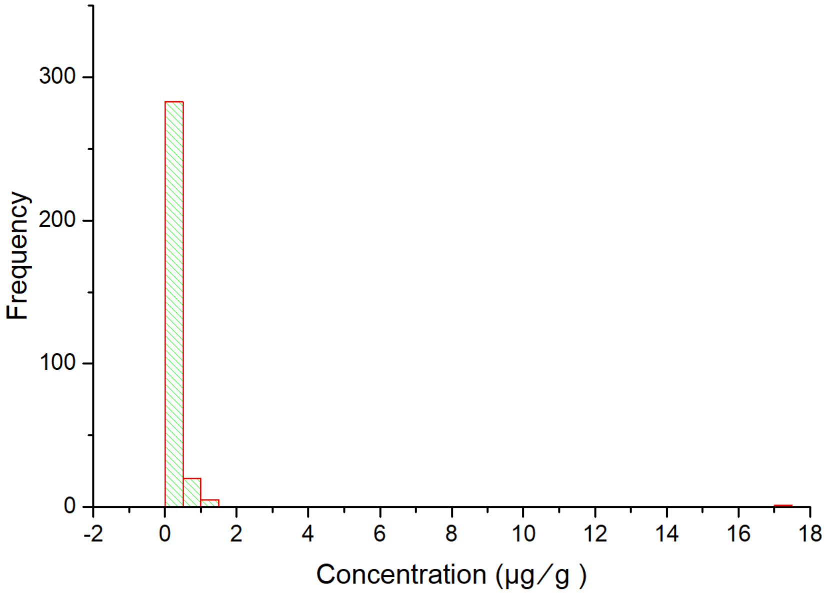

Figure i. Distribution of cadmium concentration in *OTR* data (rural parkland)

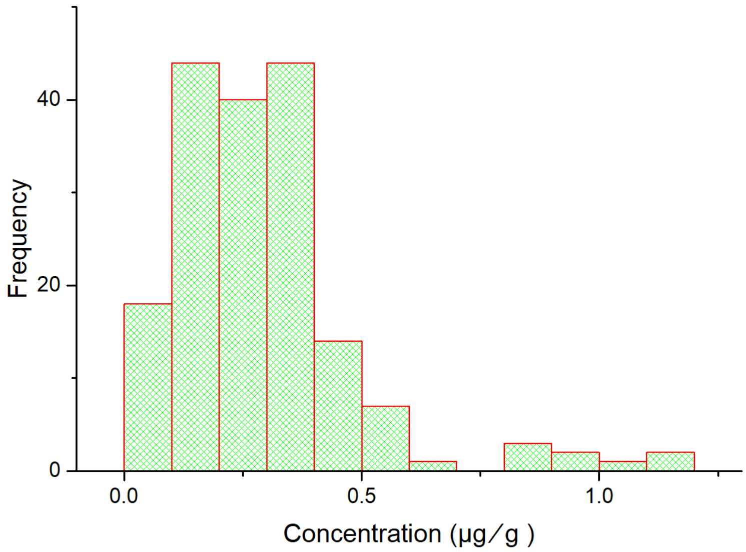

Figure j. Distribution of cadmium concentration in *OTR* data (urban parkland)

To better assess the normality of the data, a Q-Q plot was used as well. A Q-Q graph (Wilk and Gnanadesikan 1968) is a popular graphical method in which a dataset is plotted against a perfectly normally distributed data with the same statistical parameters. If the dataset of interest is normally distributed the resulting plot will be very close to a straight line. Figure h shows the Q-Q plot for barium data (which its histogram was shown above in Figure e). The resulting plot clearly does not overlap with the trendline, suggesting that the data is not normally distributed. Similar results were observed after the subsets of data for urban and rural sites were studied separately. A Q-Q plot was also created for cadmium data, which is shown in Figure l. Here too the Q-Q plot is far from the theoretical straight line, and thus the cadmium data is not normal either.

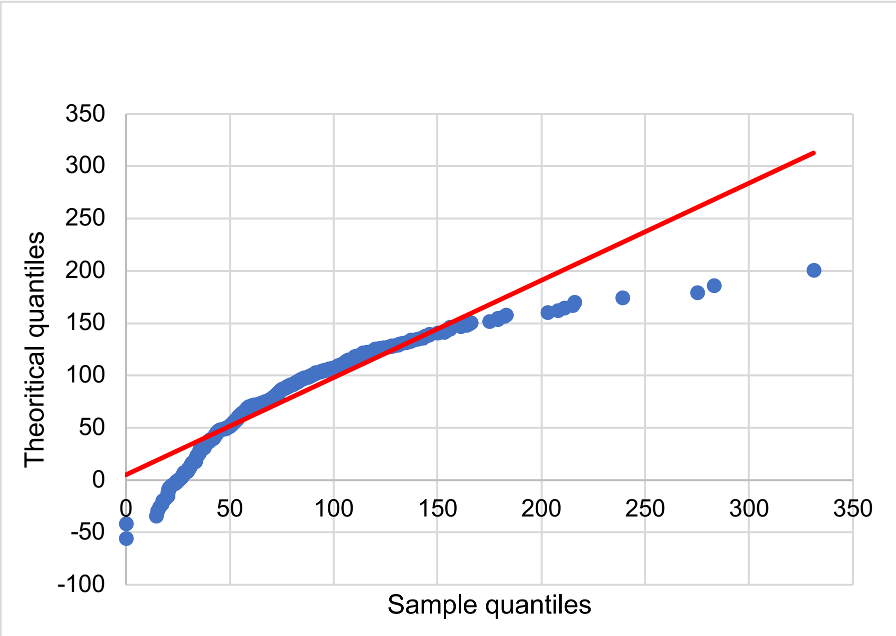

Figure k. Q-Q plot of barium concentration in *OTR* data (both rural and urban)

