Guideline for Phase II Environmental Site Assessments in Ontario

Ministry of the Environment

Legislative Authority:
*Environmental Protection Act, R.S.O. 1990, Part XV.1*
Ontario Regulation 153/04

Last Revision Date:
Draft March 22, 2006

/BrownfieldsPhaseIIManualDraft Mar 22/06
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Preface

This guideline provides guidance to property owners, municipalities, consultants (i.e. Qualified Persons) and other interested parties on conducting a phase two environmental site assessment (Phase II ESA) under Part XV.1 of the Environmental Protection Act (EPA) and Ontario Regulation 153/04. This guideline provides guidance on generally accepted practice for planning a Phase II ESA, sampling methods for soil and groundwater, quality assurance/quality control procedures, data interpretation and reporting. For guidance on the sampling procedures for sediment, reference should be made to the Ministry of the Environment publication “Guideline for Sampling Sediments for the Purpose of Filing a Record of Site Condition” dated yyyy, 2006.

The legislative and regulatory requirements for conducting a Phase II ESA are set out in Part XV.1 of the EPA and Ontario Regulation 153/04. A phase one environmental site assessment (Phase I ESA) is required to file a record of site condition in the Environmental Site Registry. A Phase II ESA is also required to file a record of site condition for certain types of property use changes as set out in Section 27 of Ontario Regulation 153/04 or when a Qualified Person determines a Phase II ESA is necessary.

Ontario Regulation 153/04 sets out the basic components of a Phase II ESA and adopts, with some modifications, the Phase II ESA standard published by the Canadian Standards Association (CSA). These requirements must be complied with at all times. The CSA should be contacted to obtain a copy of the CSA standard (designated CAN/CSA Z769-00).

It is important to note that this guideline does not take into account site-specific conditions or the development of improved practices in conducting Phase II ESAs and is not a substitute for the use of good professional judgement in conducting Phase II ESAs. The particular sampling and site assessment requirements and procedures to be followed for any particular property depends on the specific circumstances of the property and must be determined by the Qualified Person responsible conducting the Phase II ESA.

Some of the activities contemplated in this guideline may require approval from the Ministry of the Environment or other bodies, or may have other legislative requirements. Persons using this guideline should ensure that all appropriate approvals are obtained and the applicable requirements followed.

It should be noted that the description of the legislative and regulatory requirements given in this guideline is for convenience only. A copy of the relevant legislation and regulations should be obtained to determine the exact requirements.

This guideline may be amended from time to time.
1. Introduction

This guideline provides guidance to property owners, municipalities, consultants (i.e. Qualified Persons) and other interested parties on conducting a phase two environmental site assessment (Phase II ESA) under Part XV.1 of the Environmental Protection Act (EPA) and Ontario Regulation 153/04. This guideline provides guidance on generally accepted practice for planning a Phase II ESA, sampling methods for soil and groundwater, quality assurance/quality control procedures, data interpretation and reporting. For guidance on the sampling procedures for sediment, reference should be made to the Ministry of the Environment (Ministry) publication “Guideline for Sampling Sediments for the Purpose of Filing a Record of Site Condition” dated yyyy, 2006.

Under Part XV.1 of the EPA, a property owner may file a record of site condition in Ontario’s Environmental Site Registry if the applicable standards are met for soil, groundwater and sediment. Part XV.1 of the EPA defines two types of environmental site assessment: a phase one environmental site assessment (Phase I ESA) and a phase two environmental site assessment (Phase II ESA). A Phase I ESA is an initial assessment of a property and is undertaken to determine the likelihood that contaminants have affected the property. A Phase II ESA is a more detailed assessment of the property and is undertaken to determine the concentration of contaminants on the property (i.e. to determine if suspected contaminants identified in the Phase I ESA are present or not; and if present, at what concentrations the contaminants are found and whether or not any contaminants are found at concentrations exceeding generic or property-specific standards applicable to the property).

A Phase I ESA is required to file a record of site condition in the Environmental Site Registry. A Phase II ESA is also required to file a record of site condition for certain types of property use changes as set out in Section 27 of Ontario Regulation 153/04 or when a Qualified Person determines a Phase II ESA is necessary.

The legislative and regulatory requirements for conducting a Phase II ESA are set out in Part XV.1 of the EPA and Ontario Regulation 153/04. Ontario Regulation 153/04 sets out the basic components of a Phase II ESA and adopts, with some modifications, the Phase II ESA standard published by the Canadian Standards Association (CSA). These requirements must be complied with at all times. The CSA should be contacted to obtain a copy of the CSA standard (CAN/CSA Z769-00).

It is important to note that this guideline does not take into account site-specific conditions or the development of improved practices in conducting Phase II ESAs and is not a substitute for the use of good professional judgement in conducting Phase II ESAs. The particular sampling and site assessment requirements and procedures to be followed for any particular property depends on the specific circumstances of the property and must be determined by the Qualified Person responsible conducting the Phase II ESA.

This guideline provides guidance in the following areas:
• **Planning a Phase II ESA** – including setting study objectives, developing a detailed work plan, preparing for field work, and undertaking site testing and sampling (Section 3);

• **Sampling methods** for soil and groundwater (Sections 4 and 5). Sediment sampling methods/procedures are described in the Ministry publication “Guideline for Sampling Sediments for the Purpose of Filing a Record of Site Condition” dated yyyy, 2006;

• **Quality assurance/quality control** for the overall project and in conducting field work (Section 6); and

• **Data interpretation and reporting** (Section 7).

This guideline also briefly summarizes Phase I ESA requirements (Section 2).
2. Phase I Environmental Site Assessments

The first step in the site assessment process involves the systematic gathering of information to identify actual or potential contamination and sources of contamination. This is referred to as a Phase I Environmental Site Assessment (Phase I ESA).

A Phase I ESA is required in order to file a record of site condition in the Environmental Site Registry and serves as the basis for the planning of a Phase II ESA (if a Qualified Person determines there is a potential for contamination or a mandatory Phase II ESA is required under Ontario Regulation 153/04). A Phase I ESA therefore should be conducted in a thorough and comprehensive manner such that the information gathered is suitable for use in planning the Phase II ESA. Information from the Phase I ESA will help provide direction on the media to be sampled (i.e. soil, groundwater or sediment), the chemical parameters to be analyzed for and the areas of the property to be sampled and assessed.

2.1 Legislative Requirements

The legislative and regulatory requirements for conducting a Phase I ESA are set out in Part XV.1 of the EPA and Ontario Regulation 153/04. The specific requirements for a Phase I ESA are set out in Part VII of Ontario Regulation 153/04.

A Phase I ESA is conducted to determine “the likelihood that one or more contaminants have affected all or part of the property” and is required to file a record of site condition in the Environmental Site Registry. Under Ontario Regulation 153/04, a Phase I ESA must include a records review, a site visit, interviews, an evaluation of the information from these activities, the preparation of a written report and submission of the report to the client (property owner). A Phase I ESA generally does not include sampling and analysis of the property (i.e. soil, groundwater or sediment). Sampling and analysis is part of a Phase II ESA.

For the more detailed requirements of a Phase I ESA, Ontario Regulation 153/04 adopts, with some modifications, the Phase I ESA standard published by the Canadian Standards Association (CSA). In particular, the regulation adopts Clauses 7, 8 and 9 of the CSA document “Phase I Environmental Site Assessment,” designated CAN/CSA Z768-01 and dated November 2001 (as it may be amended from time to time). The CSA should be contacted to obtain a copy of CAN/CSA Z768-01. Reference should be made to the modifications to these clauses contained in Ontario Regulation 153/04.

Reference should be made to the specific requirements in Ontario Regulation 153/04.
3. Phase II Environmental Site Assessments

A Phase II Environmental Site Assessment (Phase II ESA) is undertaken to determine the nature and extent of any potential contamination of soil, groundwater or sediment at a property. A Phase II ESA, requires that sampling (of soil, at a minimum) be conducted on the site, and in general, consists of a planning stage, a sampling and chemical analysis stage, and an interpretation and evaluation stage. It is important that provisions for feedback be incorporated in the planning stage to allow for additional sampling, as appropriate, based on the interpretation of results. The activities, findings and conclusions of the Phase II ESA should be clearly documented in a Phase II ESA report.

