Geotechnical Investigation and Reporting Guidelines for Development Applications in the City of Ottawa

[PDF 163 KB]

Introduction

1.1 General

A report addressing the geotechnical aspects of site development, prepared by a qualified geotechnical engineer licensed in the Province of Ontario, will generally be required at the time of submission for all applications for site plan approval, plan of condominium, or for building permits. The submission of a geotechnical report will also be a condition included in all draft plans of subdivision. Geotechnical reports can also, under certain conditions, be a requirement of other applications to the City, as described in Section 1.2.

In a broad sense, the report should address the geotechnical design requirements for the subsurface conditions at the site to support the planned structures, roadways, utilities, or other infrastructure. The geotechnical report can also establish limitations on the site grading, which may be critical to the design of services, roadways, and structures.

The extent of the report content and any required geotechnical investigation varies with the project, its location, and the stage in the design and planning process.

As discussed further in Section 3, the intent of this document is not to relieve the geotechnical engineer of responsibility for the completeness or accuracy of the geotechnical report. Rather, the intent is to provide guidelines on minimum requirements for these reports and thereby facilitate review by City staff, particularly for situations where the City will ultimately have ownership of a part of the project (e.g., new services and roadways in residential subdivisions) or where the public may be impacted by the development (e.g., house settlement).

1.2 Scope

This document addresses geotechnical reports that are submitted to the City of Ottawa in support of any of the following:

- Site Plan Approval
- Plan of Subdivision
- Plan of Condominium
- Re-zoning Application
- Official Plan Amendment (OPA)
- Building Permit Application
- Severance (consent to sever)

Community Design Plans (CDPs), which occur earlier in the development process, are discussed separately in this document.

1.3 Review Process

Section 4.8.3 of the City of Ottawa’s 2003 Official Plan requires that applications for Site Plan approval, plan of subdivision, severance (consent to sever), or plan of condominium be supported by geotechnical study. City staff will review the report to confirm that the site is suitable for development, or can be made suitable for development. The study must also demonstrate that the development will not cause adverse effects or aggravate a hazard either on site or elsewhere. The report must be submitted at the time of application in most cases; the application will not generally proceed for review until the geotechnical report is submitted.

Under some conditions, applications for re-zoning or an OPA may also need to be supported by a geotechnical study. This would typically be the case where the site lies within lands designated on Schedule K of the City's Official Plan as being within an area of organic soil or unstable slopes. The City could also request a geotechnical study where the site lies in an area of known poor ground conditions, such as soft and compressible Champlain Sea clays, former landfill sites, or where a land use change would result in a densification of development. For any of these conditions, City staff may, after review of the initial submission, request that a geotechnical report be provided. The objective of this review will be to confirm that the approvals review is not carried out for a site that is unfeasible for development in a manner consistent with the re-zoning or OPA.

Applications for any of the above approvals would generally be made to the Infrastructure Approvals division of the City's Planning Branch of the Planning, Transit and Environment Department.

A geotechnical investigation report is also required by the Ontario Building Code (OBC) for building permit applications for some structures. The scope of this guideline does not necessarily include geotechnical reports submitted for building permit applications, although the requirements may be similar. Rather, this document addresses reports which are submitted with the aforementioned applications for planning approval.

1.4 Roles and Responsibilities

1.4.1 Geotechnical Engineer

The geotechnical engineer, working for the project applicant and/or owner, must be licensed to practise with the Association of Professional Engineers of Ontario, and must be qualified, based on experience in the profession, to provide geotechnical engineering services. The geotechnical engineer is responsible for coordinating the geotechnical investigation and preparing the geotechnical investigation report.

Since geotechnical engineering involves analysis and design using natural materials, there are many uncertainties. It is therefore a common requirement for there to be geotechnical inspection and testing during construction, so that the conditions at the site can be confirmed in regards to the findings of the original investigation. The geotechnical engineer is therefore typically also tasked with review and inspection during construction of the project, and ultimately documenting the adequacy of the geotechnical aspects of the completed works.

1.4.2 Project Applicant

The project applicant, who may be the owner of the property or may be working on behalf of the owner, is responsible for submitting the application and supporting documents to the City of Ottawa and for liaising with City staff. The project applicant would therefore be responsible for submitting the geotechnical report. All correspondence from the City regarding the geotechnical investigation report is generally directed to the project applicant.

1.4.3 Other Engineers and Designers

For most projects, the geotechnical engineer is not directly responsible for the project design, but rather other engineers and designers are responsible for implementing in their own design the recommendations and guidelines included in the geotechnical report. These other engineers and designers could include civil engineers, municipal engineers, water resource engineers, structural engineers, and architects, as well as many other professionals and para-professionals. These other engineers and designers would typically also be working for the project applicant or project owner.

1.4.4 City Staff

City staff from the Infrastructure Approvals Division of the City's Planning Branch will receive the geotechnical report along with the other documentation (e.g., reports, drawings, etc.). City staff will examine/study the geotechnical report and, in that study, compare the design to the guidance provided in the geotechnical report. City staff need to be satisfied that the geotechnical issues have been adequately addressed. City staff may also choose to have the report peer reviewed by a separate qualified geotechnical engineer.

1.5 Applicable Codes, Standards, and References

The following codes, standards, and references are applicable in regards to the scope and methods of geotechnical investigations as well as the content of geotechnical reports:

- The City of Ottawa's Official Plan.
- City of Ottawa Sewer Design Guidelines (current version).
- City of Ottawa Water Design Guidelines (current version).
- City of Ottawa Standard Tender Documents for Unit Price Contracts, Volumes 1 & 2 (current version).
- City of Ottawa Standard Right-of-Way Cross-Sections.
- City of Ottawa document "*Trees And Foundations Strategy In Areas Of Sensitive Marine Clay In The City Of Ottawa.*"
- Other City of Ottawa documents (as may be available) relating to the terms of reference for Geotechnical and Environmental Investigations for the City.
- City of Ottawa's document "Technical Requirements for Hydrogeology and Terrain Analysis Studies for Privately Serviced Developments" (currently in development).
- The Ontario Building Code, current edition.
- The Canadian Foundation Engineering Manual, current edition. Note: This document, though not a code or standard, is published by the Canadian Geotechnical Society and forms a reference for reasonable geotechnical engineering practices in Canada.
- City document "Slope Stability Guidelines for Development Applications in the City of Ottawa" and its Appendix A "Minimum Requirements for Slope Stability Assessment Reports", as approved by the City of Ottawa's Planning and Environment Committee on November 29, 2004 and by the Council of the City of Ottawa on November 24, 2004.
- City of Ottawa road design guidelines.

1.6 Types of Projects

Although the requirements for geotechnical investigations and geotechnical reports will vary with the type of application (e.g., OPA versus Site Plan, or Building Permit) the requirements also depend on the type of project, the site characteristics, and its location.

In Sections 2 and 3 of this document, which outline the geotechnical investigation and geotechnical report requirements, respectively, the types of projects listed below may be referenced. The names of the project types and their descriptions are not used in this document in the context of any particular reference to the planning process and associated regulations and bylaws. Rather, the names and descriptions are those commonly used in the development industry. Some projects could be classified according to more than one of these project types, and the descriptions are not expected to be all-inclusive. Some judgement needs to be exercised in evaluating which category would apply to a specific project.