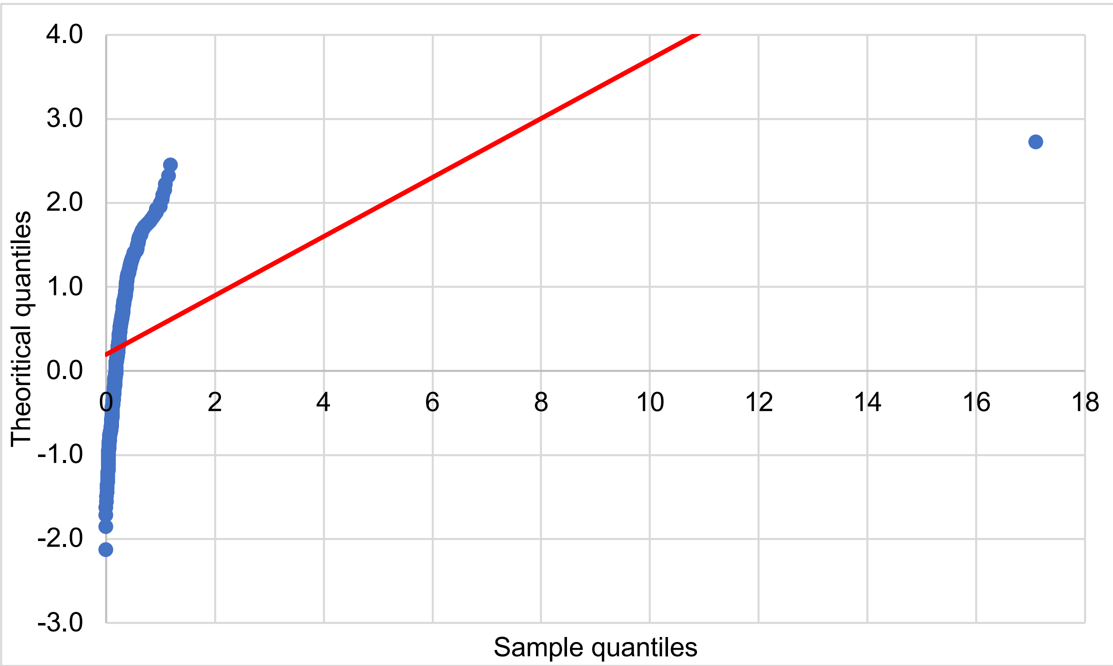

Figure l. Q-Q plot of cadmium concentration in *OTR* data (both rural and urban)

To show an example of a chemical within *OTR* data that its data is nearly normally distributed, the iron concentration data was visualized. The histogram is given in Figure m. This figure is symmetric, and, compared to the figures above, it is closer to a normal distribution. The Q-Q plot for iron data is given in Figure n, which is much closer to a straight line especially in comparison to cadmium and barium data. This means that the iron data is most probably normal.

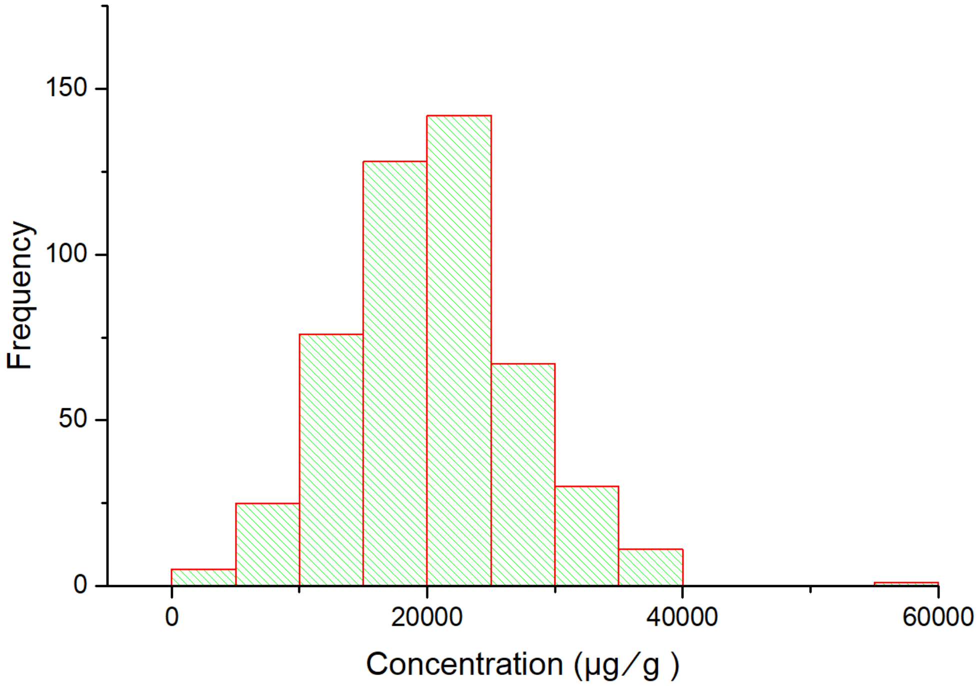

Figure m. Distribution of iron concentration in *OTR* data

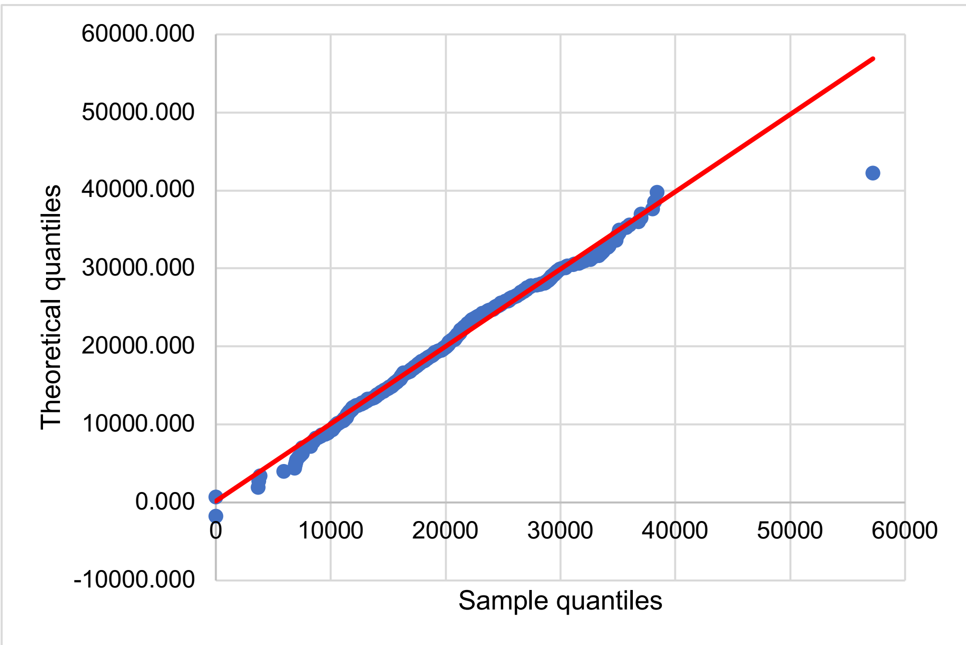

Figure n. Q-Q plot of iron concentration in *OTR* data

To confirm the results shown above, a K-S normality test was performed at a 0.05 significance level, which is a more objective method. The results of the tests are shown in Table c. This table shows that the claim of normality is rejected for all chemicals except for iron. This is in line with what was observed in the histograms and Q-Q plots. Note that a smaller p-value in a K-S test means stronger evidence against the null hypothesis (i.e., normality).

Table c. Results of Kolmogorov-Smirnov (K-S) normality test

	DF	Statistic	p-value	Decision at level (5%)
Cadmium (all)	485	0.35117	1.36E-52	Reject normality
Cadmium (urban)	176	0.1437	0.00128	Reject normality
Cadmium (rural)	309	0.37629	1.13E-38	Reject normality
Barium (all)	485	0.11353	7.06E-06	Reject normality
Barium (rural)	309	0.12487	1.23E-04	Reject normality
Barium (urban)	176	0.11637	0.01612	Reject normality
Iron (all)	485	0.06069	0.0553	Cannot reject normality

It is worth mentioning that having non-symmetric distributions, such as log-normal distribution, for chemical backgrounds in soil is sufficiently documented in the literature (Chen et al. 2001, 2002; Zhang et al. 2002). In such cases, geometric mean, which can be determined as the exponentiated mean of the log-transformed data, can be deployed to estimate the true distribution of the chemical concentration.