A Phase II ESA is required (along with a Phase I ESA) in order to file a record of site condition in the Environmental Site Registry if:

- The property has been used for an industrial use or for certain commercials uses (refer to mandatory Phase II ESA requirements in Section 27 of Ontario Regulation 153/04); or
- A Qualified Person determines a Phase II ESA is needed (i.e. when the Phase I ESA indicates a Phase II ESA is needed).

A Phase II ESA (and Phase I ESA) may also be conducted for purposes other than filing a record of site condition, such as for purposes of a sale of property between parties or to obtain financing or a mortgage.

When a Phase II ESA is to be conducted, the findings of the Phase I ESA for the property will provide an indication of the sampling locations to be included in the Phase II ESA and will provide direction for determining which chemical parameters from soil, groundwater or sediment samples to select for analysis at each sampling location included in the Phase II ESA. The results of the Phase II ESA will indicate whether site conditions meet the generic or property-specific standards for the proposed property use.

3.1 Legislative Requirements

The legislative and regulatory requirements for conducting a Phase II ESA for purposes of filing a record of site condition are set out in Part XV.1 of the EPA and Ontario Regulation 153/04. The specific requirements for a Phase II ESA are set out in Part VIII of Ontario Regulation 153/04.

Under Part XV.1 of the EPA, a Phase II ESA is conducted “to determine the location and concentration of one or more contaminants in the natural environment.” A Phase II ESA is required for purposes of filing a record of site condition in the Environmental Site Registry for some types of proposed changes of property use as set out in Section 27 of Ontario Regulation 153/04. A Phase II ESA is also required when the Qualified Person (a person meeting the qualifications as set out in Section 5 of Ontario Regulation 153/04) is of the opinion that a Phase II ESA is necessary based, for example, on the results of a Phase I ESA for the property.
Under Ontario Regulation 153/04, a Phase II ESA must include planning and conducting a site investigation, interpreting and evaluating the information from the investigation, the preparation of a written report and submission of the report to the client (property owner). A Phase II ESA must include, at a minimum, soil sampling and analysis. Sampling and analysis of groundwater and/or sediment, if any, is required if the Qualified Person conducting the Phase II ESA determines it to be necessary.

For the more detailed requirements of a Phase II ESA, Ontario Regulation 153/04 adopts, with some modifications, the Phase II ESA standard published by the Canadian Standards Association (CSA). In particular, the regulation adopts Clauses 6, 7, 8 and 9 of the CSA document “Phase II Environmental Site Assessment,” designated CAN/CSA Z769-00 and dated March 2000 (as it may be amended from time to time). The CSA should be contacted to obtain a copy of CAN/CSA Z769-00. Reference should be made to the modifications in Ontario Regulation 153/04.

Reference should be made to the specific requirements in Ontario Regulation 153/04.

### 3.2 Planning Stage

Information from a Phase I ESA is used in designing and conducting a Phase II ESA as it helps identify potential source areas of contamination, potential pathways and directions of contaminant migration as well as the types of contaminants which may be present. Appropriate sampling should be conducted during the Phase II ESA in any areas where the Phase I ESA has identified the potential for contamination. Additional sampling may be needed if the initial Phase II ESA work indicates there may be other possible areas of contamination or other contaminants present.

To ensure a Phase II ESA is conducted in a complete and thorough manner, it is important that the site assessment be properly planned. The key steps in planning a Phase II ESA include a review of available information in order to develop a preliminary or conceptual understanding of the site characteristics, developing the detailed work plan and preparing for field work. Establishment of the study objectives and determination of site assessment criteria (i.e. potential contaminants of concern) should be established early in the planning process as the scope of work for the Phase II ESA is based to a large extent on these factors. The study objectives and site assessment criteria should be clearly stated in the Phase II ESA report.

Phase II ESAs are often carried out using a combination of non-intrusive and intrusive testing techniques. Non-intrusive testing is conducted to obtain additional information about the site to help identify natural or constructed features that may affect the work plan and to reduce the number of analyses that would otherwise have to be conducted. Intrusive sampling is conducted to obtain the necessary samples and field information for site and contaminant characterization.

The planning of a Phase II ESA is also closely linked with quality assurance (QA) and quality control (QC) issues. Reference should be made to Section 6 of this guideline which describes QA/QC for Phase II ESAs.
3.2.1 Study Objectives

The purpose of a Phase II ESA is to determine the location and concentration of contaminants on a property. The specific study objectives for the Phase II ESA follow from this purpose and should be determined by the Qualified Person after a comprehensive review of the available site data (e.g. Phase I ESA findings). These objectives normally include the following:

- Developing a basic understanding of the site geology and hydrogeology, often referred to as developing a “hydrogeological conceptual site model.” The specific nature and level of detail required of such an understanding, and the level of effort required to achieve this depends on the specific study objectives and site conditions;
- The properties of media (e.g. soil texture classification) that will affect the generic or property-specific (i.e. as determined by a risk assessment) standards applicable to the property;
- Delineating the nature and extent of any contamination. This will include considering the spatial distribution of the potential contamination. It will also consider the chemical composition of potential contaminants (as this will drive the selection of criteria for laboratory analysis) and the media in which the potential contamination may be found (i.e. soil, groundwater or sediment). If possible, identify/describe the origin or source of the contaminants (including whether on-site or off-site source); and
- Identifying any potential for off-site impacts (note that work such as off-site sampling and analysis to determine the specific extent and nature of any potential off-site impact is not generally part of the Phase II ESA of the subject property).

If the findings of the Phase II ESA allow the Qualified Person to conclude that site conditions meet the applicable standards for the intended use of the property, then further site investigation or site cleanup/remediation or risk assessment/mitigation is not required. However, should initial findings of the Phase II ESA indicate that site conditions are not appropriate for the property’s intended use, further site investigation to fully delineate the nature and extent of contamination would be necessary. This information would then be used for purposes of site cleanup/remediation, or for purposes of conducting a risk assessment and developing, if appropriate, a risk mitigation or cleanup/remediation plan.

When site cleanup/remediation is needed, additional confirmatory or verification sampling is needed to confirm that the property, after cleanup, meets the applicable generic or property-specific standards. Although not strictly part of a Phase II ESA, this sampling should generally be conducted in a similar manner to the Phase II ESA sampling. The results of the confirmatory sampling should be included in a site cleanup/remediation report.

3.2.2 Review of Existing Information

Defining the scope of work for a Phase II ESA includes all activities necessary to plan and undertake the field work and analysis of data. These activities include a review of the Phase I
ESA for the property and a review of any other available information that is considered appropriate. This review serves the following purposes:

- Identifies potential contaminants and contaminant sources, including potential on-site and off-site sources;
- Provides an understanding of the physical characteristics of the site, which includes the site geology and hydrogeology, identification of potential receptors (e.g. well users, surface water bodies), etc.;
- Provides information for an initial representation of the potential distribution of contaminants in soil and groundwater (and sediment, if any); and
- Establishes a basis for designing field investigations.

The following information should be reviewed, as appropriate, during the planning phase of a Phase II ESA:

- Previous site assessments (the Phase I ESA and any previous Phase II ESA) and any previous site cleanup/remediation reports (this information may require validation and any limitations or inaccuracies should be identified if possible); and
- Any other relevant information not included in previous site assessment or cleanup/remediation reports.

### 3.2.3 Preliminary Site Characterization

Based on available information, a preliminary understanding of the site geology and hydrogeology, or “hydrogeological conceptual site model,” should be developed to assist in the planning of field activities at the site. A summary of the preliminary site conceptualization characterization should be presented in the Phase II ESA work plan, as a means of rationalizing the proposed site activities. Data gaps will be filled through the collection and interpretation of the field data. The site characterization developed should have a level of detail appropriate for the complexity of the site and the extent of contamination, if any, at the site. Determination of the level of detail will be based upon the professional judgement of the Qualified Person responsible for the performance of the Phase II ESA. Upon completion of the Phase II ESA, the site characterization, as confirmed by the Phase II ESA work, should be included in the final Phase II ESA report.

### 3.2.4 Development of a Detailed Work Plan

The work plan should be designed to guide the collection of information that will refine the site characterization and define the distribution and concentration of any contaminants. The work plan should be flexible enough to account for unexpected field conditions or inability to gain access to intended sampling locations. The field activities described in the work plan generally fall within the following areas:
• Sampling locations;
• Analytical parameters;
• Non-intrusive testing;
• Intrusive testing; and
• Quality assurance/quality control.