1.6.1 Low-rise (Ground Oriented) Housing and related works

Residential subdivision:

In regards to the planning process, the term “residential subdivision” applies to any development that involves the subdividing of a larger parcel of land into smaller lots for the design and construction of residential units, and therefore would apply to any project which creates two or more residences on separate lots. However, in practice, a residential subdivision typically consists of many more lots, possibly dozens or hundreds, which are developed with single family homes and/or townhouse blocks. Typically, though not always, residential subdivisions include new roadways and related site services, which are internal to the development. Residential subdivisions are most commonly located in the suburban communities of Ottawa, but can also be located in infill situations or in the rural parts of Ottawa, with larger lots and private individual or communal services.

Infill housing:

Infill developments are typically located in established urban neighbourhoods of Ottawa, and typically involve the design and construction of a single new house, a small number of new houses, or a block of attached homes, located on a severed or subdivided lot or in the place of a demolished former building. The project typically includes an increase in the current density of the community. These projects may require a plan of subdivision, site plan, severance, or re-zoning.

Single Residences, Additions, Decks, and Swimming Pools:

Smaller projects can include the construction of a single house, an addition to a single house, or the construction of rear yard decks and swimming pools. Various planning approvals can be required for these projects. Depending on the specifics and location of the project, the input of a geotechnical engineer may be required to obtain planning approval.

1.6.2 Projects with Buildings

Projects involving the design and construction of buildings typically include those for which Site Plan approval must be obtained; other planning approvals may also be required.

Residential Developments:

These projects generally involve the design and construction of a mid-rise or high-rise structure. Typical examples include rental apartments, condominium apartments, and senior’s residences. However, Site Plan approval can also be required for condominium townhouse or street townhouse developments.

Commercial Office Developments:

These projects can include low, mid, or high-rise structures that are intended as office space.

Commercial Retail Developments:

These projects include buildings intended as space for retail sales and could include a single building or numerous buildings (i.e., as a campus) on a single site. There can be a large range in the intended use, such as small convenience stores, retail fuel outlets, individual retail buildings, “big box” stores, and enclosed malls.

Industrial Developments:

These projects, which typically (though not necessarily) include low-rise buildings, would generally include space for manufacturing or assembly of goods, or for warehousing. The buildings, though typically only one level in height, often have a large footprint, may have high internal clear ceiling heights, may have large column spacings, and may have high design floor loading.

Institutional Developments:

These projects including “public” development projects, such as schools, hospitals, and government buildings.

Other Types of Developments:

Many other types of projects exist, which cannot be classified into one of these categories, such as the construction of communication or utility towers. However the intent of this document is not to address the geotechnical requirements for every type of project, but only to describe general requirements for the more common project types. Ultimately the scope of the geotechnical investigation would be the responsibility of the geotechnical engineer, but should conform to the current standard of practice at the time of the work and must be to the satisfaction of the City of Ottawa.

Extent of Investigation

2.1 Introduction

The extent of the investigation required for any project depends on a number of factors, including the geologic conditions, the site’s features or characteristics, its location (e.g., urban, suburban, or rural), and the type of development. This section of the document provides some general minimum requirements on the extent of geotechnical investigations, recognizing however that it is not always practical to specify requirements that will address all situations. This document also does not describe all possible methods of investigation. For the more common situations, some general minimum requirements are provided on typical testing methods and extents of investigation. Where the requirements in this document are not adhered to, at the recommendation of the geotechnical engineer (who is ultimately responsible for the completeness of the investigation), City staff will require a written explanation for that deviation. City staff must ultimately be satisfied that the scope of the investigation undertaken by the geotechnical consultant adequately addresses the geotechnical issues at the site.

2.2 Geologic Conditions in the City of Ottawa

The City is located within a physiographic region known as the Ottawa Valley Clay Plain, which is characterized by relatively thick deposits of sensitive marine silty clay that were deposited within the Champlain Sea basin following the last glaciation. These deposits, known as the Champlain Sea clay or Leda clay, overlie glacial till, that in turn overlies bedrock. Most of this physiographic region is underlain by a series of sedimentary rocks, consisting of sandstones, dolostones, limestones and shales that are, in turn, underlain by igneous and metamorphic bedrock of the Precambrian Shield. More recent deposits of alluvial sand locally overlie the Champlain Sea clay. Organic soils (such as peat) have also developed in some poorly drained areas.

The compressibility of the sensitive marine Champlain Sea clay is an issue that must be addressed by most development projects underlain by this soil; since that deposit underlies much of the City, this is an issue for many projects.

The Ontario Building Code also indicates eastern Ontario as having a relatively significant design earthquake.

2.3 Methods of Investigation

There are many different methods available for geotechnical investigations, however this section summarizes the general local practise.

Common forms of geotechnical investigation include:

Borehole Drilling:

In the Ottawa area, boreholes in the overburden are typically drilled with hollow-stem augers, although other forms of drilling may at times be feasible such as: wash boring, solid-stem augers, air-rotary, etc. In general, due to the high water levels and soft soils present throughout much of the Ottawa area, boreholes must be cased to remain open, resulting in the common use of hollow-stem auger drilling.

Drilling into the bedrock and retrieving of bedrock core samples is typically carried out using rotary diamond (core) drilling equipment. However other forms of drilling may at times be feasible, such as air-percussion drilling. Rotary diamond drilling is also used to penetrate bouldery soils.

A wide variety of in situ testing techniques are carried out in boreholes, including:

- Standard Penetration Testing (SPT);
- ‘Quick’ in situ vane testing, which is typically carried out using the Ministry of Transportation of Ontario standard sized ‘N’ or ‘B’ vane;
- Strain-rate controlled in situ vane testing (e.g., Nilcon vane testing); and,
- Piezocone (i.e., CPT) testing.

Piezometers, typically consisting 19 millimetre to 50 millimetre nominal size HDPE or PVC tubing with slotted opening over the bottom portion, can be installed in boreholes to enable monitoring of the groundwater levels. Ontario Regulation 903 may require future decommissioning (i.e., abandonment) of piezometers, depending on the strata penetrated by the borehole.

There is no practical limit on the depth of investigation by borehole drilling.

Test Pit Excavation:

Test pits would typically be excavated with hydraulic excavators. Rubber tired ‘backhoes’ or track mounted excavators are both commonly used.

‘Grab’ samples can be obtained from the sides of the test pit (if shallow enough to allow safe entry) or from the excavated spoil.

Some limited in situ testing can be carried out in test pits; the undrained shear strength of clayey soils can be measured using a small size ‘inspection’ or ‘field’ vane. However the results of such testing may not be as accurate as the results of in situ vane testing in boreholes and as such further testing may be required.

The geotechnical engineer, property owner, and project developer should be aware that test pits leave a zone of disturbed soil that is not generally suitable for the future support of structures, unless engineered backfill materials are used, placed under controlled compaction conditions. Test pits are not therefore suitable for all situations and must be reinstated or identified for reinstatement during construction.