As an additional note, the *OTR* data is made available online in two files each containing two tables (sheets) in normal form. The normal form is not the most convenient format for performing analysis. Given that the size of the data is small, there is no need for normalization. In other words, it would be more beneficial if the land use category of each test is written in front of it for further clarification. This makes the results more verifiable and the data more workable. Also, the dataset has a small discrepancy. The land use category of the following tests given in Table d (with a STATION_ID of 2008023) is missing.

Table d. Examples with missing land use category in the *OTR* data

STATION_ID	PIMS_NUMBER	SAMPLE_NUMBER	SAMPLE_DESCRIPTION
2008023	8390	8304	SOIL 0-5 CM
2008023	8390	8305	SOIL 0-5 CM
2008023	8390	8306	SOIL 0-5 CM

8.4. Appendix 4: Further Detail About Fill Quality Evaluation for Shore Infilling

When criteria mentioned above are satisfied, the following material can be placed on site for shore infilling: quarried rock, clean brick, concrete rubble, sand, gravel, and excavated soils. These materials should not contain other construction debris or putrescible material. They also should be free of staining and odour. There is no need to characterize or test these materials except where there may be a concern regarding the origin of the material. Therefore, the history of the source site must be clear. Quarried rocks from some areas have naturally high levels of metal concentration. Where locally high occurrences of some metals may be of concern, the material must be subjected to a Receiving Water Simulation test to assess the possibility of rapid leaching.

Typical materials that might introduce contamination and are not allowed in unconfined shore infilling are asphalt and construction debris, chimney brick or painted brick, slag, fly ash, and other industrial/commercial wastes and/or byproducts.

8.4.1. Rationale Behind Criteria for Sediment Quality Guidelines

Fletcher et al. (2008), developed tables for fill quality, discusses five approaches for the development of sediment guidelines. The advantages and disadvantages of each method are discussed. These methods include:

- Sediment Background Approach
- Equilibrium Partitioning Approach (Water-Sediment and Biota-Water-Sediment Partitioning)
- Apparent Effects Threshold Approach
- Screening Level Concentration Approach
- Spiked Bioassay Approach

8.4.1.1. Sediment Background Approach

Sediment Background Approach is the simplest approach, and the amount of data required for its implementation is minimal. In this approach the pre-industrial background concentrations of different chemicals in the sediment are calculated and set as the threshold. This approach has no biological basis because it only relies on chemical background data. This exclusive reliance on chemical data makes it unable to consider sediment characteristics influence on biological effects.

8.4.1.2. Equilibrium Partitioning Approaches

In this method it is assumed that interstitial water is the primary route of organism exposure to contaminants. So, this method is only concerned with the amount of contaminant partitioning to the water and considers the amounts partitioning to the sediments as unavailable. Therefore, the criteria for fill quality is calculated as follows. A generic organic carbon-normalized partition coefficient (K_{oc}) is calculated. This coefficient is multiplied by existing water quality thresholds to derive a sediment guideline value. Note that this approach could only be used for contaminants that partition between environmental phases. Contaminants that do not partition appreciably into sediment organic matter and those that have highly unpredictable behaviour (such as metals) cannot be considered using this approach.

There are two main methods for calculating Sediment Quality Guidelines (SQGs) using Equilibrium Partitioning Approaches: Water-Sediment Equilibrium Partitioning Approach and Biota-Water-Sediment Equilibrium Partitioning Approach. The first derives SQGs from the partitioning of chemicals to the water and the sediment solid phases. The derived partition coefficient, K_{sed}, is normalized for organic content and a new partition coefficient is derived (K_{oc}) to be multiplied by water quality thresholds. The Biota-Water-Sediment Equilibrium Partitioning Approach, on the other hand, derives a SQG from an existing tissue residue criterion.

The main benefit of Equilibrium Partitioning Approaches is that, unlike background concentrations, they are biologically based. Furthermore, since the guidelines developed using this method are established based on water quality criteria, they use the same toxicological data developed for water quality and do not require a separate toxicological evaluation (water quality guidelines are protective of benthic organisms). This method also has some limitations. For instance, it considers interstitial water as the only significant pathway of exposure. Moreover, the tissue residue criteria are only concerned with human health, hence only apply to organisms such as fish, rather than benthic organisms. This method is currently used for those contaminants that exhibit predictable partitioning behaviour and cannot be applied to metals (as their behaviour is highly unpredictable).

8.4.1.3. Apparent Effects Threshold (AET) Approach

The AET approach is a statistical method that attempts to establish relationships between contaminants and observed biological effects. Therefore, the objective of this approach is to find the concentration of a contaminant above which significant biological effects are always observed. Such effects include acute or chronic toxicity, bioaccumulation, and changes in community composition of organisms. The AET Approach performs well in discriminating between contaminated and uncontaminated areas within a site, since the data used usually tends to be highly site-specific. So, all derived guidelines using this approach will be site-specific. The main caveat lies in the assumption of a cause-effect relationship that the methods cannot demonstrate. The lack of chronic effects data suitable for AET applications is another problem, particularly if consistency in level of protection (i.e., single species and endpoint) is of interest. Therefore, the AET Approach is perceived to be less suitable than the other effects-based approaches.

8.4.1.4. The Screening Level Concentration (SLC) Approach

The SLC approach is another effects-based approach applicable mainly to benthic organisms. First proposed by Neff et al. (1986), this approach uses field data on the co-occurrence in sediments of benthic species and different concentrations of contaminants. The SLC represents the highest concentration of a contaminant that can be tolerated by a specific proportion (e.g., 95 per cent) of benthic species. This approach is composed of two steps. First, for at least ten species for each chemical, a reference Species SLC (SSLC) is calculated by plotting the frequency distribution of concentrations over all sites (at least ten) where the species is present. The SSLC for each species is the 90th percentile of this distribution. In the next step, the SSLCs for each species are plotted as a frequency distribution, and the 5th percentile is determined from this curve. This is the SLC and shows the concentration which 95 per cent of the species can tolerate.

An assumption in the SLC approach is that the data covers the full tolerance range for each species. So, there is need to sample a large range of chemical concentrations in each case. A considerable volume of data is required to establish a guideline using this approach. Another problem is that the full tolerance range of some species may be unknown.

Since the SLC method uses field data on the co-occurrence in the field of contaminants and benthic species, the environmental factors affecting the species distribution are integrated into the dataset. So, the determined response reflects both the environmental factors and the contaminant levels. This method is also capable of incorporating changes in chronic responses such as reproduction and sensitive life-stages. Furthermore, it can consider the additive effects from multiple contaminants as they would occur in natural sediments. Although the original threshold used in the development of SLC was 95 per cent, if the dataset is large enough, the threshold can be increased to 99 per cent.