A site plan is required for Phase II ESA work plan development. The scale of the plan should be sufficient to depict key site conditions, including key topographical information, as appropriate. The site plan should indicate available information on all potential sources of contamination, above ground and underground utilities, roads and site access, site drainage, buildings, structures, tank systems, and other information needed for the planning of field work.

3.2.4.1 Sampling Locations

The media to be sampled (i.e. soil, groundwater or sediment) and the locations, and number of samples to be obtained should be identified in the work plan. Proposed sampling locations should be shown on a site plan. The location (and depth) and number of samples, and the suite of chemical analyses, will depend upon site characteristics, but should be sufficient to identify contaminant source areas, if possible, and to define the distribution of contaminants (i.e. to delineate areas of impact and concentrations).

Since a judgemental or focused sampling approach is typically used for Phase II ESA field investigation programs, clear rationale should be provided for the medium being sampled and each sample location. For ease of review, it may be helpful to present all sampling in tabular form, including the sample medium, sample location (horizontal) and depth, as well as the sampling method, analytical parameters and sampling rationale.

3.2.4.2 Analytical Parameters

Parameters required for analysis should be determined during the planning stage on the basis of the history of the site and the potential for contamination, as determined in the Phase I ESA. Normally, there should be no need to have samples analyzed for all parameters found in the Ministry publication “Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act” dated March 9, 2004. In some cases, however, there may be potential contaminants of concern identified by the Qualified Person which should be tested for although they have not been included in the Ministry publication “Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act.”

As required by Ontario Regulation 153/04, the handling and analysis of samples must be in accordance with the Ministry publication “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” dated March 9, 2004 and with the use of an accredited laboratory.
3.2.4.3  Non-Intrusive Testing

Any non-intrusive methods to be used during the field program should be described in the work plan.

Non-intrusive testing is the use of sensing devices to locate underground features, such as buried tanks/objects, bedrock, or contaminant plumes, without digging, drilling or the use of sampling probes. The use of such methods is often useful in guiding the location of the sampling points.

The main methods or devices used are electromagnetic (EM), magnetic (M) and ground penetrating radar.

Electromagnetic devices measure changes in electrical conductivity. They can be used to detect underground structures such as storage tanks, and well defined inorganic contaminant plumes where the contaminants alter the electrical conductivity. Interference with EM readings is often created by above ground structures.

Magnetic devices measure local changes in the earth’s magnetic field. As such, they can detect underground structures containing iron. Magnetic devices are more sensitive than EM and are not as sensitive to interference from above ground structures.

Ground Penetrating Radar devices measure the change in wavelength of a radar signal that results as the signal travels through the ground and returns back to the device. This change is proportional to the electrical conductivity, the ionic conductivity, and the water content of the ground. These devices can also provide the depth to the anomaly or buried object; however, in most soils they are only useful for detection of near surface objects and contaminant plumes. Since the penetration of the radar decreases as soil water content increases, it is generally only useful under relatively dry soil conditions.

3.2.4.4  Intrusive Testing

All field methodologies to be used for soil, groundwater and sediment sampling, soil drilling, monitoring well construction, trenching, and other activities should be identified. This includes certain field screening activities, such as soil headspace vapour screening and visual observations that will be employed during the field program.

Intrusive sampling is necessary to obtain samples of the relevant media from which accurate analytical determinations of contaminant concentrations can be made. Methods for conducting sampling are described for each media (i.e. soil and groundwater) in detail in Sections 4 and 5 of this guideline.

When relevant (i.e. taking into consideration the properties of the media and the contaminants), sampling should extend to below the zone of contamination where technically possible in order to achieve vertical contaminant delineation. When drilling through confined subsurface layers, appropriate drilling and well construction practices should be used to prevent the creation of
conduits for vertical migration of contaminants. All boreholes and wells must be properly abandoned when no longer required for further sampling and/or monitoring.

3.2.4.5 Quality Assurance/Quality Control

Quality Assurance/Quality Control (QA/QC) requirements should be determined at this stage to ensure sampling and sample handling is carried out in accordance with required protocols. These could include items such as numbers and types of field QC samples, QA measures such as requirements for field instrument calibration and documentation, field checks for instruments, review or establishment of standard field procedures with field staff, review of sample holding times and decontamination requirements. In all cases the analytical protocols set out in Section 47 of Ontario Regulation 153/04 must be met.

QA/QC procedures are discussed in Section 6 of this guideline.

3.2.5 Preparation for Field Work

An initial site reconnaissance may be made prior to or during work plan development. This allows confirmation of accessibility of sampling locations and requirements for access for mechanized sampling equipment such as drill rigs. Site contacts should be established for field personnel if required. Safety considerations for completion of the field work should be considered.

3.2.5.1 Health and Safety Plan/Emergency Plan

A health and safety plan (HSP) and emergency plan should be completed prior to the start of field work. The plan documents that a hazard assessment has been made regarding the proposed field tasks and indicates what protective and response actions and procedures are to be taken in response to events occurring at the site. Emergency planning procedures can be incorporated in the HSP or described separately.

The HSP and emergency planning procedures should include the following items:

- An identification of potential chemical hazards, based on possible contaminants of concern, their properties and toxicology;
- An identification of potential physical hazards, based on the proposed field tasks, manual or mechanical equipment;
- Field procedures to be followed when entering and leaving the site (e.g. sign in and out procedures);
- Emergency response phone numbers, including: local fire/emergency services, client/property owner, field staff head office, on-site staff, local public works and utilities; and
• The location (on a map and written directions) of the closest hospital to the site (equipped with emergency facilities).

The HSP should be reviewed and retained by field staff while field work is being done. Persons completing the field tasks should have appropriate health and safety training as required by applicable Ontario health and safety regulations.

3.2.5.2 Utility Locations

Location and clearance of buried and overhead utilities at the site must be completed prior to the start of intrusive field sampling work. This is primarily a requirement for safety and to prevent damage to infrastructure, but this also helps with the site characterization. For example, utility trenches backfilled with granular fill may provide a potential transport path for contaminants. The utility locators and the project field staff should meet at the site to identify the exact location of any utilities.

3.3 Sampling and Analysis Stage

A Phase II ESA must include, at a minimum, soil sampling and analysis (except in a “no-soil situation” refer to subsection 3.3.1). Sampling and analysis of groundwater and sediment, if any, is to be done if considered appropriate by the Qualified Person conducting the Phase II ESA. Sampling should be conducted in all potentially contaminated areas identified in the Phase I ESA. A sufficient number of sampling sites should be established to clearly delineate each potential area of contamination. This often means that some sampling will occur in areas where contamination is not suspected.

3.3.1 Soil Sampling

The actual pattern and number of sample sites will depend on the expected distribution of the contaminants. The depth(s) of sampling will depend on the nature and location of the source (i.e. underground vs. surface) of the contamination, soil stratigraphy (i.e. sand vs. clay), and type of contaminant (i.e. mobile vs. non-mobile). Normally, soil sampling should extend beyond the zone of contamination in order to obtain vertical delineation of the contaminants. Many contaminants, especially liquids, however do not move downwards in a broad uniform front and therefore in these situations a single clean sample beneath found contamination does not necessarily mean that elsewhere the contaminants have not migrated further down.

In some situations all soil on a property may have been excavated to bedrock and to the property boundaries, and is being left that way for future construction purposes. In other situations, the property may be a naturally occurring Shallow Soil Property with the bedrock at surface and essentially no soil available for sampling. Each of these cases may be considered as a no-soil situation. In these situations, if the property owner needs to file a Phase II record of site condition (RSC) for the property and there is essentially no soil available for sampling, a Phase II RSC may be filed without including soil sampling results provided:
The Qualified Person completes the section of the Phase II RSC entitled “Soil Remediation Process” and states that at the time of filing all of the soil had been excavated to bedrock to the extent of the property boundaries and has been removed off-site; or

- Shallow Soil Property conditions existed and there is essentially no soil available for sampling for the entire property; and

- Where the excavated soil or Shallow Soil Property may have been contaminated, the Qualified Person has assessed the potential for impact on groundwater at the property and, if appropriate, has included groundwater results in the Phase II RSC.

Soil sampling is discussed further in Section 4 of this guideline.

### 3.3.2 Groundwater Sampling

In general, a minimum of one groundwater monitoring well should be established for each potential source area of contamination. If soil sampling clearly indicates that contaminants from a specific source could not have reached the groundwater, then the Qualified Person conducting the Phase II ESA may decide that a monitoring well may not be required at that location.