The groundwater level conditions observed in test pits may not represent the stabilized conditions, unless the test pit is left open for an extended period of time, in which case it must be safely barricaded and treated as a construction excavation.

The depth of investigation for test pits is also more limited compared to drilled boreholes. The maximum depth of investigation with a rubber tired ‘backhoe’ is about 4 to 5 metres. Test pits excavated using a larger track-mounted excavator could reach as deep as about 8 to 10 metres.

The excavation of test pits is particularly suited to sites with shallow bedrock, where the bedrock surface profile can be economically profiled at a large number of locations. However this method of investigation may also be suitable for other conditions. In general, investigation by means of test pits is generally only acceptable where either one or more of the following conditions are satisfied:

- The structures are relatively light (e.g., conventional wood frame housing or low rise buildings), such that the depth of influence of the loading will be quite shallow.
- The rock surface is fairly shallow and the intent of the investigation is to profile the rock surface.
- The soil overburden is not highly compressible (in comparison to the loads from light structures), e.g., glacial till, stiff clays, etc.

Investigation by test pits is generally not appropriate where a site is underlain by soft sensitive marine clay (i.e., shear strength less than 25 kilopascals), since measurements using an ‘inspection’ or field’ vane would typically not be as accurate as in situ vane tests carried out in boreholes.

Investigation with test pits may also not be feasible in sandy soils below the groundwater level (i.e., in ‘running’ sands). In these conditions, the rapid inflow of groundwater and soil makes it impractical to observe the excavated soils or obtain samples.

- Cone Penetration Testing:

Cone penetration testing (CPT) is much less common than investigation by conventional borehole drilling or test pit excavation. The CPT involves the pushing of an instrumented probe into the ground (vertically) at an essentially constant rate of penetration. The instrumentation on the probe typically measures both the force on the conical ‘tip’ of the probe required to advance it into the ground as well as the friction along the ‘sleeve’ of the probe. This information can be used to evaluate the type of soil being penetrated as well as various engineering properties of the soil. A particular advantage of the CPT testing is that it provides an almost continuous profile of the soil conditions and properties. The probe can also include an instrument for measuring the water pressure in the ground, in which case the probe is called a ‘piezocone’. The probe can also be instrumented with a geophone, to allow for shear wave velocity testing, as required to evaluate the seismic design Site Class (see Section 3.3.3); this testing is known as seismic cone penetration testing (SCPT).

2.4 Borehole and Test Pit Spacing

The borehole and test pit spacing appropriate for an investigation depends on a number of factors, including:

- The stage in the design/approval process (e.g., OPA, re-zoning, draft conditions of subdivision, Site Plan Approval, or Building Permit Application);
- The geologic conditions at a site (e.g., shallow bedrock, soft marine clay, saturated sands, etc.) and the known or expected variation in the conditions;
- The location and features of the site (e.g., urban, suburban, or rural; flat or sloping; nearby watercourse, etc.); and,
- The type of project (e.g., suburban subdivision, commercial/retail development, high-rise residential buildings, etc.).

For plans of subdivision or condominium, and Site Plan applications where the project is progressing to, or has reached, detailed design, the minimum requirements regarding spacing or number of boreholes provided in Table 1 should generally be adhered to. Where these requirements are not adhered to, at the recommendation of the geotechnical engineer (who is ultimately responsible for the completeness of the investigation), City staff will require a written explanation for that deviation. City staff must ultimately be satisfied that the scope of the investigation undertaken by the geotechnical consultant adequately addresses the geotechnical issues at the site.

TABLE 1
General Maximum Spacing Between Boreholes & Test Pits

Project Type		General Maximum Borehole or	Applicable Notes	Comments
Residential Subdivision	Rural location	300 metres	Notes 1 and 4	
Residential Subdivision	Urban, Suburban, or Village Location	150 metres	Notes 1 and 4	For these projects, there is typically less flexibility with the site grading design due to the municipal servicing, such that it must be confirmed at an early stage that the site is developable, from a geotechnical standpoint.
Infill Housing		30 to 50 metres	Note 2	Infill housing is typically located in previously developed urban areas of the City and typically involves a smaller project footprint. If only a single house is proposed, then confirmation of the bearing capacity at the time of construction may be sufficient. However, the surrounding land uses may impose constraints and costs on the project (e.g., need for underpinning adjacent structures). Past uses of the site (e.g., past filling, or demolition of old buildings) may have a large impact on the project feasibility and economics. A full geotechnical investigation, prior to obtaining a building permit, should be considered where such development conditions exist.
Single House, Additions, and Decks on sites that are not part of a previously approved planning application		N/A		The geotechnical evaluation must meet the requirements of the Ontario Building Code. In general, unless the footprint is large or the site is
Individual Buildings		30 to 50 metres, within the building area	Note 3	Essentially all building projects (residential, commercial, retail, industrial, and institutional) require a geotechnical investigation. A closer borehole/test pit spacing is required, compared to residential subdivisions, due to the generally higher loading.
Low-rise Building Campus		100 metres	Note 3	Where multiple low-rise buildings are proposed in a 'campus' layout, such as a 'big box' retail development, a wider borehole spacing may be acceptable, providing a broad coverage of the overall site rather than focused on each individual building location (which may change as development progresses), provided the following conditions are satisfied; the buildings are generally a
Widening of Existing Roadway		50 metres		A maximum 50 metre borehole spacing is applicable for any

Notes:
1. For smaller residential subdivision sites, where the specified maximum spacing is large in a comparison to the site measurements and would result in less than three boreholes or test pits, the number of boreholes or test pits should be no less than:
One for every 3 blocks of townhouses
One for every 15 single family homes
2. For smaller infill development sites, where the specified maximum spacing is large in comparison to the site measurements and would result in less than three boreholes or test pits, the number of boreholes or test pits should be no less than:
One for every 2 blocks of townhouses
One for every 5 singe family homes
3. Where a building will be supported on piled foundations bearing on bedrock, a smaller number of boreholes (i.e., larger borehole spacing) may be acceptable. A minimum of one borehole per building may be acceptable.
4. These spacings are appropriate only if subgrade inspections will be carried out for every house in the development.

The requirements described in the above table are minimum expectations (i.e., maximum borehole spacing and/or minimum number of boreholes). However this document does not relieve the geotechnical engineer of the responsibility for making the decision to exceed these requirements. For example, where the conditions on a site are variable or anomalous (e.g., where the strength of the clay deposit is variable, where there may have been past filling of a site or past structures, or if the bedrock surface profile is important), the appropriate borehole/test pit spacing could be much less. The variability could be known in advance (such as from past experience on the site or in the area) or could be shown by the results of initial investigation. In the latter case, the geotechnical engineer would be responsible for making the decision to exceed the requirements of this document by carrying out a second phase of site investigation. Investigation in excess of these requirements may be appropriate not only to assist with making design decisions but also to quantify construction costs (e.g., to better define the amount of bedrock excavation).