The SLC approach requires data collection and analysis. Other limitations include:

- Difficulty in determining an explicit cause-effect relationship between a certain contaminant and the benthic organisms because contaminants usually co-occur in natural situations. So, the effects observed cannot be related to a single chemical.
- Sensitivity to the type of species used in the database. The SCL may not be protective of other species present in the natural environment.
- Variability in the shape of SLC curve. Unlike the partitioning approach, the SLC approach does not limit exposure pathways to interstitial water and considers all possible modes of exposure. Since contaminant availability from the sediments may change with the feeding habits of the organisms, the ratio of species from each of the feeding categories will affect the shape of the SLC curve.

8.4.1.5. Spiked Bioassay Approach

In this approach, organisms are exposed to sediments that have been intentionally contaminated under laboratory conditions to determine dose-response relationships. Sediment quality guidelines are established using the sediment bioassay data using an approach in which aqueous bioassays are used to determine water quality criteria. What makes the spiked bioassay approach superior is that a direct cause-effect relationship can be established, under laboratory conditions, for a specific chemical for any species of organism.

A limitation of the spiked bioassay approach is that techniques have not been well standardized for spiking sediments, and differences in these techniques can substantially affect the results. Also, laboratory results may not be directly comparable to field conditions.

8.5. Appendix 5: An Example on the Effect of Hydraulic Conductivity

To understand the impact of hydraulic conductivity on component values, a sensitivity analysis was performed using the BRAT. The BRAT allows for changing the parameters, including hydraulic conductivity, to derive site-specific standards.

The BRAT was run against the following parameters:

- Four values for hydraulic conductivity: K1 = 0.001, K2 = 0.0001, K3 = 0.00003 and K4 = 0.00001 (the last two are within the same order of magnitude)
- Two values for travel distance from the centre of contaminant source area to the edge of surface water body: x1= 36.5 m[30] and x2= 780 m

Table e. Inputs of BRAT model for sensitivity analysis

Variable	Value
Volume	Volume independent
Texture	Coarse
Land use	Industrial/Commercial/Community
Groundwater conditions	Potable
Full depth or stratified	Full depth
Distance from body of water	More than 30 m
Shallow soil	No
Soil type – vadose zone	General coarse
Soil type – capillary fringe	Sand
Number of frozen ground days per year	100

After the BRAT model was run using the values of Table e, it was observed that the majority of soil quality standards and leachate screening levels remained unchanged. This is partially because S-GW component values are not calculated for metals due to the high uncertainty in metal fate and transport. Therefore, the leachate levels remain unchanged for metals regardless of values of K. For organic chemicals, this observation suggests that conductivity is not a significant driver of some component values. The increase in hydraulic conductivity resulted in a more stringent standard value for a handful of chemicals. This finding (i.e., more stringent component values for higher conductivities) is expected knowing that the transport is modeled using Domenico equation (Equation 7.19 in *Brownfield Rationale Document* (Ontario Ministry of the Environment 2011)), but knowing the chemicals that are more sensitive

[30] Typical travel distance used by the MECP in the Rationale Document (MECP 2020c)

to hydraulic conductivity may be useful to QPs in evaluating the risk associated with placement of excess soil in pits and quarries based on the contaminants of concern.

The BRAT was initially run using the values of Table e, K4 = 0.00001 and x1 = 36.5 m. The output was used as a benchmark. Next, the model was run with the other three values of hydraulic conductivity. Since K1, K2 and K3 are larger than K4, it is expected that the resulting soil quality standards and leachate screening levels associated with them would be more stringent (i.e., lower). To measure this change, the soil quality standards and leachate screening levels resulting from K1, K2 and K3 were compared against those of K4. The results are shown in Figure o.

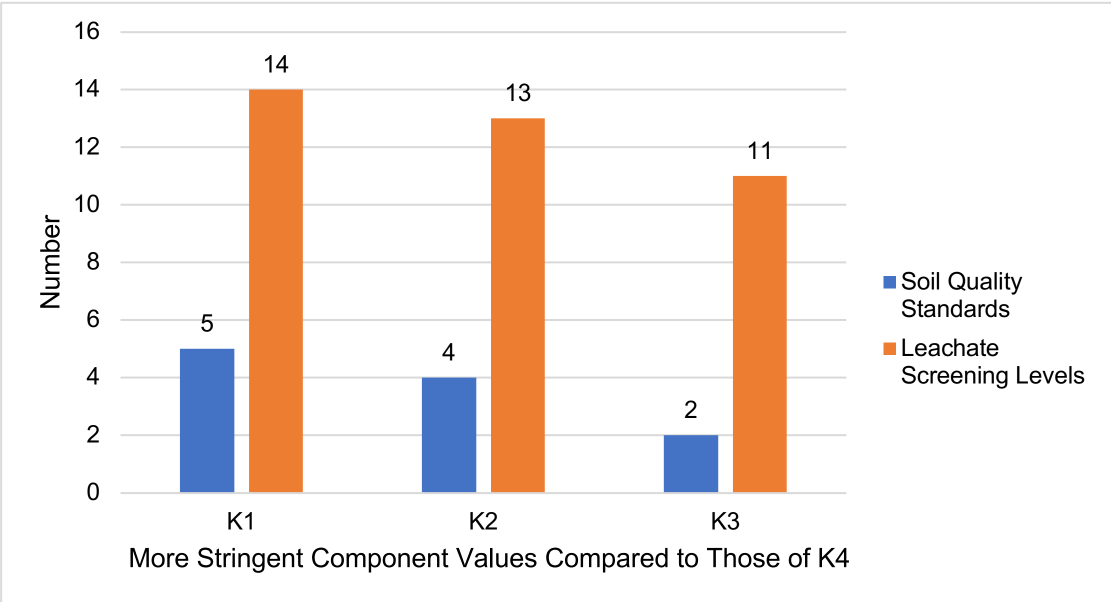

Figure o. The number of parameters for which a change in the value (of soil quality standards and leachate screening levels) was observed after changing hydraulic conductivity from K4 to K1, K2 and K3.

Figure o shows that out of 134 chemicals presented in the BRAT output, the standard for only five (i.e., approximately 4 per cent) became more stringent after varying the hydraulic conductivity by multiple orders of magnitude. For a change within the same order of magnitude (K4 to K3) only two chemicals were affected.

Leachate screening levels were more sensitive to change in hydraulic conductivity. After the hydraulic conductivity was changed from K4 to K1, the derived leachate screening levels became more sensitive for 14 chemicals (approximately 10 per cent). A similar shift was observed with 11 chemicals (approximately 8 per cent) after moving from K4 to K3. The reason for this change lies in Domenico equation used to model transport of chemicals. This equation includes velocity, which is a function of hydraulic conductivity. Therefore, according to this equation a larger value for hydraulic conductivity facilitates the transport of larger concentrations of chemicals over larger distances from the source. This observation can be verified using the solutions developed for Domenico equation. An example of such solutions is an Excel-based tool developed by Pennsylvania Department of Environmental Protection (2021).

The observed variation in standards and leachate screening levels in Figure o was unaffected by travel distance (i.e., x2 = 780 m). Another important point is the typical change in reference standard or leachate screening values because of a change in hydraulic conductivity. In some cases, this change was within the same order of magnitude (e.g., from 6.4 μg/g to 5.6 μg/g), but the order of magnitude was changed for some other chemicals (e.g., from 1.4 μg/g to 0.01 μg/g).