If groundwater flow gradients need to be determined and there is insufficient existing information available for the site or area, then additional monitoring wells may need to be installed. Unless there is good existing knowledge of the groundwater flow gradients, more than three wells would normally be needed to demonstrate that the flow direction is uniform across the site or area. The presence of utility trenches and subsurface heterogeneity would indicate that even more wells may be needed. The decision on the number and location of additional wells however should be determined by the Qualified Person on a case-by-case basis.

Groundwater sampling is discussed further in Section 5 of this guideline.

### 3.3.3 Sediment Sampling

In general, sediment sampling sites should be established at upstream and downstream property boundaries. Sediment sampling locations would typically also be established immediately downstream of any point source discharges from the property, any runoff from any potentially contaminated areas of the property and within any potentially contaminated storm water ponds which are to remain on the property.

For guidance on sediment sampling, reference should be made to the Ministry publication “Guideline for Sampling Sediments for the Purpose of Filing a Record of Site Condition” dated yyyy, 2006.
3.3.4 Confirmatory Sampling (Site Cleanup/Remediation)

If a property does not meet the applicable site condition standards or any property-specific standards as determined by a risk assessment, site cleanup/remediation would be needed before a record of site condition can be filed in the Environmental Site Registry.

A Phase II ESA does not specifically include confirmatory (site cleanup/remediation) sampling. In general however, sampling to confirm the effectiveness of cleanup measures would be undertaken in a similar manner to a Phase II ESA. The confirmatory sampling should normally be conducted in conjunction with the remedial work program to provide feedback to the remedial work. Cleanup/remediation would continue until the confirmatory sampling shows that the cleanup/remediation targets (i.e. the applicable site standards) have been met. A report should be prepared upon completion of site cleanup documenting the site cleanup/remediation activities and results of the confirmatory sampling. The results of the confirmatory sampling would be used in conjunction with the Phase II ESA sampling results for purposes of filing a record of site condition.

3.3.5 Analytical Protocols and Laboratory Accreditation

Section 47 of Ontario Regulation 153/04 requires that the sampling and analysis of soil, groundwater and sediment be carried out using proper analytical procedures and with the use of an accredited laboratory.

3.3.5.1 Analytical Protocols

Under Section 47 of Ontario Regulation 153/04, the procedures for the handling and analysis of samples must be in accordance with the Ministry publication “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” dated March 9, 2004. The analytical methods and quality control protocols set out in the “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” address matters such as sampling requirements, quality control and quality assurance, the protocol for accepting analytical results, and reporting of data. Reference should be made to the specific requirements in Ontario Regulation 153/04. Discuss sampling requirements with the laboratory prior to sampling.

3.3.5.2 Laboratory Accreditation

Section 47 of Ontario Regulation 153/04 requires the use of an accredited laboratory for the analysis of soil, groundwater and sediment. The laboratory must be accredited in accordance with:

- The International Standard ISO/IEC 17025 – General Requirements for the Competence of Testing and Calibration Laboratories, dated December 15, 1999, as amended from time to time; and
• Any laboratory standard that may have been developed by the Standards Counsel of Canada for a parameter set out in the Ministry publication “Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the *Environmental Protection Act*” dated March 9, 2004.

Reference should be made to the specific requirements in Ontario Regulation 153/04.

### 3.4 Interpretation and Evaluation Stage

Data interpretation and evaluation is done to determine if the Phase II ESA findings are sufficient and correct, and to understand the significance of those findings with respect to the study objectives. The primary purpose of a Phase II ESA is to determine the location and concentration of contaminants on a property for purposes of filing a record of site condition in the Environmental Site Registry. In order to make such a conclusion, however, the interpretation and evaluation would also have to consider whether the sampling and site assessment work was sufficient and done properly.

In order to file a record of site condition the contaminant concentrations must meet the applicable site condition standards. Sections 48 and 49 of Ontario Regulation 153/04 set out regulatory requirements with respect to samples meeting standards.

#### 3.4.1 Data Analysis and Interpretation

Data analysis and interpretation should seek to present and summarize the data in a clear and logical way which establishes the existing conditions with respect to chemical concentrations of contaminants and provides conclusions concerning meeting the standards.

Patterns of contamination may be related to the physical characteristics of the site, such as grain size in soils, and can be used to establish linkages to contaminant sources. This is why it is important to have good information on the physical characteristics and previous uses of the site.

The process of sampling and interpretation is often iterative, with the results of one sampling program indicating the need for further sampling to fully define the contaminants present, their distribution and contaminant concentrations. In cases where the sampling results indicate the property meets the standards, and the Qualified Person is confident sufficient sampling has been carried out to assess potentially contaminated areas of the property, further assessment can often be limited to confirming sufficient sampling has been done. In cases where sampling indicates the standards are not met, additional sampling and analysis would be needed.

In some cases, sampling may also indicate a potential off-site impact from contaminants originating from the subject property (particularly in groundwater). Although determining the extent of possible off-site impacts is not strictly a part of the Phase II ESA of the subject property, any such potential should be identified and described in the Phase II ESA report.
If sampling results do not meet the standards, comparison of results among sampling locations should be done. By comparing results between impacted and non-impacted areas, the areas of contamination, including potential sources of contamination, either on-site or off-site, can be determined. Comparing results among sampling locations can also help identify possible anomalies and the need for additional sampling.

### 3.4.2 Meeting Standards

Section 48 of Ontario Regulation 153/04 specifies that a property meets an applicable site condition standard in the Ministry publication “Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the *Environmental Protection Act*” or a property-specific standard as determined by a risk assessment of the property if the standard is met at each sampling point from which a sample is taken. The Qualified Person of course must ensure that the sampling points include points representative of maximum contaminant concentrations on the property. A record of site condition lists these maximum concentrations.

If a sampling result does not meet the applicable site condition standard, a record of site condition cannot be filed for the property without further work being done. Further sampling and assessment would have to be done for the area of the sampling point to determine if the initial sampling result is truly representative of that sampling point, and to determine if any site cleanup or risk assessment work is necessary. A record of site condition could only be filed after such sampling, assessment, cleanup or risk assessment work has been completed, as appropriate, and only if the sampling shows that the affected area/location meets the applicable site condition standards.

Section 48 of Ontario Regulation 153/04 also specifies that if two or more samples of soil (or sediment) are taken from the same location, the standard is met if the average of the sampling results meets the standard. This provision deals with composite sampling and is discussed further in subsection 4.2.2.1 of this guideline.

For petroleum hydrocarbon related standards, Section 49 of Ontario Regulation 153/04 specifies that the Qualified Person must also determine (in addition to meeting Section 48 requirements) that there is no evidence of “free product” present.

Reference should be made to the specific requirements in Ontario Regulation 153/04.
4. **Soil Sampling**

The assessment of soil quality is a fundamental component of a Phase II ESA. A Phase II ESA must include soil sampling and analysis (except in a “no-soil situation” refer to subsection 3.3.1). Soil sampling and analysis will indicate whether soil conditions are appropriate for the site use or whether site cleanup/remediation (or a risk assessment) is necessary. The results of the soil sampling will also help indicate, along with the results of the Phase I ESA, if the groundwater (or sediment, if any) at the property may be contaminated and should also be sampled.

Within any soil there is inherent variability in physical and chemical properties. The degree of variability differs according to numerous factors, including the size of the area, mode of contamination, the physical/chemical properties of the contaminant, stratigraphy and soil type. These factors can produce spatial variability that is considerably larger than that encountered in other media. The personnel conducting soil sampling should consider this variability in assessing potential contamination of a property.

4.1 **Design of a Soil Sampling Program**

Adequate planning of the sampling program must occur in order to assure that samples represent the areas and depths desired, that sampling variability is properly determined and accounted for, and that there are sufficient numbers of samples at the appropriate locations to fulfil the purposes of the sampling.

4.1.1 **Planning for Field Sampling**

During the planning phase, all the requirements of a proper field sampling program should be detailed and accounted for. The program should outline the sampling methods that are to be used for different types of samples, as well as the field collection and laboratory submission procedures to be used. This will help ensure that consistent procedures are followed to the extent necessary for comparability of results between sampling locations and between samplings conducted by different personnel.

The planning for field sampling should result in sampling personnel having full knowledge of sampling procedures to be used, observations of field and soil conditions to be recorded, the planned sampling locations, criteria for relocating planned sampling sites, methods of recording site locations, proper containers and labelling of samples, and proper procedures for storing and delivering samples to the analytical laboratory. If appropriate, contact should be made at this stage with the analytical laboratory, especially if analysis for many of the trace organic contaminants is being considered.