The above guidelines do not address applications for an OPA or re-zoning. For these cases, the City can require to have it shown, with reasonable confidence, that the proposed new use/zoning or proposed development is geotechnically feasible. This could be required by the City for a site where there is a known hazard/challenge associated with a site (e.g., soft soils, former landfill, unstable slope, etc.). A standardized minimum extent of investigation required for these submissions is more difficult to define since the scope of the project may not yet be known. The extent of investigation should also depend on the nature and severity of the concern/hazard. At this stage in the development process, it is not necessary, at least for the City, to have all the geotechnical design issues identified and addressed. It may therefore be sufficient to have an opinion provided by the geotechnical engineer based on a lesser extent of investigation than indicated by the requirements of Table 1.

2.5 Depth of Investigation

The required depth of investigation depends on many factors, including the type of structure and the associated magnitude of the loading, the subsurface conditions and their variability, the depth of planned excavation, and the types of foundations to be constructed.

In regards to the foundation loading, if a building will be founded on spread footing foundations, the general practice is to investigate to a depth below the planned founding level equal to at least 2 to 3 times the footing width (noting however that the founding level and/or footing widths are not always known at the time of investigation). If however weaker or compressible strata could exist at greater than this depth (such as is often the case in the sensitive marine Champlain Sea clays) and could compress under the loading from foundations or the weight of site grading fill and lead to foundation settlements, then greater depth of investigation is required. The investigation should extend to at least sufficient depth to investigate the most compressible (i.e., softest) portions of the deposit (which are generally the upper few metres of the unweathered clay, below the weathered surficial crust). If the grade on a site will be raised (i.e., if underslab and/or landscaping fills will be placed on the site), the additional loading will increase the stress level in the underlying clay over a significant depth. In this case, the investigation should extend to sufficient depth to show that the *preconsolidation pressure* of the deposit is in excess of the final stress level that will be achieved.

Where deep foundations (such as piles or caissons) may be required, the investigation should extend at least to the bedrock surface.

Where a site is to be developed with a building and is underlain by generally cohesionless (granular/sandy) soil, which extends below the groundwater level, the depth of investigation should be sufficient to address the potential for seismic liquefaction.

Notwithstanding the above, the following general minimum investigation depths should be adhered to:

TABLE 2
MINIMUM DEPTHS OF INVESTIGATION

Project Type / Location / Subsurface Conditions	Minimum Depth of Investigation
Residential subdivisions or infill housing on sites underlain by competent soils (e.g., glacial till, compact sand, or only stiff weathered clay).	4 to 5 metres, or to the bedrock surface, but no less than one metre below the maximum depth of excavation for basements or buried site services.
Residential subdivisions or infill housing on sites underlain by potentially compressible Champlain Sea clay deposits (even if overlain by surficial sand deposits or a crust of stiff weathered clay)	5 to 6 metres, or to the glacial till or bedrock surface, but no less than one metre below the maximum depth of excavation for basements or buried site services. If grade raises of more than about 0.75 metres are proposed, the depth of investigation should also be sufficient to reach below the soil having the lowest strength (e.g., should show an increase in the undrained shear strength with depth).
Single house, addition, or deck on a site that is not part of a previously approved planning application.	The geotechnical evaluation must meet the requirements of the Ontario Building Code. An inspection of the excavation (founding level) surface may be sufficient Where the site is, or could be, underlain by compressible Champlain Sea clay (even if located beneath other soils), it would generally be necessary to investigate to at least 1.5 metres below founding level.
Buildings.	The depth of investigation will depend on the expected loading and site grading. Low rise (≤2 storeys): 6 to 7 metres depth Mid rise (3 to 5 storeys): 8 to 10 metres depth High rise (≥ 6 storeys): 10 to 15 metres depth Or, in each case, to the confirmed bedrock surface. For low-rise buildings (i.e., where the foundation loads are lighter) ,it may also be sufficient to terminate the boreholes once glacial till is encountered. For sites underlain by Champlain Sea clay, if grade raises of more than about 0.75 metres are proposed, the depth of investigation should also be sufficient to reach below the soil having the lowest strength (e.g., should show an increase in the undrained shear strength with depth). The investigation depth should be increased where the building will have a basement level, and therefore deeper footing levels. The depth must also be sufficient to evaluate the excavation conditions (e.g., whether basal heaving or instability of the excavation are concerns). Where the building will be supported on deep foundations, the investigation should extend to the confirmed bedrock surface. To evaluate the seismic Site Class (see Section 3.3.3 of this document), at least one borehole may need to be advanced to the bedrock surface to determine the total thickness of soil.

Project Type / Location / Subsurface Conditions	Minimum Depth of Investigation
	If the potential for seismic liquefaction needs to be evaluated (see Section 3.3.3 of this document) , investigation to 15 metres depth (or to the bottom of the suspect soils) would be the standard practice.
Widening of Existing Roadway	1.5 metres, but no less than the planned excavation depth

The requirements described in the above table are general minimum expectations. Where these requirements are not adhered to, at the recommendation of the geotechnical engineer, City staff will require a written explanation for that deviation. However this document does not relieve the geotechnical engineer of the responsibility for making the decision to exceed these requirements and investigate to greater depth.

2.6 Soil Sampling and In-situ Testing

The type and frequency of soil sampling and in situ testing required by an investigation depends on the type of project and the subsurface conditions. The Canadian Foundation Engineering Manual provides a description of the various sampling methods and their applicability.

In local practice, for investigation by boreholes, soil sampling is typically achieved using split-barrel samplers (i.e., split spoon, or drive-open samplers) in conjunction with the Standard Penetration Test. Relatively undisturbed samples of the Champlain Sea clay deposits can also be obtained using Shelby tube samplers.

In situ testing typically consists of the Standard Penetration Test and, for the Champlain Sea clay, in situ vane testing.

Where the investigation is being carried out for the purposes of foundation design, the soil sampling and in situ testing should be ‘near-continuous’. That is, 0.6 metre long split-barrel samples should be retrieved at 0.75 metre depth intervals. In clay, one or two in situ vane tests can be substituted for one of the split-barrel sample intervals.

For deeper boreholes, the sampling intervals can be increased at depth (e.g., 1.5 metre sampling and in situ testing intervals below about 7 to 10 metres depth). Similar sampling intervals may also be acceptable where the investigation is being carried for purposes other than foundation design, such as to define the conditions for sewer trench excavation in residential subdivisions.

Below the needed depth of sampling, but where the depth to bedrock/refusal is to be investigated, the borehole might be advanced without sampling. The borehole might then be terminated at the refusal depth or might be advanced into the bedrock by coring to confirm the position and type of bedrock. If bouldery conditions at depth are known or expected, then the preference would be to confirm the bedrock surface by coring.

Shelby tube sampling, if included in the investigation program, should generally be carried out (at a minimum) in the weaker portions of the deposit, which are typically the upper portions of the unweathered silty clay.

When investigating by test pits, it is good practice to obtain at least one (grab) sample per test pit and/or one sample per strata encountered in each test pit.
The sampling procedures described above table are general minimum requirements. Where these requirements are not adhered to, at the recommendation of the geotechnical engineer, City staff will require a written explanation for that deviation. However this document does not relieve the geotechnical engineer of the responsibility for making the decision to exceed these requirements.