Table f. List of chemical quality standards becoming more conservative after changing hydraulic conductivity from K4 to K1, K2 and K3. "X" indicates that the soil quality standard or leachate screening level became more stringent as the hydraulic conductivity increased (K1>K2>K3>K4).

Chemicals	**K1**		**K2**		**K3**	
	Soil Quality Standard	Leachate Screening Level	Soil Quality Standard	Leachate Screening Level	Soil Quality Standard	Leachate Screening Level
Aliphatic C6-C8			X		X	
Aliphatic C>8-C10	X		X			
Aliphatic C>10-C12	X					
Aromatic C>12-C16	X		X		X	
Anthracene		X		X		X
Benz[a]anthracene		X				
Chlordane						X
Chrysene		X				
DDD		X		X		
DDE		X				
DDT		X		X		
Dieldrin		X		X		X
Endosulfan		X		X		X
Endrin		X		X		X
Fluorene		X		X		X
Heptachlor	X	X	X	X		X
Methoxychlor		X		X		X
Methyl Mercury				X		X
Pentachlorophenol				X		X
Phenanthrene		X		X		X
Polychlorinated Biphenyls	X					
Pyrene		X		X		

The chemicals that are sensitive to hydraulic conductivity are listed in Table f. This information may assist QPs in identifying higher risk chemicals when working with sites that have a higher hydraulic conductivity and may cause a QP to consider operational controls limiting receipt of materials where these higher risk chemicals may be a contaminant of concern. The component values for metals within MECP Tables remained unaffected by variations conductivity values because S-GW component values are not modeled for them. Metal fate and transport in saturated conditions involves a great deal of uncertainty (see Section 3.7 on metal fate and transport). All chemicals of Table f are organic compounds.

8.6. Appendix 6: Geochemical Models for Metal Fate and Transport

8.6.1. Static Models

Static models have three approaches to assess the risk of metal toxicity: speciation models, solubility and precipitation-dissolution models, and sorption models. Speciation models are used to determine the concentrations and activities of the ionic and complexed species, calculate the saturation indices of mineral phases, and the stable species. These models use chemical analyses and require a complete chemical analysis of water properties such as existing major ions, pH and potential for redox. All reactions are assumed to be at equilibrium. The main information gained from speciation models is the distribution of species and complexes in water for given conditions. They also can predict whether various mineral phases will tend to dissolve or precipitate. Furthermore, bioavailability of some metals can be assessed using speciation models. Examples of computer programs that use these models include PHREEQC2 (Parkhurst and Appelo 1999), WATEQ4F (Ball and Nordstrom 1991) and MINTEQA2 (Allison et al. 1991).

When analyzing groundwater pathways, precipitation-dissolution models determine the percentage of metal that is likely to precipitate and the amount that will remain in solution. The degree of saturation of a metal is defined by using saturation index (SI), via an analysis of Gibbs free energy for the reaction (Zhu and Anderson 2002). Speciation modeling coupled with solubility and precipitation-dissolution analysis should be fundamental to any geochemical assessment. Some examples of models that can examine solubility, and precipitation-dissolution reactions are PHREEQC2 (Parkhurst and Appelo 1999), WATEQ4F (Ball and Nordstrom 1991) and MINTEQA2 (Allison et al. 1991).

8.6.1.1. Sorption Models

The mobility of metals in groundwater may be hindered by sorption reactions, which tend to leave metals in the solid phase and prevent them from dissolving (Małecki et al. 2017). To address this issue, sorption models investigate the interaction of dissolved metals with surrounding minerals in groundwater. Three types of sorption models are isotherm-based models, ion exchange models and surface complexation models.

8.6.1.1.1. Isotherm-Based Models (K_d)

Isotherm-based approaches use the slope of a linear isotherm,[31] also known as K_d or the distribution coefficient, to assess the interaction between dissolved ions in solution with solid minerals. The distribution coefficient or K_d approach uses a single parameter to determine partitioning between the solution and soil matrix. It is assumed that K_d is constant for an

[31] Isotherm is a graph showing the mass sorbed on the solid surface versus the concentration of the constituent in solution, at a constant temperature.

aquifer. Another assumption is equilibrium and reversibility of reactions. Despite these simplistic assumptions, the models based on K_d have been widely used to assess metal sorption in surface and groundwater (US EPA 2001). Values of K_d for different metals in different soils are documented for both surface and groundwater (Allison and Allison 2005; Heuel-Fabianek 2014).

Note that values of K_d (distribution coefficients) contain a large level of uncertainty, and they can vary over a few orders of magnitude for a particular metal. For a certain metal, K_d values are dependent upon various geochemical properties of the soil and its porewater. The main geochemical parameters that have the largest impact on Kd values include the pH of the system and the nature and concentration of sorbents associated with the soil and water. Other important factors are the total concentrations of metal in the soil, organic matter content, the presence of iron and manganese oxides, and redox conditions.

8.6.1.1.2. Ion Exchange Models

Another approach for sorption modeling is based on ion exchange models. This approach assumes that the soil matrix is always negatively charged, thus attracting cations. The capacity of a soil for attracting different cations can be determined using a cation exchange laboratory test. This method can sufficiently address binary cation exchange (i.e., when a single cation replaces another one in the soil) but may not be able to model the competition of multiple ions. Ion exchange models may need to be collated with other geochemical reaction models to adequately explain observed processes. For example, these models cannot incorporate temporal or spatial transport issues and should be complemented by a transport code to evaluate heavy metal migration.

8.6.1.1.3. Surface Complexation Models

Surface complex models (SCMs) explain the sorption of a dissolved ion to soil surface when forming a surface complex. Common hydrous oxides of iron, manganese, and aluminum are the dominant existing sorbents because they are electrostatically active and can easily coat other particles. Factors affecting the sorption of these ions include pH, ionic strength, and competition from other ions (Davis and Curtis 2003; Faur-Brasquet et al. 2002). The adsorption reactions in these models are described by an equilibrium mass action equation. The binding constants for the mass action equations are parameters calculated empirically. The data for calibration of SCMs are often based on laboratory experiments of adsorption on pure solid phases. Natural soils usually contain a mixture of minerals and amorphous mineral coatings rather than a pure mineral.

Some strengths of surface complex modelling include:

- Changes in solution characteristics are reflected in surface properties

- Superiority to the distribution coefficient method (K_d) because of retaining the linkage between surface and aqueous species
- A small number of fitting parameters needed

A few points of weakness of SCMs are:

- Difficult to identify adsorption sites, their types, and densities
- Predictive capabilities hindered by the availability of geochemical data
- Unrealistic about pure surface of mineral (in reality, it is more heterogenous)
- Developing SCMs for heterogeneous aquifer materials (e.g., aquifer with lenses of clay) is still an open research area

Site-specific properties must be taken into consideration when deciding about appropriate models. If a QP decides that mineral dissolution or precipitation is significant to metal attenuation, sorption models may be inadequate and reactive transport models (discussed below) may be more suitable. If determined that a certain metal is not soluble at concentrations of concern for certain conditions at a certain site, the QP may conclude that the risk of exposure is low. On the other hand, if chemical dissolution-precipitation is not significant and conditions are predicted to remain unchanged along a groundwater pathway, sorption models may be the most appropriate tool for assessment.