The planning for sampling should include consideration of all aspects of the safety of the sampling personnel, as well as of the environment. This includes the potential for exposure to hazardous materials, dangers posed by equipment, and field conditions for which safety
protocols should be in place such as excavations, encountering buried pipes and storage tanks, etc.

4.1.2 Staged Sampling

For most contaminants of concern at a site, the movement through the soil is sufficiently slow that concentrations do not change significantly over short periods of time. This allows sampling to be conducted in either one or two (or more) stages. A one stage sampling plan results in all samples being collected and analyzed in one survey. A two (or more) stage plan begins with a limited sampling plan to determine the presence or absence of the chemical parameters of interest, any significant variability of the chemical parameters, and the location of “hot spots” exceeding the applicable standards. From the results of the initial sampling, additional sampling scheme can be planned to define more precisely the areas of concern. Two stage sampling is generally more efficient in that it normally results in better characterization of the site with fewer analyses, however, it may take more time to conduct than one stage sampling.

4.1.3 Sampling Plan Designs

Using the available background information, a sampling plan design that is most appropriate for the specific situation can be developed. A sampling design should account for both the likelihood of the contamination originating from a particular source and how the contaminants may have moved over time. The main types of sampling plan designs are as follows:

- Simple random sampling;
- Stratified random sampling;
- Systematic sampling; and
- Judgement (or Focused) sampling.

4.1.3.1 Simple Random Sampling

Locations for sampling are chosen in advance using a proper randomizing method. As there is no other restriction, all locations have an equal chance of being sampled, even if an immediately adjacent location has already been chosen.

This approach is rarely used on its own. It would only be useful if there was no indication of probable contaminant sources or distribution, soil type was uniform across the site, and obtaining a uniform distribution of samples across the area was not important.

4.1.3.2 Stratified Random Sampling

Areas likely to have higher concentrations of contaminants, or higher variability of contaminants, are delineated (thus “stratifying” the design), then sampled, normally at a higher frequency than the other areas. Sampling within “strata” is properly randomized, as in subsection 4.1.3.1 above.
This approach is used when knowledge of the site is sufficient to delineate areas that are more likely to be contaminated, or are likely to have differences in background concentrations or in variability. If done properly, stratification reduces sampling variability by separating out areas of high and low concentrations and/or variability, and reduces the number of samples required. It defines the areas of greatest interest and provides for reduction of sampling in other areas.

4.1.3.3 Systematic Sampling

Samples are collected in a regular pattern. This may be along specified radii, or on points of a grid. The pattern is chosen according to knowledge of the site. Based on initial sampling results, additional systematic sampling would be undertaken to determine maximum concentrations in areas where contamination has been identified.

This approach normally provides better, or more complete coverage of the area than the random methods.

4.1.3.4 Judgement (or Focused) Sampling

This is the most commonly used sampling approach in conducting Phase II ESAs. In this sampling design, sampling locations are chosen solely on judgement, one location at a time. This judgement is based largely on the results of the Phase I ESA and the review of any other existing information, the conceptual understanding of the site and the results of previous sampling. In conducting judgement sampling, therefore, it is important that information used to focus the sampling program be as accurate and complete as possible, with the choice of each sampling location having an appropriate rationale.

Where this approach is used, it is usually prudent to combine it with other designs, such as systematic sampling, to ensure other areas of the property have been checked for contamination. This check is important as the review of existing information about the site may not reveal all potential sources of contamination.

4.2 Sampling Methods

Sampling methods should consider the type of material likely to be encountered on the site and the depth of sampling, and match this with appropriate sampling equipment/device and sampling procedures.

4.2.1 Sampling Equipment

Sampling equipment or devices fall into two main groups: manual samplers for surficial soils and mechanical (core) samplers for at-depth soils. In some cases, mechanical excavation (test pits) may also be used.
4.2.1.1 Manual Samplers (Surface Soil)

Manual soil sampling is typically done for surface or shallow soil sampling.

For samples collected at ground surface, or at shallow depths (less than about 30 centimetres), hand scoops, tulip bulb planters, dutch augers, or trowels can be used. Equipment should be constructed of stainless steel.

Devices, such as hand (or power) augers, can access soils at depths up to approximately 5 metres. These samplers will provide “disturbed” soil samples. Augering devices are not considered suitable for samples to be analyzed for volatiles, due to soil disturbance, and the possibility for cross-contamination between layers. It is preferable to reach the desired sample depth with an auger, then collect the soil sample with a soil probe or other device. Manual sampling methods, such as with a hand trowel, or hand auger, are suitable for shallow and surface soil only. Decontamination of manual sampling equipment is required between each sampling point.

Table 1 provides a summary of manual samplers.

<table>
<thead>
<tr>
<th>Device</th>
<th>Use</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trier</td>
<td>Loose surface soil</td>
<td>Inexpensive, easy to use and decontaminate</td>
<td>Difficult to use in dry, stony or sandy soil</td>
</tr>
<tr>
<td>Scoop or trowel</td>
<td>Loose to compact surface soil</td>
<td>Inexpensive, easy to use and decontaminate</td>
<td>Difficult to use in dry, stony or sandy soil, difficult to obtain sample at a specific depth</td>
</tr>
<tr>
<td>Tulip bulb planter</td>
<td>Loose to compact surface soil</td>
<td>Easy to use and decontaminate. Can provide samples with uniform diameter and volume, less soil disturbance, samples suitable for volatiles analysis</td>
<td>Limited depth capability, not suitable for hard soils</td>
</tr>
<tr>
<td>Soil/subsoil probe or corer (e.g. Oakfield sampler)</td>
<td>Loose to compact surface soils 0 to 60 centimetres</td>
<td>Easy to use, soil core has less disturbance, suitable for volatiles analysis</td>
<td>Limited depth capability, difficult to use in hard, stony soils, decontamination requires more effort</td>
</tr>
<tr>
<td>Dutch auger</td>
<td>Surface soils to approximately 1 metre</td>
<td>Can be used to greater depths than above equipment, can be used in more firm and cohesive soils</td>
<td>Borehole walls may collapse under certain soil conditions, soil mixing occurs, not suited for volatiles</td>
</tr>
<tr>
<td>Hand operated power auger</td>
<td>15 centimetres to 5 metres</td>
<td>Suitable for most soils, good depth range</td>
<td>Soils are mixed, therefore not suitable for volatiles, requires two operators, requires gas-powered engine, with potential for cross-contamination</td>
</tr>
</tbody>
</table>
4.2.1.2  Mechanical Samplers (Subsurface Soil, Core)

Mechanical samplers are used with a drill rig (or a direct push rig) and are used for soil sampling at depth. Methods used to access soils at depth so they can be sampled include hollow stem augers (HSA) drilling, solid stem augers (SSA) drilling, resonant sonic drilling and direct push sampling. Most samplers are designed to sample soils ahead of the drilling bit. Commonly used samplers include split-spoon (split-barrel) sampler, thin-wall sampler (Shelby tube) and continuous tube.

4.2.1.2.1  Split-Spoon (Split-Barrel) Sampler

The split-spoon sampler is a long cylinder, 18 to 24 inches in length that splits in half lengthwise. The sampler is advanced in front of the soil cutting surface using a manual or hydraulic 140-pound hammer. The Standard Penetration Test (N-count) is performed during sampling. Basket or spring retainers are available to improve sample retention. ASTM Standard D1586-99 (Test Method for Penetration Test and Split-Barrel of Sampling of Soils) provides a detailed description of the use of the split-spoon sampler. A split-spoon is acceptable for the identification and characterization of soil, but samples are somewhat “disturbed” due to the relatively large wall thickness of the spoon, which causes some compaction.

After being driven in advance of the auger, the split-spoon sampling tube is retrieved. The soil sample that is removed from the split-spoon can be used for constructing the borehole log.

Once the split-spoon is opened, soil recovery is calculated and noted. Soil classification and observations are made of the core and recorded in the borehole log. Note that soil observations should be made on a freshly exposed surface of the core sample.