2.7 Groundwater Level Measurement

Measurement of the static groundwater level is not necessarily required for all projects or all ground conditions. The measurement of the groundwater level should, in particular, be carried out where:

- Excavations may extend below the groundwater level, particularly in permeable soils.
- Basement levels will be constructed and therefore the need for a foundation drainage system must be evaluated.
- Soils that are potentially vulnerable to seismic liquefaction exist on the site.
- The site is potentially underlain by compressible Champlain Sea clay, and therefore where the capacity of the deposit to accept additional load depends on the groundwater level.

Where none of these conditions are satisfied, it may be sufficient to observe the groundwater level in the 'open' boreholes or test pits, during the short time before they are backfilled. The groundwater level could also be inferred from the colour and water content of the samples. In some cases, an accurate assessment of the groundwater level may be entirely unnecessary (e.g., for a building to be supported on shallow bedrock).

However, for any of the aforementioned conditions, it will be important that a relatively accurate measurement of the groundwater level be made. One standpipe type piezometer should be installed for at least every fourth or fifth borehole, though additional piezometers should be installed where there are several water-bearing strata or where the site has variable topography.

For piezometers in lower permeability soils or rock, the groundwater level could take a week or more before stabilizing and should not be recorded prematurely.

Ontario Regulation 903 may require abandonment/decommissioning of water level monitoring devices, such as standpipe piezometers.

2.8 Laboratory Testing

Conventional laboratory testing includes:

- Water content testing, particularly on fine grained soils (e.g., clays and silts);
- Atterberg limit testing, on fine grained soils;
- Grain size distribution testing, particularly on cohesionless soils, such as sandy or silty soils;
- Laboratory oedometer consolidation testing on compressible clay soils; and,
- Basic chemical analyses related to potential corrosion of buried ferrous elements or sulphate attack on buried concrete elements.

Water content and Atterberg limit (i.e., liquid and plastic limit) testing are more useful in clay soils and assist the geotechnical engineer with:

- Estimating the unit weight (i.e., density) of the soil, and hence the current stress level in the ground.
- Evaluating the compactability of the soil, if it is to be excavated and re-used as fill.
- Estimating the deposit's preconsolidation pressure from other parameters, such as the in situ vane test results.

Grain size distribution test results are useful to the geotechnical engineer, particularly for sandy/granular soils, in:

- Estimating the permeability (i.e., hydraulic conductivity) of soil, in regards to the potential groundwater inflow to an excavation.

- Evaluating the resistance of a soil to seismic liquefaction, and hence the potential seismic settlements or reduced bearing capacity.
- Assessing the potential compressibility of granular soil (i.e., sandy and silty soils).

Laboratory oedometer consolidation testing is a method of essentially directly measuring the *preconsolidation pressure* of clay soils. The *preconsolidation pressure* can also be estimated from the results of in situ vane testing, but with only limited accuracy. These estimates are therefore generally made fairly conservatively, and should only be made where the design will not raise the stress level unduly close to the estimated *preconsolidation pressure*. Estimation of the *preconsolidation pressure*, using in-situ vane test results, should not generally be relied upon for sites with soft clays (i.e., Champlain Sea clay deposits with an undrained shear strength less than 25 kilopascals) and/or in particular may not be appropriate where the grade will be raised by more than about 0.8 metres (i.e., where the predominant additional loading to the deposit may come from the weight of underslab or landscape fill material placed on the site).

It may be important to carry out laboratory oedometer consolidation testing on samples from different depths in the deposit and to thereby develop a profile of the preconsolidation pressure with depth. This requirement would be particularly important where the deposit is thick and/or where the results of the in situ vane testing indicate that the deeper portions of the deposit may also be compressible (and not only the shallower portions of the deposit, which are typically the softest).

Basic chemical analysis of soil or groundwater is useful for evaluating:

- The potential for corrosion of buried ferrous elements, which could result in premature failure or deterioration of steel piles, rock anchors (such as may be required to resist buoyant uplift forces or lateral seismic forces on a building), reinforcing steel in the foundations, or site servicing pipes and connecting hardware.
- The potential for sulphate attack on buried concrete.

A common cause of a corrosive environment is the presence of elevated chloride ion concentrations due to infiltration of road salt used for ice control. At a minimum, the testing related to potential corrosion should include measurement of the soil or groundwater conductivity. Measurement of the chloride ion concentration and pH is also useful.

Sulphate attack can occur when soluble sulphates are present in the soil or groundwater. Reaction with concrete can result in premature deterioration. CSA standard A23.1 contains criteria regarding sulphate ion concentrations in soil or groundwater above which sulphate resistant Portland cement should be used in the manufacture of concrete.

Although it would probably be good practice to carry out chemical analyses on both soil *and* groundwater samples, and this program should be considered for critical applications, this testing should at a minimum be carried out on samples of either the soil <u>or</u> the groundwater. Samples should ideally come from the same depth(s) at which ferrous or concrete elements will be constructed. On a small site, it would be conventional practice to test a single sample. On a larger site (e.g., a residential subdivision site measuring hundreds of metres in size), multiple samples should be tested.

Geotechnical Reports

3.1 Introduction

This section provides some minimum requirements for geotechnical reports submitted to the City for plans of subdivision, plans of condominium, Site Plan approval, or other development related applications. Guidelines are also provided on issues that should be considered in preparing these reports.

The reporting requirements for geotechnical investigations relating to OPA or re-zoning applications should be decided on a case-by-case basis, at the discretion of the City, based on the hazard/issue of concern.

The intent of this section is not to relieve the geotechnical engineer of responsibility for the completeness or accuracy of the geotechnical report. Rather, the intent is to:

- Provide direction in particular on the geotechnical reporting relating to the design and construction of facilities where the City will ultimately have ownership (e.g., new services and roadways in residential subdivisions). For example, restrictions on the site grading may impact on the design profile of buried services and on the design pavement structures of roadways.
- Provide direction on issues where the public (e.g., adjacent property owners or the future purchasers of houses, etc.) may be impacted by development. For example, restrictions on the site grading can be necessary to avoid settlement of foundations and damage to structures.
- Provide a common framework for geotechnical reports to facilitate review by City staff. For example, this document provides a summary of the current level of local practice and therefore provides City staff with a tool for reviewing geotechnical report prepared by geotechnical engineers not familiar with some issues particular to geotechnical design in the geologic conditions of eastern Ontario.

This document should under no circumstances be interpreted to supersede the requirements of the Ontario Building Code or, for new house construction, of the Tarion Warranty Corporation, or any other standard of practice.

3.2 Report Contents

The geotechnical report shall contain, at a minimum:

- A description of the site location, current land use, and topography. Adjacent land uses should also be discussed, if relevant to the proposed works, or if there is a potential for impacts (e.g., potential settlements, or if shoring or underpinning are required).
- A description of the planned development, including the proposed buildings and site grading (if known). If significant excavations will be required (e.g., for basement levels), these should also be described.
- A discussion of existing geotechnical information for the site (e.g., from previous investigations) or the expected conditions based on geologic mapping or previous experience in the area.
- A description of the subsurface investigation procedure (e.g., borehole drilling, sampling and in situ testing, laboratory testing, and groundwater level measurement).
- A summary of the subsurface conditions on the site and the results of the in situ and laboratory testing.
- A scaled plan showing the site and the locations of the boreholes and test pits.
- Drawings or tables showing the findings of the investigation (i.e., borehole and test pit logs, with elevations).
- Drawings or tables showing the factual results of the laboratory testing.
- Recommendations and guidelines on the geotechnical design issues.