8.6.2. Reaction Path Models

Reaction path models identify reactions causing changes in chemistry between two points. They are used to solve a series of equilibrium reactions in response to incremental changes in concentration along a flow path. These models can simulate many reactions and can be complemented by geochemical data or different elements and their isotopes. The available models can consider processes of dissolution, ion exchange, precipitation, redox, degradation of organic compounds, incongruent reaction, mixing, evaporation, gas exchange, dilution, isotope fractionation, and isotope exchange. However, they cannot incorporate the effects of spatial compositional changes. An example of a reaction path model is NETPATH (Plummer et al. 1994).

8.6.3. Coupled Reactive Transport Models

Coupled reactive transport models can simulate how a geochemical system evolves along a flow path in up to three special dimensions and over time. These models can describe advective-dispersive transport of reactive chemicals. As their name suggests, coupled reactive transport models are composed of two modules: a module containing process-based approaches to solve geochemical mass-action reactions and one modeling the transport of groundwater using different equations. Therefore, the computational demand of these models are higher than those discussed above (King 2005; Walter et al. 1994). Of course, the level of complexity of coupled reactive transport models can vary. The simplest model may include one-dimensional groundwater transport model linked to an ion exchange geochemical model for a single chemical. More complex models include more dimensions and multiple components. Furthermore, some models can assess biological processes, which sometimes can have impact on metal fate and transport (Brun and Engesgaard 2002; Steefel et al. 2005).

Considering the discussion above, Table g shows the three main categories of geochemical models and summarizes the advantages and disadvantages of each group. Finally, Table h shows several examples of the available geochemical models that are used by practitioners and academics. The table also mention their modeling approach and whether they are in public domain (i.e., available for free).

Table g. Different categories of geochemical modeling and their strengths and weaknesses

Category of models		**Advantages**	**Disadvantages**
Static	Speciation models	• Simple and easy to use	• Overlooking some aspects such as sorption
	Solubility and precipitation-dissolution models	• Simple and easy to use	• Overlooking some aspects such as sorption
	Sorption models (e.g. K_d)	• Simplicity and ease of incorporation into transport models • Availability of numerous models with this formulation • Good performance for weakly sorbing, low-concentration, metals, which participate in few reactions • Good performance for stable (or constant) chemical conditions and pH.	• Overlooking the aquifer geochemistry • Overlooking ion competition • Inability to simulate multiple solutes simultaneously • Inability to account for transient system conditions and changes in aqueous speciation • Overestimate plume advance and underestimate tailing
Reaction path		• Interpreting mass balance reactions • Ability to include constraining reactions	• Inability to distinguish equally likely reaction paths • Overlooking temporal or spatial changes

		• Constrained by assumptions of aquifer composition along flow path
Coupled reactive transport	• More accurate results due to mechanistic approach to describe mass-action reactions based on thermodynamic principles • Including the transport process explicitly • Including kinetic and equilibrium reactions • Considering multiple components in geochemical reactions • Easier comparison of model results to available observations (such as plume distribution)	• More input data needed due to complexity • Larger computational requirements • Uncertainty or missing thermodynamic data for some reactions • Many adjustable parameters • Lack of detailed mineralogical data • Requiring greater skill for model development and interpretation

Table h. Examples of geochemical models for assessing the risk of metal fate and transport

Model	Category	Public domain
2DFATMIC	Coupled reactive transport	Yes
3DFATMIC	Coupled reactive transport	Yes
BIOMOC	Coupled reactive transport	Yes
BIOPLUME III	Coupled reactive transport	Yes
BIOSCREEN	Coupled reactive transport	Yes
CHEMFLO	Coupled reactive transport	Yes
FEHM	Coupled reactive transport	Yes
FLOTRAN	Coupled reactive transport	No
HST3D	Coupled reactive transport	Yes
HYDROBIOGEOCHEM	Coupled reactive transport	Yes
MOC	Coupled reactive transport	Yes
MOC3D	Coupled reactive transport	Yes
MOFAT	Coupled reactive transport	Yes
MPATH	Coupled reactive transport	Yes
MIN3P	Coupled reactive transport	No

MT3D	Coupled reactive transport	Yes
PHAST	Coupled reactive transport	Yes
PHREEQC	Coupled reactive transport	Yes
RITZ	Coupled reactive transport	Yes
RT3D	Coupled reactive transport	Yes
SUTRA	Coupled reactive transport	Yes
UNSATCHEM	Coupled reactive transport	Yes
VLEACH	Coupled reactive transport	Yes
VS2DT	Coupled reactive transport	Yes
AquaChem	Static models	No
CHESS	Static models	Yes
EQ3/6	Static models	No
Geochemist's Workbench	Static models	No
MinEQL+	Static models	No
MINTEQA2	Static models	Yes
NETPATH	Reaction path or static	Yes
PHREEQC2	Static or reactive transport	Yes
PHRQPITZ	Static models	Yes
SteadyQL	Static models	No
WATEQ4F	Static models	Yes
WHAM	Static models	No

8.7. Appendix 7: Case Studies

This section presents two case studies of aggregate sites in Ontario and the soil quality standards used in their rehabilitation. Next, the approach proposed in Figure b of this document and the 'layer-cake' approach[32] is deployed to derive new standards based on *O. Reg. 406/19* and associated rules.

8.7.1. Case Study 1: United Soil Management (USM) 9th Line, Whitchurch-Stouffville

Address: 14245 Ninth Line (approved 2014) and 14395 Ninth Line (approved 2020)

Municipality: Town of Whitchurch-Stouffville

Owner: Hummel Holdings Inc.

Operator: United Soils Management

Site: Former Gravel Pit - 14245 Licence surrendered in 2016, 14395 Licence pending surrender

Property Size: 14245 – 46 ha and 14395 – 34 ha

Approved Excess Soil Capacity: 14245 -13 million cubic metres and 14395 - 9 million cubic metres (total 22M m^3)

Approval Instrument: Permit and Agreement as per Town of Whitchurch-Stouffville Site Alteration By-law 2013-007-RE

Approved Fill Rate: 600 tri-axle trucks per day (approximately 6,000m^3/day)

Duration of Filling: approximately 25 years

Fill Quality:

- Final surface grade to 1.5m depth: *O. Reg. 153/04* Table 2 Agricultural
- 1.5m below surface to base of pit: *O. Reg. 153/04* Table 2 Agricultural with EC and SAR waived

Groundwater: All filling above the water table

Surface water: Filling into stormwater ponds

Final Approved Site Conditions: Original pre-extraction topography and agricultural land use.

Additional Site Features:

- Hydrovac Truck dumping station and refill water supply
- Small Quantities dumping area for local contractors
- Community engagement area through the Tiny Seedlings program

Website: http://unitedsoilsmanagement.com/

[32] For details on the layer-cake approach see *OSPE Best Management Practices for Aggregate Pit and Quarry Rehabilitation in Ontario*.