When sampling of the soil core taken using a split-spoon sampler, a decontaminated putty knife, stainless steel spoon or similar implement should be used. Any smeared soil on the outer layer of the core should be removed using this implement, prior to sampling the soil (to limit the potential for cross-contamination). If possible, the sample core should be split longitudinally, along the length of the split-spoon sampler. If varying levels of contamination and/or varying soil types are observed within the length of the split-spoon core sample, then a sample should be taken from each distinct zone within the split-spoon sample.

The collection of samples for VOC laboratory analysis posses the greatest loss of contaminants due to the disruption of the soil matrix within the split-spoon. It is not recommended that the soil be exposed for an extended length of time (i.e. >2 minutes) once the split-spoon has been opened if the soil is to be used for soil headspace vapour measurements or laboratory chemical analysis for organic parameters.

When volatile organic contaminants are contaminants of concern at a site, every split-spoon soil sample taken from the borehole should undergo field vapour screening measurement. Primarily field vapour screening is used to determine the number samples required and to help determine if another sample location is required. When there is insufficient sample recovery in the split-spoon to provide enough soil for both field vapour screening and filling sample bottles for
laboratory analysis, use the available sample to fill the bottles for submission to the laboratory. Note that every split-spoon sample taken from a borehole does not need to be submitted for laboratory analysis.

Samples being submitted to the laboratory for volatile organic compounds (VOCs) analysis should not be composited or mixed in the field. It is recommended that VOC samples be cored out using a stainless steel hand held wide corer from the centre most part of the split-spoon before the split-spoon is completely opened. These samples should be collected into bottles (completely fill bottle with soil, so that there is no zero headspace) from a location that best represents the contamination of the zone being sampled. Samples should be keep cool (<10°C), ice is recommended. In the field, decant standing water and minimize headspace.

When there is insufficient sample recovery in the split-spoon to provide enough soil for both field vapour screening.

4.2.1.2.2 Thin-Wall Sampler (Shelby Tube)

A thin-wall sampler is used for collecting undisturbed, in situ soil samples. The thickness of the sampling tube should be less than 2.5 per cent of the total outside diameter of the sampling tube. The thin-wall and wide diameter of the sampler causes minimal sample disturbance. The sampler is attached to drill rods and pushed into the soil ahead of the auger. It is more suited to cohesive soils and may not work in sandy soils. Due to the low structural strength of the thin-wall sampler, it may collapse when sampling compact soils with “N” values of 30 or larger.

4.2.1.2.3 Continuous Sampling Tube

The continuous sampling tube can be used with standard hollow stem augers or other rotary methods. A thin-wall tube, 1.5 metres (5 feet) in length is attached to a drilling rod with a bearing head and is continuously advanced ahead of the augers while drilling. The sample column can be retrieved when fully through the hollow stem. It enables fast and efficient sample collection and is suited to sampling depths greater than 30 metres (100 feet). It is more suited to fine-grained or cohesive soils. It is applicable for collection of undisturbed soil cores for hydraulic conductivity and other physical parameters. Standard Penetration Testing cannot be done in the soil interval sampled.

4.2.1.2.4 Direct Push Sampling

Soil samples can be collected from a discrete depth using direct push sampling systems. In general, the sampling device consists of a hollow sampling tube with a retractable drive point. The drive point is connected to a narrow piston rod that runs the length of the sampler tube. Once removed to the ground surface the discrete soil sampler is opened by removal of the cutting shoe, and the soil liner (with recovered soil) is extracted from the sampler body. The soil liner is placed into a holder and cut lengthwise to expose the collected soil core.
4.2.1.2.5 Soil Sampling Principles for Boreholes

For boreholes, it is good practice that a minimum of one sample per borehole be sent to the laboratory for analysis of the contaminants of concern:

- If contamination is not detected in the borehole samples based on field screening observations or measurements (i.e. physical observations or soil headspace vapour screening results), one sample should be submitted from the borehole.

- If contamination is detected in the borehole samples based on field screening observations or measurements, the sample with the suspected highest contamination should be selected for laboratory analysis. In addition, a sample from the first suspected non-impacted interval underneath the contaminated zone should be selected for laboratory analysis, in order to provide vertical delineation of the contamination.

Samples being submitted to the laboratory for volatile organic compounds (VOCs) analysis should not be composited or mixed in the field. These samples should be collected into bottles (completely filled with soil, so that they have zero headspace) from a location that best represents the contamination of the zone being sampled.

Site conditions may make the use of mechanical subsurface sampling devices impractical (e.g. cobbles or glacial till may make it impossible to drive the sampler). While it is preferred to utilize another borehole drilling method at such sites (e.g. Resonant Sonic), in some case this is not possible. Under these conditions, the Qualified Person should try to obtain the best possible soil samples with the standard equipment available at the site (e.g. take disturbed soil samples from the auger flights, if this is the only type of soil sample it is possible to collect).

4.2.1.3 Mechanical Excavation (Test Pits and Excavations)

Test pit excavation is useful for locating and identifying shallow buried contaminated zones, contamination around underground storage tanks (USTs) and other infrastructure, or shallow soil horizons. Test pit samples are considered to be “disturbed,” but are generally suitable for chemical analysis. Due to the depth limitations of a standard backhoe or excavator, the maximum sampling depth is relatively shallow (5 to 6 metres). Drilling methods should be used for the collection of samples beyond the reach of the backhoe/excavator bucket (i.e. >5 metres below surface). Adequate health and safety precautions should be implemented for this type of sampling.

In many instances, test pits are the recommended method for the assessment of contaminated sites. A test pit allows better visualization of the subsurface stratigraphy and provides a larger sample for testing purposes than a borehole. In addition, test pits are usually more economical than boreholes and take less time to complete. In some cases, soil conditions will cause frequent collapse of the sides of the test pit, making it difficult to obtain a sample from a discrete depth with any degree of confidence. In such conditions, borehole drilling will be the preferred method for the collection of soil samples at depth.
In addition to test pits, larger excavations are sometimes dug to remove underground infrastructure (e.g. underground tanks or lines, building foundations). In cases where this work is being performed in conjunction with the Phase II ESA, the floors and walls of the excavation can also be sampled as part of the Phase II ESA program.

Where field personnel cannot enter the excavation (refer to current Ontario Occupational Health and Safety Act and regulations), samples should be collected from the excavator bucket (or appropriate support systems should be installed in the excavation or trench). The soil sampled should not be in direct contact with the bucket, but should be collected from a representative soil area within the bucket.

### 4.2.1.3.1 Soil Sampling Principles for Test Pits

Test pits should be advanced until a clean bottom is reached, or until the maximum equipment-reachable depth of investigation has been reached, whichever comes first. A clean bottom is defined as the point where field observations and sampling indicate there has been no contamination of the soil.

In cases where contaminated soils are not encountered, the test pit should be advanced to the maximum depth achievable with the backhoe or excavator (typically, just over 5 metres below grade); or in cases where contaminants are less dense than water (e.g. petroleum hydrocarbons), until the borehole has been advanced 1 metre below the lowest expected seasonal water table level (if practical); or until refusal is reached; or until unstable soil conditions and/or the collapse of the test pits walls make further excavation unsafe and/or unfeasible; whichever condition is satisfied first.

Soil samples may be collected at various intervals during the test pitting process. Typically, samples are taken from the test pit for field screening every 0.5 to 1.0 metre in depth. The sampling interval used will depend on the stratigraphic conditions encountered at the site, as well as the distribution of the contaminants through the soil horizon. The sampling interval should provide an adequate number of samples to allow delineation of contamination.

The backhoe/excavator bucket is the recommended device to be used when sampling soils from a test pit. Standard test pit sampling during a Phase II ESA involves collecting discrete grab samples over a series of 0.5 to 1.0 metre depth intervals (typically every 0.5 metre) along the entire depth of the test pit. If there is no significant difference of visual/olfactory contamination and/or soil classification observed within the 0.5 to 1.0 metre length of the sampling interval, then a single composite sample should be taken from each distinct zone of the sampling interval. If this is not the case, more than one sample may be required to be taken from the interval.

Every interval sample taken from the test pit should undergo field screening measurement, if VOCs contamination is suspected. To ensure the quality of the sample taken from the test pit has not been compromised, precautions should be taken when obtaining the discrete grab sample from the backhoe/excavator bucket. Where possible, ensure that the test pit is excavated with stable walls to minimize the possibility that soil that has fallen into the bottom of the test pit from shallower soil horizons. Samples should not be taken near the edges of the metal.
by sampling soil from the middle of the bucket, the possibility of cross-contamination from soil adhering to the bucket from other soil horizons of the test pit will be minimized. Before taking a sample from the middle of the bucket, the outer layer of soil should be removed. This will help ensure that smearing of contamination from the bucket is not included in the sample. It will also minimize the loss of volatiles from soil samples taken from the bucket.