The report should be signed and sealed by a geotechnical engineer licensed in the Province of Ontario who is qualified, based on experience in the profession, to prepare such reports.
Preliminary geotechnical investigation reports, such as might have been prepared for the due diligence assessment carried out during property acquisition, are not suitable for submission to the City. Preliminary geotechnical investigation reports are not prepared by the geotechnical engineer in the context of the detailed design of the development.

3.3 Geotechnical Recommendations and Guidelines

Identification of the geotechnical design issues that apply to the project/development and the manner in which they are to be addressed is the responsibility of the geotechnical engineer. However, the report must be sufficiently complete that city staff can confirm that the issues have been properly identified and adequately addressed. The following issues should be considered by the geotechnical engineer.

3.3.1 Site Grading

Site grading should be considered in as much as it could relate to:

- The potential for settlements resulting from compression of the underlying soils.
- The need to limit excavations due to high water levels and permeable ground conditions.
- The stability of slopes or the need for retaining walls. These issues should be addressed in accordance with the City document “Slope Stability Guidelines for Development Applications in the City of Ottawa” and its Appendix A “Minimum Requirements for Slope Stability Assessment Reports.”
- The feasibility of constructing cut slopes.
- The feasibility of excavating, transporting, placing, and compacting materials excavated from one part of the site to another.
- The need for removal of surficial topsoil or other organic soils as well as fill materials.

The first issue (potential settlements) is particularly critical for sites underlain by compressible sensitive marine Champlain Sea clay. For these sites, the geologic profile will often consist of a surficial ‘crust’ of stiffer and drier clay (typically brown or grey brown in colour) underlain by weaker and more compressible unweathered clay (typically grey in colour). In simplified terms, the unweathered clay lies below the groundwater level and has therefore not been desiccated and weathered.

The sensitive marine Champlain Sea clay can undergo large compression if the stress level acting on it is raised above the deposit’s *preconsolidation pressure*, which is effectively the ‘yield’ strength of the material. At stress levels below the preconsolidation pressure, settlements are typically quite limited. At stress levels above the preconsolidation pressure, or approaching it, settlements can be large. The difference between the preconsolidation pressure of the deposit and the existing effective stress level is the called the *overconsolidation*. The stress level must be maintained at a sufficient margin below the preconsolidation pressure; i.e., the stress increase must be sufficiently less than the overconsolidation.

Where overlying structures will be supported on shallow foundations (e.g., spread footings or rafts), the stress increase on the clay deposit will result from the combination of the weight of the site grading fill and the loads from the building foundations. Those combined loads must therefore be considered when evaluating the permissible site filling/raising.

In making that assessment, the geotechnical engineer must evaluate the potential long term lowest sustained groundwater level that could occur on the site. That groundwater level would be the critical condition in regards to an increase in the stress in the clay deposit since lower water levels result in a reduction of buoyant forces that resist the loading between soil particles. Groundwater levels vary seasonally (e.g., are typically higher in the spring due to increased rainfall and infiltration) and may therefore be lower than the levels recorded in the piezometers. Over time, groundwater levels may also lower due to a reduction in the amount of permeable surface through which rain fall and snow melt can infiltrate (e.g., due to the construction of paved surfaces and structures [roofs]). The installation of buried services (e.g., storm and sanitary sewers) may also result in some groundwater level lowering due to groundwater drainage through the granular pipe bedding and surround materials (although the geotechnical engineer may specify the use of seepage barriers [i.e., clay dykes] in the service trenches to mitigate this potential). The geotechnical engineer must therefore predict the potential future *low* groundwater level. The value used in the analyses should be discussed in the report, along with the restrictions on the site grading (e.g., maximum permitted grade raise).

In most cases, this evaluation of the potential future low groundwater level can be made based on the soil stratigraphy, measured groundwater levels, and a review of the development plans. For sites that are hydrogeologically sensitive, such as where the clays are particularly compressible and/or where the natural recharge will be severely reduced, a hydrogeologic study may be justified. However that study is outside of the scope of a conventional geotechnical investigation.

The evaluation should also consider the additional loading that could come from the loading on slab-on-grade floors; these loadings can be large in warehouses and some other structures.

The Canadian Foundation Engineering Manual suggests that the stress increase in clay soils be maintained below about 80 percent of the *overconsolidation.* This guideline accounts for the phenomenon of secondary compression whereby a clay soil will start to creep and compress even at stress levels slightly below, but close to, the preconsolidation pressure. This guideline also provides a margin against uncertainty in the evaluation of the current stress level in the ground, the predicted future lowest sustained groundwater level, and the estimated or measured preconsolidation pressure, which could vary across the site.

3.3.2 Foundation Design

The report should provide geotechnical engineering guidelines on the design of structure foundations, particularly if the report will ultimately be included in support of the application for a building permit.

In regards to applications for planning approval, the following issues should be addressed:

- The requirements for engineered fill for buildings or other elements (e.g., location, thickness, extents/sideslope, subgrade preparation, materials, compaction, etc.).
- The relationship between the foundation design parameters and site grading, such as may be the case for sites underlain by compressible clay.
- The presence of expansive shale and required foundation treatments.
- Restrictions on the planting of trees or the preservation of existing trees.
- Measures required to maintain the local groundwater level (e.g., lowest foundation or foundation drain level, water-tight construction, etc.).

Expansive Shale

Where the foundations will be constructed on shale bedrock of the Billings or Carlsbad formations, the potential for heaving of the shale bedrock should be considered in the foundation design. These bedrock types have the potential to heave due to weathering of pyrite and the formation of volumetrically larger gypsum crystals.

This process involves a series of chemical reactions, some of which are purely chemical and others of which are at least catalyzed by micro-organisms. The general mechanism is considered to be that pyrite (FeS_2) which is present at low concentrations in the shale is weathered in the combined presence of oxygen and water to form sulphuric acid. That sulphuric acid then reacts with calcite, which is also present within the shale either as an integral part of the rock or as filling within fractures, to form gypsum. The gypsum crystals tend to form within existing fractures and to be volumetrically larger than the materials that formed them, thus resulting in heaving.

For the above reactions to occur there must be both water and oxygen available. An increase in the ground temperature, such as due to the heat from the basement area, is also considered to promote the above reactions.

It is also possible for the products of the above reactions to attack concrete (i.e., sulphate attack).

For the above reactions to occur, there must be both water and oxygen available. This process will therefore only occur in the humid environment above the water table. Groundwater level lowering is therefore one possible trigger of such heaving.

Heaving of the shale can damage floor slabs and services. Lightly loaded foundations could also potentially be impacted. The report should discuss measures to prevent such heaving.

The use of sulphate resistant cement in concrete mixes should also be considered.

Trees

Moisture depletion of silty clay soil caused by water demand of trees is a known cause of foundation distress in the Ottawa area, although many other causes of foundation distress exist.