Background

The property at 14245 Ninth Line, Town of Whitchurch-Stouffville is a former gravel pit and was previously mined for aggregates since the 1950's under the Aggregate Resources Act. Commencement of this fill operation under the Town of Whitchurch-Stouffville Site Alteration Permit followed the surrender of Ministry of Natural Resources and Forestry (MNRF) extraction Licence in 2014.

Topographic mapping from a Government of Canada Department of Defence Army Survey along with photos of the Site prior to the beginning of the aggregate extraction were used to develop the proposed grading design that is reflective of the original Oak Ridges Moraine topography. The Permit was based on restoring the original topography and agricultural land use.

Quality Control, Site Protection and Oversight Strategy

The site follows a multi-step process to approve source sites, audit incoming material, maintain strict site operations, mud and dust control, and report to the Town regularly as follows:

- Source Site Assessment
- Third Party QP Review and Approval
- Fill Site Quality Control and Operational Reporting
- Groundwater Monitoring, Site Inspections and Reporting
- Financial Assurance
- Regulatory Approvals and Compliance
- Town Oversight and Auditing

Alignment with *Ontario Regulation 406/19*

The Site operates under a municipal instrument in the form of a Permit and Agreement issued by the Town of Whitchurch-Stouffville that is reviewed for re-approval annually.

Practices, procedures, and environmental protective measures are aligned with the requirements of *O. Reg. 406/19*.

8.7.2. Deriving Alternative Standards for Case Study 1

In this section, Figure b and the layer-cake approach described in OSPE BMP are used to derive new standards for Case Study 1. Based on the given information, filling takes place above the water table and sufficiently far from any surface water body such as a river or a wetland. Therefore, filling should take place in two main layers:

- Layer A: Table 2.1 may be used for the top 1.5 m layer.
- Layer B: Table 4.1 may be used for backfilling below 1.5 m.

The paths for deriving standards for these two layers are highlighted on the flowchart of Figure p.

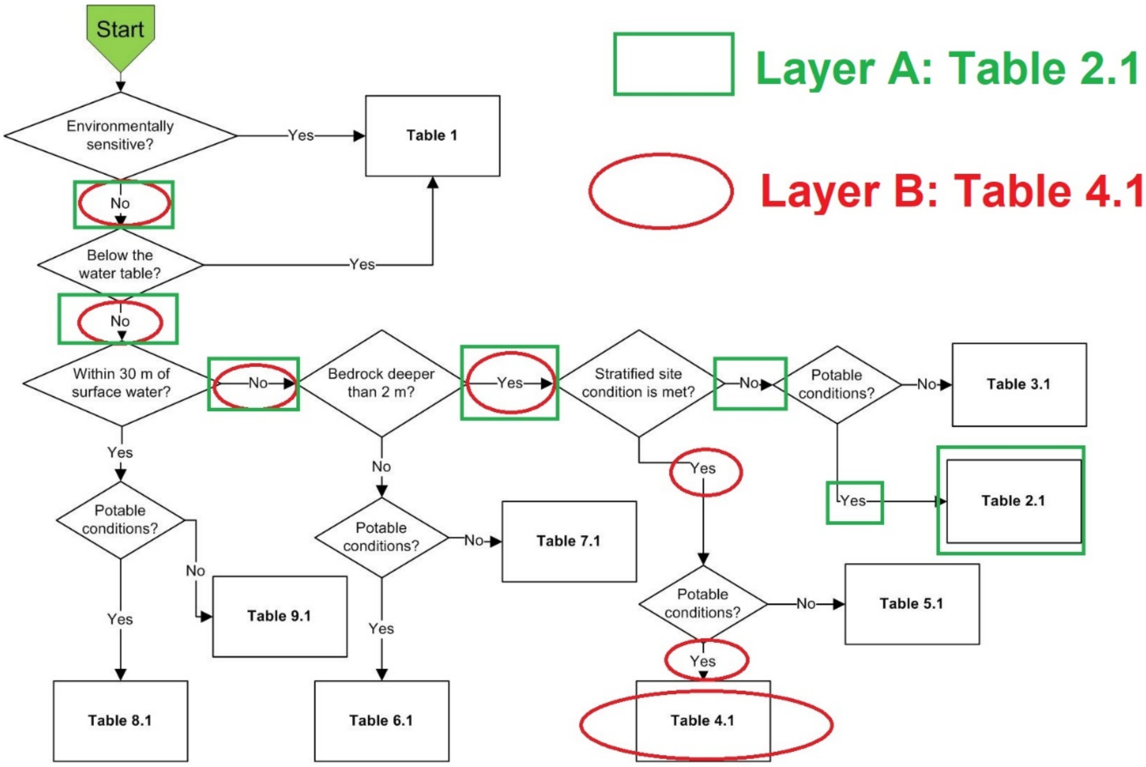

Figure p. Deriving soil quality standards for two layers of soil for reuse at Case Study 1.

Figure q. USM 9th Line Excess Soil Disposal Site

Figure r. Hydrovac Dumping Station and Small Quantities Dumping Area

Figure s. Gatehouse and incoming truck control.

Figure t. Looking south across fill area.

Figure u. Hydrovac truck dumping into containment.

Figure v. Emptying hydrovac containment following testing.

Figure w. Tire wash station

8.7.3. Case Study 2: Mount Albert Pit, Town of East Gwillimbury

Address: Part of Lots 12 and 13 Concession 7, Mount Albert Road,

Municipality: Town of East Gwillimbury

Owner: Mount Albert Pit Inc.

Operator: GFL Environmental Inc.

Site: Former Gravel Pit – Licence surrendered prior to filling application in 2008.

Approved Excess Soil Capacity: Phase I for approximately 800,000 m^3 approved in 2008. Phase II approved 2014 for approximately 2 million m^3. Total 2.8 million m^3

Approval Instrument: Permit and Agreement for each Phase as per Town of East Gwillimbury Alteration By-law 2013-066.

Approved Fill Rate: 200 tri-axle trucks per day (approximately 2,000m^3/day)

Duration of Filling: approximately 15 years

Fill Quality:

- Final surface grade to 1.5m depth: *O. Reg. 153/04* Table 2 Industrial/Commercial
- 1.5m below surface to base of pit: *O. Reg. 153/04* Table 2 Industrial/Commercial with EC and SAR waived

Groundwater: All filling above the water table.

Surface water: Filling into small stormwater pond.

Final Approved Site Conditions: Original pre-extraction topography and commercial/industrial land use with ultimately returning to agricultural land use.

Additional Items:

- Agreement with the Town to take 500 m^3/annually

Background

Following the surrender of the Aggregate Licence prior to 2008 an agreement was made with the Town of East Gwillimbury to import approximately 0.8M m^3 of excess soil for rehabilitation. Soil quality standards were commercial/industrial with EC and SAR waived below 1.5m of final grade.