If contamination is not detected in the test pit samples based on field screening measurements or physical observations, one sample should be submitted to the laboratory for analysis for the contaminants of concern from the test pit. If contamination is detected in the test pit samples based on soil headspace vapour screening results or physical observations, the sample with the suspected highest contamination should be selected for laboratory analysis. In addition, a sample from the first non-impacted interval underneath the contaminated zone should be selected for laboratory analysis, in order to provide vertical delineation of the contamination.

When excavating the test pit, two areas for spoil piles should be used for the soils removed from the test pits. On one side of the test pit, soils that are considered “clean” (based on visual/olfactory observations, if appropriate) should be deposited. On the other side of the test pit, soils that are considered “contaminated” (based on visual/olfactory observations, if appropriate) should be deposited. After completion of sampling from the test pit and when all observations/notations have been made in the field log book, the test pit should be backfilled with the excavated soil (nominally compacted using the excavator bucket) in the approximate order that it was removed. Use of this methodology will ensure that pre-excavation conditions are restored (approximately) and contaminated soil is not buried at the bottom of a test pit and missed if a remedial excavation is performed at the site at a later date.

4.2.2 Sampling Procedures

Adequate numbers of soil samples should be collected for site and contaminant source characterization. The procedure for determining the requisite number and location of soil samples will be based on information obtained during the Phase I ESA and any other available site information. Sampling is an iterative process with the need for additional sampling depending on the results of previous sampling. If contamination is detected, soil between adjacent sampling points should be considered contaminated up to the next uncontaminated sampling point. Sufficient samples are needed from within and from outside the contaminated area to delineate the horizontal and vertical extent of contamination. The Qualified Person is responsible for determining where samples are to be obtained from and for deciding which specific sampling procedures, such as composite sampling or soil screening for VOCs, should be followed.

4.2.2.1 Composite Sampling

Section 48 of Ontario Regulation 153/04 defines “sampling location” and requires that any samples being combined into a single composite sample must be taken from locations that are within an area with no more than a two-metre radius. The objective of composite sampling is to
ensure that the sample best represents the volume of material nearest the point of interest and which can be treated separately for remediation purposes. The distances between samples making up a composite are limited in order to prevent mixing of contaminated soils with clean soils in the sampling.

Due to the difficulties of depth sampling, more samples will be used to make up a composite sample where sampling is near the surface than will be used for composite sampling at depth. The following procedures can be used for making up composite samples:

- For surface or near surface soils, samples should be collected from within a two-metre radius, with a minimum of 10 cores or grab samples constituting the composite sample for analysis from each depth increment. For sites where surface soil is expected to remain on site, the 0 to 5 centimetres depth should be sampled separately from materials at greater depth, since this is the soil that will contribute most to exposure of future site users to any potential contamination.

- For sampling at depth, composite sampling would typically involve taking soil from different locations within the split-spoon sampler and combining these samples into a single composite sample. However if a contaminated layer is evident within the split-spoon, a discrete sample of the contaminated layer should be obtained and composite sampling of the split-spoon material should not be done.

Composite sampling should not be used for collecting samples for analysis for VOCs since the mixing process results in the loss of some of these compounds.

Whatever method is selected for collecting samples, care must be taken to ensure that samples from particular depth increments are not mixed with soil from other depths. Soil horizons displaying different properties should be sampled separately since they may behave very differently with respect to contaminant accumulation and movement.

It is stressed that composite sampling is conducted to obtain a better representative sample of the specific layer and area of interest, not to combine layers or areas that are different. The composite sampling produces separate samples for analysis for each distinct layer and area; it does not merge samples from different layers or areas.

Collection of control samples taken from nearby areas of similar soil type that are not suspected of contamination is recommended as a useful interpretive tool.

### 4.2.2.2 Soil Texture (Grain Size)

Soil texture (grain size) must be assessed because some of the soil (and groundwater) standards given in the Ministry publication “Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act” have different values for coarse or medium/fine textured soil. These different values reflect the effect that grain size has on the mobility of contaminants.
Soil texture can normally be determined in the field using professional judgement and commonly accepted field methods for soil texture determination. Typically, however, at least one representative soil sample should be submitted for laboratory grain size analysis (from the zone(s) of concern or most frequently sampled stratum) for confirmation of initial field characterization.

If the generally more stringent coarse-textured soil standards are being applied to the site, grain size analysis is not required for purposes of selecting the appropriate site standards, except in the case of potential petroleum hydrocarbon contamination. The medium/fine-grained values for certain petroleum hydrocarbon F1 standards in Tables 2 and 4 of the Ministry publication “Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act” are more stringent than the coarse-textured standards.

In addition to classifying soils for application of site standards, grain size analysis and soil classification may also be needed to:

- Identify relative heterogeneity in soil materials (and soil hydraulic conductivity) over depth and lateral extent in an aquifer; and
- Identify low-permeability layers that can act as a barrier for vertical chemical migration.

Grain size analysis is used to evaluate the particle size distribution in a soil sample, and to summarize the per cent of soil particles that are categorized as gravel, sand, silt, and clay. Classification of soils should be done using industry accepted methods such as the Unified Soil Classification System (USCS).

ASTM Standard D2488-00 (Visual-Manual Procedure for Description and Identification of Soils) should be referenced for more information on field characterization of soil. In conducting field characterization of potentially contaminated soil, however, appropriate safety procedures should be used (e.g. soil screening for VOCs in place of direct or close contact).

### 4.2.2.3 Soil Screening (Visual and Physical Observation)

Soil screening is carried out to guide the selection of the number, location, and depth of soil samples that will be collected for laboratory analysis. Careful screening will help to reduce the number of soil samples requiring laboratory analysis, thus optimizing the sampling program.

Visual observations of soil samples should be made and the results recorded in the field log book. The visual observations should include any evidence of staining, discolouration or phase-separated contaminants (e.g. free petroleum product in the soil sample). Observations on soil texture and soil colour should be included. Results of visual observations should be included in test pit logs, borehole logs and excavation cross-sections contained in the report that is prepared to summarize the field work that was performed.
Any odours (e.g. petroleum hydrocarbon or solvent odours) that are observed in the normal course of collection of the soil samples should be recorded. For health reasons, samples should not be deliberately smelled in order to further quantify or distinguish the odours.

### 4.2.2.4 Soil Screening Instruments for VOCs

Screening of soils for volatile organic compounds (VOCs) using gas detectors, sometimes referred to as soil headspace vapour measurement, is a field screening technique used to indicate the contamination of soil samples with volatile organic concentrations in soil. Although the screening results are not directly comparable with site standards, they can be used to aid in determining the extent of contamination and to direct sampling for laboratory analysis. In all cases where field soil headspace vapour measurements are used, confirmatory laboratory analysis must be conducted for volatile components of potential concern identified in the Phase I ESA or other Phase II ESA work.

Screening methods using hand-held instruments are used to identify the potential presence or absence of chemical contamination. The methods provide a general indication of the presence or absence of volatile organic contaminants and some metals.

At sites with organic contaminants, field soil headspace vapour screening is particularly useful to detect the lighter fractions of petroleum hydrocarbons (benzene, toluene, xylenes and F1 petroleum hydrocarbon fraction), chlorinated solvents and non-chlorinated solvents. It is less applicable for soils contaminated with heavier petroleum fractions (e.g. weathered fuels, and F3 and F4 petroleum hydrocarbon fractions). Such contamination is often more easily discernible by visual observation of staining or discolouration compared to the instrumental screening technique.

The most common screening instruments for detecting organic contaminants are photo-ionization detectors and combustible gas detectors (i.e. catalytic explosimeters). Less commonly used screening method are the colourimetric (or immunoassay) and flame-ionization techniques. More recently, portable gas chromatograph equipment can be used as a screening method for VOCs.

#### 4.2.2.4.1 Photo-Ionization Detectors

Photo-ionization detectors (PIDs) can be used to detect a wide range of organic contaminants including the lighter petroleum hydrocarbon compounds (benzene, toluene and xylenes) and chlorinated hydrocarbons such as trichloroethylene. The readings do not indicate the presence of a particular contaminant but represent a total concentration of the organic contaminants in the sample.