Trees are living organisms which require water for their continued existence (transpiration) and to support their natural growth. In part, trees obtain water with their root systems that draw water from the soil. The amount of water drawn from the soil is particularly high during periods of low rainfall when water infiltration is minimal. When the roots withdraw water from a soil that is volumetrically susceptible to moisture change (such as the sensitive marine Champlain Sea clay), soil shrinkage results. Such shrinkage can result in vertical settlement and horizontal movement, which can affect structures and utilities that draw their support from the soil at shallow depth.

Structures with shallower foundations are more vulnerable to settlement due to moisture depletion from the water demand of trees. For example, a structure founded at 1.5 metres depth is more vulnerable than a structure with a full conventional basement level and a founding depth of 2.4 metres. Silty clays with a higher water content and a softer consistency are also more likely to undergo significant shrinkage. However even stiffer clays and weathered clays are potentially vulnerable to shrinkage due to moisture depletion. Sandy soils and glacial till are generally not susceptible to shrinkage due to moisture depletion.

The report should therefore identify whether soils sensitive to moisture depletion and settlement due to the water demand from trees exist at the site (such as Champlain Sea clay). This issue should be addressed both in regards to the planting of new trees near foundations as well as the preservation of existing trees around new foundations. Reference should be made to the City of Ottawa report to the Planning and Environment Committee of September 9, 2005 titled "*Trees And Foundations Strategy In Areas Of Sensitive Marine Clay In The City Of Ottawa*." In general, trees should be planted no nearer to the foundations than their ultimate (mature) height and trees of lower water demand should be used.

Structures can alternatively be supported on deep foundations, which derive their support below the depth of root penetration and potential moisture depletion. In some situations, it may also be feasible to install a barrier between the tree and the structure which would prevent root growth below the foundations.

The above guidelines relate to the design of new developments. Where damage to an existing structure occurs, due to settlement of foundations, a specific assessment should be made to determine the cause of the settlement.

3.3.3 Seismic Design and Seismic Liquefaction

The potential for seismic liquefaction may need to be addressed. Seismic liquefaction occurs when earthquake vibrations cause an increase in pore water pressure within the soil. The presence of excess pore water pressures reduces the effective stress between the soil particles and the soil's frictional resistance to shearing. This phenomenon, which leads to a temporary reduction in the shear strength of the soil, may cause large lateral movements of even gently sloping ground, referred to as "lateral spreading", as well as reduced support to foundations against vertical and lateral loading.

In addition, 'seismic settlements' may occur once the vibrations and shear stresses have ceased. Seismic settlement is the process whereby the soils stabilize into a denser arrangement after an earthquake, causing potentially large surface settlements.
The following conditions are more prone to experiencing seismic liquefaction:

- Coarser grained cohesionless (granular) soils (i.e., more probable for sands than for silts);
- Soils having a loose state of packing; and,
- Soils located below the groundwater level.

The assessment of the potential for seismic liquefaction should also consider the potential for soft ground conditions to amplify the seismic motion.

The assessment should be carried out using the design earthquake acceleration specified in the current version of the Ontario Building Code.

For the design of structures, design guidance should also be provided in regards to the impacts of the underlying subsurface conditions on the site response and the lateral seismic loading to the structure (e.g., the Site Class). For sites underlain by soft soils or deep bedrock, the Site Class may, for certain types of structures, dictate that larger seismic forces need to be considered in the structural design.

The selection of a Site Class, in accordance with the Ontario Building Code (OBC), is based on the average shear wave velocity of the 30 metres of soil and bedrock that underlie the foundations. This evaluation can be made by several geophysical methods including:

- Multichannel Analysis of Surface Wave (MASW), using measurement of the speed of transmission of surface ground vibrations, which can typically be generated by an impact on the ground surface (e.g., a sledge hammer impact or weight drop). This method does not require the drilling of a borehole.
- Vertical Seismic Profiling (VSP), whereby a borehole is drilled to 30 metres depth, a permanent casing is installed in the borehole, a probe is inserted down the casing, and the transmission of vibrations from ground surface (from a small impact) to the probe at depth is measured.
- Crosshole Seismic Testing whereby two boreholes are drilled to 30 metres depth, casings installed in each, and the transmission of vibrations is measured from a vibration source in one casing to a probe in the other.
- Seismic piezocone testing, whereby a piezocone probe (see Section 2.3) is pushed to depth (30 metres, if possible) and the transmission of ground vibrations from an impact on the ground surface to the probe at depth is measured. However this method does not provide the shear wave velocity of the bedrock to be used in the 'averaging' calculation (if bedrock is present within the 30 metre depth) since the probe cannot be pushed into the rock. In this case, the shear wave velocity of the bedrock would need to either be already known or estimated conservatively.
- These methods all have different levels of accuracy, and some may be more appropriate to certain site conditions, however they all are considered generally acceptable for the purposes of determining the Site Class.

The shear wave velocity can also, in some cases, be *estimated* from the results of the Standard Penetration Testing and in situ vane testing carried out in boreholes. However this assessment is not as accurate and the shear wave velocities should be estimated conservatively. Further, the shear wave velocity of the bedrock cannot be estimated in the same manner and must either be known or estimated conservatively (similar to the requirements for seismic piezocone testing). This overall method, although acceptable under the OBC, is not preferred and should only be applied conservatively.

3.3.4 Excavations and Impacts on Adjacent Structures/Properties

Where excavations will be required to construct the building and its foundations, guidelines should be provided on:

- The materials that will be excavated and the methods of excavation;
- The required stable side slope inclinations for excavations; and,
- Groundwater inflow and control.

For some sites, the geotechnical engineer may need to evaluate:

- The factor of safety against basal instability of braced/shored excavation sides slopes.
- The factor of safety against basal heaving due to piezometric pressures in permeable strata at depth.
- The potential for piping and disturbance of the subgrade soils due to the groundwater inflow.
- The need for a Permit-to-Take-Water from the Ministry of the Environment, due to the expected rate of pumping exceeding 50 cubic metres per day.

Where appropriate, the report must also include a discussion/assessment of the potential impacts on the performance of neighbouring (off-site) buildings, infrastructure, and property due to:

- Ground movements around the excavation, including shoring movements and underpinning movements;
- temporary or permanent groundwater level lowering in sensitive clay deposits;
- drying of expansive shale bedrock; and,
- blasting.
- Mitigation measures should be discussed, if appropriate.

If shoring will be provided around the excavation, or underpinning of adjacent buildings will be required, guidelines may be provided on the design.

The effects of groundwater level lowering on the productivity of adjacent wells should also be considered.

Where potential impacts are identified and/or need to be mitigated, the report should identify whether, in the opinion of the geotechnical engineer, a preconstruction survey should be considered. Guidelines should be provided on the scope of that preconstruction survey (e.g., adjacent wells, nearby buildings, services, etc.).

3.3.5 Foundation Drainage

The need for foundation drainage should be discussed in the geotechnical report. The need for foundation drainage should consider:

- The measured groundwater levels and the expected variation.
- The site grading.
- The types and depths of foundations (e.g., the depth of planned basements).
- Potential flood levels from adjacent water courses.
- The potential impacts on adjacent structures (e.g., settlement) due to groundwater level lowering resulting from drainage of the foundations.
- The potential for buoyant uplift forces if the foundations are not drained.