The Agreement includes the requirement for:

- Financial security
- Liability insurance
- Source site assessment by a QP
- Quarterly, semi - annual and annual reporting
- Groundwater monitoring
- Regular importation volume and source site specific audit sampling
- Site security and source site documentation archiving

- Complete open access to Town inspectors and Town QP to the site and all documentation
- Comprehensive Fill Management Plan that is reviewed and updated annually following Township review
- Town and operator philosophy of *continuous improvement*

Alignment with *Ontario Regulation 406/19*

Site operates under a municipal instrument in the form of a Permit and Agreement issued by the Town of East Gwillimbury. The Agreement which is registered on title remains until all conditions are fulfilled. The Permit is reviewed for re-approval annually.

Practices, procedures, and environmental protective measures are aligned with the requirements of *O. Reg. 406/19* except for the finalization of the end use. The site is being filled with commercial/industrial quality fill as the site has been considered commercial/industrial through the period of extraction, completion of Phase I filling and into Phase II filling.

8.7.4. Deriving Alternative Standards for Case Study 2

The site-specific information for Case Study 2 is similar to that of Case Study 1. This site too is located above the water table and sufficiently far from any surface water body such as a river or a wetland. Therefore, filling should take place in two layers:

- Layer A: Table 2.1 may be used for the top 1.5 m layer.
- Layer B: Table 4.1 may be used for backfilling below 1.5 m.

The paths for deriving these standards for these two layers are same as what is shown on the flowchart of Figure p.

Issued to:	Mount Albert Pit Inc.
Date of Issuance:	February 13, 2018
Date of Expiry:	March 31, 2019
Project Description:	Commercial fill operation and rehabilitation of former gravel pit to farm lands
Type of Permit:	Commercial Fill Operation
Project Location:	19199 & 19503 McCowan Road
Fill Quantity:	2,068,500m^3

Conditions:

1. The Applicant is to comply with the East Gwillimbury By-Law 2013-066, the Operational Guideline, and MOUNT ALBERT PIT PHASE II AGREEMENT dated July 31, 2014
2. The Applicant grants the Town right of access to the property immediately upon request for inspection of works and compliance with By-Law 2013-066, the Operational Guidelines and the Phase II Agreement
3. A copy of the Fill & Site Alteration permit shall be posted on site at all times during site operation in a conspicuous place
4. Spills are to be reported to the Town and MOECC, and remediated in accordance with the Environmental Protection Act and its Regulations
5. Town is to be notified upon commencement of work when the site has been inactive for six (6) weeks & completion of work if the site is to become inactive for six (6) weeks
6. Fill Management Plan is a living document and to be updated over the term of this permit and from time to time to the satisfaction of the Town
7. Source Site material shall not include remediated soils
8. A new revised permit will be required and issued if there are any changes to the above

Issued By: Mike Molinari, *P.Eng*
General Manager,
Community Infrastructure & Environmental Services

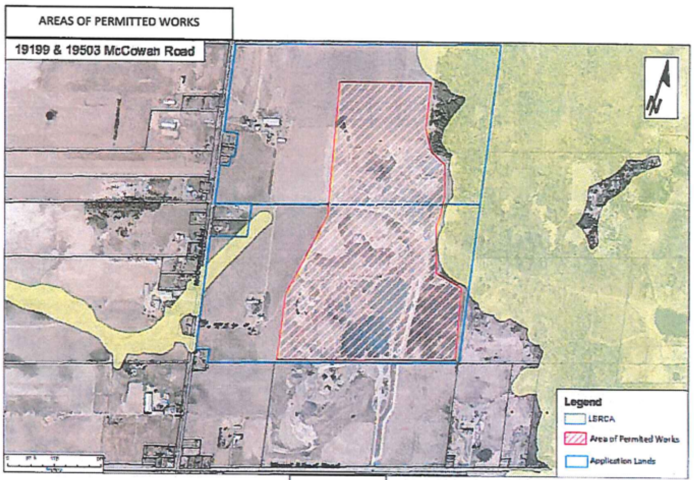

Figure 1

Figure x. Project information for Case Study 2

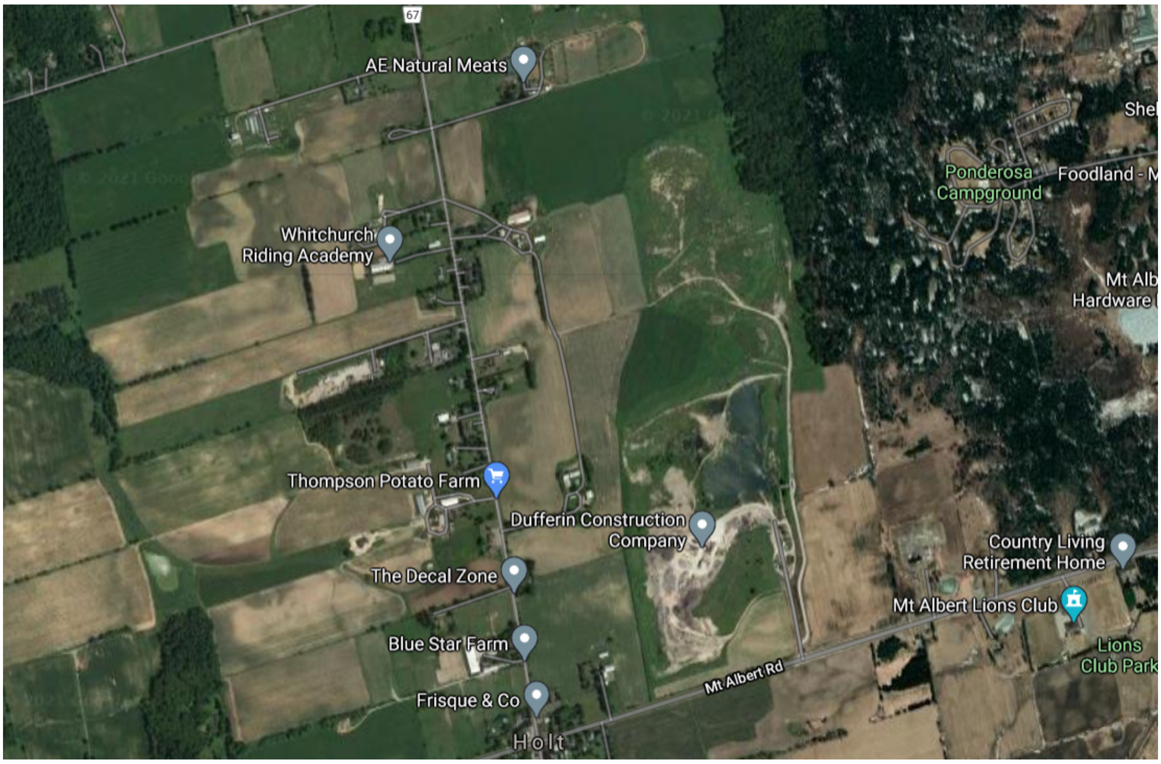

Figure y. Location of Case Study 2

Figure z. Looking north over Phase II fill area.

Figure aa. Looking south east at Phase II source site designated receiving areas.

Figure bb. Looking east across former storm water pond towards access road and site operator and access control building.

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