The report should clearly state the interpreted level of the groundwater surface (i.e., of the water table).

3.3.6 Earthworks Related to Site Servicing

For residential subdivisions with new internal roadways and site services, or for building sites with new services, geotechnical design guidelines should be provided in regards to excavations (per Section 3.3.4 of this document), bedding, cover, and backfilling. Where the City will ultimately become the owner of those services, their design and construction must conform to City standards.

As described previously, many parts of the City of Ottawa are underlain by potentially compressible sensitive marine Champlain Sea clay deposits. These deposits are subject to volume reduction (consolidation) when overstressed, such as may occur due to a reduction in the piezometric pressure in the deposit due to a lowering of the groundwater level. These deposits may also shrink when dried, such as may also occur due to lowering of the groundwater level into the deposit itself. Consolidation or shrinkage of the deposit could cause settlement of overlying structures. Therefore, the need for seepage barriers in the service trench bedding, cover, and backfill should be considered wherever the geotechnical engineer evaluates that a lowering of the groundwater level on the site or on adjacent sites could have an adverse impact.

Other geotechnical guidelines should be provided, as appropriate, consistent with the City of Ottawa Sewer Design Guidelines and the Standard Tender Documents for Unit Price Contracts.

3.3.7 Pavement Design

Where new roadways or other pavement areas (e.g., parking lots) will be constructed, guidelines on the pavement design should be provided. Where the roadway or paved area will ultimately be transferred to City ownership, the design and construction of those pavements must conform to City standards.
The geotechnical report should include a discussion on subgrade preparation, pavement design (e.g., asphalt, granular base, and granular subbase material types and thicknesses), and drainage. Variables that should be considered in the selection of the pavement structure include:

- The subgrade material.
- The groundwater level.
- The expected traffic levels.

The pavement design should be in general conformance with the current City standards.
The report should also provide direction on the level of inspection and review that is required during construction. Inspection and review may be required to confirm that the subgrade composition is consistent with the results of the investigation and the pavement design, recognizing that the shallow subsurface conditions can be more variable (e.g., due to past filling, the presence of organic deposits, etc.) and may therefore vary between boreholes. The *condition* of the subgrade may also need to be reviewed, such as where the compaction of trench backfill materials may be problematic (e.g., where trenches have been made through saturated sensitive clays) and may impact on the pavement design.

3.3.8 Corrosion and Cement Type

As discussed previously, geotechnical investigations typically include basic chemical analyses related to the potential for corrosion of buried ferrous elements or sulphate attack on buried concrete elements (i.e., the need to sulphate resistant cement). The results of this testing should be discussed in the geotechnical report.

3.3.9 Frost Heaving

The frost susceptibility of the soils on a site may be a concern with respect to both foundation design (e.g., the earth cover requirements for footings) as well as the design of pavements. However a particular concern is the frost susceptibility of Champlain Sea clays that have not previously been exposed to frost penetration. This issue can arise where the site grade will be lowered (i.e., where the site will be constructed in ‘cut’). These soils typically have a higher water content and, when exposed to frost penetration for the first few winter seasons, can experience excessive amounts of frost penetration and then a net loss of volume upon thawing. The end result can be severe distortion of paved areas or other hard surfacing. Special details, such as insulation of the subgrade, may be required where the site grading could result in this situation.

3.3.10 Contaminated Soil and Groundwater

If the geotechnical investigation identifies buried waste or obviously/suspected contaminated soil or groundwater (as defined by the Ministry of Environment's *'Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act, March 9, 2004'*), then this finding should be discussed in the geotechnical report. Issues which may then need to be addressed include:

1. Disposal of excess soil in accordance with Ontario Regulation 347/558.

2. Disposal of groundwater pumped from excavations.
3. Potential inflow of contaminated groundwater into foundation drainage systems.
4. Potential impacts of contaminated soil and groundwater on the design of sewers and watermains.
5. The need for a venting system around structures to prevent the build-up of explosive methane gas, where buried waste is present.

Additional environmental study and investigation (i.e., Phase I and Phase II Environmental Site Assessments) would generally be required to address these issues. However the finding of a potential issue, if identified by the geotechnical investigation, should be discussed in the report.

3.3.11 Slope Stability and Retaining Walls

Guidelines on the evaluation of the stability of slopes (or the global stability of retaining walls) and the content of slope stability assessment reports are provided in the City of Ottawa's document *"Slope Stability Guidelines for Development Applications in the City of Ottawa."* For new development projects, those guidelines may apply to both permanent natural slopes as well as temporary slopes associated with construction. Where unstable slopes exist, the report should define the Limit of Hazard Lands associated with that slope.

Health and Safety

If the geotechnical investigation identifies potential issues relating to health and safety, such as for construction personnel, then the geotechnical investigation report should identify those issues. Examples of possible issues include:

- The presence of contaminated soil or groundwater in excavations.
- The possible presence of methane or other explosive gasses.
- Concerns related to excavation side slope stability or basal instability.

3.3.13 Inspection and Review During Construction

The report should describe the inspection and review activities that are required by the geotechnical engineer during construction of the project. For example, these services could be related to compaction control for engineered fills or trench backfill, review of the subgrade conditions for roadways, or inspection of foundation bearing surfaces. If further evaluation of the foundation design parameters (i.e., allowable bearing pressures) is required during construction, such as on a lot-by-lot basis due to variability of the subsurface conditions across the site, then this requirement should be clearly identified in the report.

3.4 Community Design Plans

Geotechnical input to the preparation of Community Design Plans can vary in nature, depending on the size and type of development and on the subsurface conditions. Few specific guidelines can be provided on a generic basis for the required extent of investigation and scope of reporting. However, prior to advancing the preparation of a CDP, a geotechnical report should be prepared that addresses at least the following issues:

- Identify the general subsurface conditions within the study area.
- Identify significant geotechnical challenges to development (e.g., compressible clay soils, organic soils) or hazards (e.g., unstable slopes).
- Provide preliminary geotechnical guidelines on site grading, which will also depend on the development plans (e.g., suburban residential versus commercial). This information is required for later development of the Master Servicing Plan and Master Grading Plan, so that the design of trunk servicing can be developed.

- Provide input that will assist with the planning of the community layout, built forms, and development densities. For example, the investigation may identify parts of the study area that, due to the ground conditions, cannot be economically developed with higher density housing due to the higher foundation loads. For sites underlain by compressible clay soils, the geotechnical report may also, in conjunction with a hydrogeological evaluation, restrict the development density or propose other measures such that a minimum level of water infiltration will be maintained; these measures could be required to preserve minimum groundwater levels on the site in the long term and thereby avoid excessive ground settlements. The report may also identify parts of the site that are less suitable for the construction of certain structure types due to soft soil conditions that may amplify seismic ground motions and for which the building code (by means of a 'Site Class') may therefore specify higher seismic forces; these conditions may make the parts of the site less suitable for construction of school buildings or commercial building areas.