The readings can vary considerably, particularly when more than one contaminant is present in the soil sample. The instrument is sensitive to moisture and may give unreliable readings in moist soil. Overhead power lines or radio transmission towers may interfere with the measurements.
Typically, PIDs are used as the field screening instrument when contamination of the soil with chlorinated organic solvents is suspected.

### 4.2.2.4.2 Flame-Ionization Detectors

Flame-ionization detectors (FIDs) can be used to detect a large number of hydrocarbons. A FID is generally more sensitive to hydrocarbons than any other class of organic compounds. Good applicability has been found for saturated hydrocarbons (alkanes), unsaturated hydrocarbons (alkenes and alkynes), and aromatics.

Organic compounds containing oxygen, such as alcohols, ethers, aldehydes, carbolic acid, and esters give a lower response than that observed for hydrocarbons. Compounds containing no hydrogen, such as carbon tetrachloride, have the lowest response. The instrument is very sensitive to methane. This may mask its ability to detect other hydrocarbons.

Field use of the instrument requires the transport and use of hydrogen gas which is used to fuel the flame detector. Due to safety issues and the need to handle bulky hydrogen gas, FIDs are not commonly used as a field screening device to detect contamination of soil with VOCs.

### 4.2.2.4.3 Colourimetric Detection Methods

Colourimetric detection methods, also referred to as immunoassay methods, use chemical reagents to react with contaminants to produce a change in colour. The speed and intensity of the colour change is proportional to the concentration of the target compound in the sample. The colour changes may not readily occur when mixtures of contaminants are present.

Since the detection system consists of consumable items, the cost of field screening a large number of samples at a site may be expensive. Consequently, they are not widely used in site assessment.

### 4.2.2.4.4 Combustible Gas Detectors

Combustible gas detectors are generally used to determine the presence of combustible or explosive gases, and are often been used for soil vapour screening at petroleum sites. They can also be used to detect the presence of methane.

The levels indicated by this instrument may not always be accurate, as the sensitivity of the instrument is dependent on the properties of the standard gas used to calibrate the instrument. Fuel components such as sulphur compounds and leaded gasoline vapours tend to coat the filament, thus reducing the sensitivity. This can be overcome as most combustible gas detectors have the option to be operated in methane-exclusion mode.

Typically, combustible gas detectors (operated in methane-exclusion mode) are used as the field screening instrument when contamination of the soil with petroleum hydrocarbons is suspected.
4.2.2.4.5 Field Portable Gas Chromatograph

A field portable gas chromatograph can be used to separate and detect VOCs in the headspace of soil (and groundwater) sample containers. The headspace air is pumped through an adsorbent packed trap which is then heated. The desorbed vapours are directed into a short gas chromatograph column. The separated vapours are directed onto the surface of the detector which measures the vapour concentrations. The instrument must be calibrated for the compounds of interest. Although the instrument not only detects but quantifies the compounds, it should only be used for sample screening. Laboratory analysis should still be carried out for the samples of interest.

4.2.2.4.6 VOC Screening Methodology

Field soil VOC measurements are not directly comparable with site standards, however, they can be used to aid in determining the extent of contamination and to direct sampling for laboratory analysis.

During drilling or excavations, soil samples should be collected from each stratigraphic unit of interest and logged for soil type and staining. Care must be taken to minimize losses of volatile components during sampling and storage prior to determining combustible vapour measurements. The split sample method is recommended, with one sample being analyzed for vapours and the other submitted for laboratory analysis, where appropriate. Discrete samples, as opposed to composites must be taken in order to minimize losses of volatile components. For excavations, it is recommended that samples be collected from at least 0.1 metre below the surface of the wall face or excavation floor.

The instrument manufacturer’s recommended procedure for preparing and calibrating the instrument and using it in the field should be followed. A calibration check of the instrument should be performed in the field daily. Performance based criteria should be part of the consultant’s operating practices for running the instrument. If these performance based calibration check criteria are exceeded, the instrument should be recalibrated in the field, so that it will meet the calibration check criteria before it is used in soil field screening applications.

The Qualified Person should be aware of the applications and limitations of screening techniques, and should choose the field screening instrumentation most appropriate to the type of contamination expected at the site. The following procedure generally may be used for screening soil samples using a combustible gas detector:

- Soil should be placed immediately into a (e.g. 1 litre) plastic bag to about one quarter full with soil and be tightly sealed leaving a nominal headspace;
- Break apart chunks of soil by manually kneading the soil within the closed bag;
- Allow the soil/vapours to equilibrate at least 15 minutes, at a minimum of 15°C. In winter the measurement may be conducted in a vehicle with the heater on. This will allow the VOCs to equilibrate between the soil (and pore water) and headspace. The time and
temperature restrictions are recommended to ensure consistency of readings between samples;  

• Insert the combustible gas detector probe into the headspace within the bag while preventing VOC/air leakage; and  

• Record the peak headspace vapour concentration measured during the first 15 seconds of measurement.

In conducting this soil screening procedure, the soil bags should not be exposed to direct sunlight (for an extended period of time) and field screening samples should not be stored until the end of the day in order to measure them all at once.

The soil from the plastic bags should not be submitted for laboratory analysis. Although the soil from these bags could potentially be submitted for analysis of non-volatile inorganic parameters or physical testing, this should be avoided. The split sample method is recommended when first collecting soil samples, with one longitudinal half of the split sample being used for VOC screening and the other longitudinal half submitted for analysis, where appropriate.

4.2.2.5 Soil Screening Instruments for Metals

Recent advances in instrument development have made X-ray fluorescence (XRF) screening a useful method for screening sites for the presence of metal contamination. The method is capable of providing quantitative data on metal contaminant levels. These data should not be directly compared to the regulatory standards, but they can be a useful guide for locating contamination “hot spots,” and determining the amount of contaminated soil that must be removed from a site.

XRF does not work well (and in fact may be inoperative) in saturated soils. It performs well when the soil moisture content is less than 20 per cent. For soils that are not completely dry, XRF tends to report data that is negatively biased (i.e. it registers a lower concentration result), when compared to laboratory data (which is always reported on a dry weight basis).

4.2.2.6 Sampling from Soil Piles

In some situations it may be necessary to sample from large piles of soil. These situations can pose problems with respect to obtaining samples that are representative of the piles due to the difficulty of getting other than surface samples.

The preferred method of sampling piles is for composite samples to be obtained which represent known locations within the pile. Sufficient numbers of samples should be taken at different depths to characterize the depth profile and the lateral spatial variation of the contaminants of concern. Normally, sites should be chosen in a properly randomized manner from locations in the pile, with the exception that known or suspected “hot spots” must be sampled. Where turn around time for sample analysis is appropriate for the operation, piles that are being moved can be sampled in lifts with the next layer to be removed from the pile being sampled after the previous layer is removed.
4.2.3 Sample Handling

The sampling plan for assessing the site should identify what procedures are to be followed to ensure samples are properly collected and handled, and to maintain the integrity of the samples arriving at the laboratory for analysis. In addition to the procedures described here, the principles and procedures outlined in Section 6 Quality Assurance/Quality Control Program should also be followed.

4.2.3.1 Handling of Soil Samples

Soil samples that are being bottled to be sent to the laboratory for chemical analyses should not be touched with the bare hand or by gloves that may be contaminated. Contact or handling of the soil should be minimized at all times.

Plastic residues could be transferred onto the soil core before soil is conveyed into the appropriate sample container. For soils being analyzed for organics with very low regulatory limits (such as polyaromatic hydrocarbons (PAHs), pesticides, herbicides, and dioxins/furans), the soil should not be touched by a glove made from a plastic material (e.g. latex, and nitrile). For these parameters, the soil should only be in contact with a clean stainless steel sampling device (e.g. a trowel or a spoon). For soils being analyzed for organics with higher regulatory limits (such as total petroleum hydrocarbons (TPHs) and benzene, toluene, ethylene, xylenes (BTEX)), contact with the soil by clean glove materials is acceptable, but such contact should be minimized. Metal sampling devices used should not be plated. For example, chrome plated sampling devices should not be used for metals sampling.

Samples being submitted to the laboratory for VOC analysis (e.g. BTEX or TPH fractions of $<C_{10}$) should not be composited or mixed in the field. Discrete grab samples should be taken from soil that best represents the contamination of the sampling location and then transferred directly into containers. When samples arrive at the laboratory, a representative sample of the contents of the bottle should be obtained by coring the contents of the bottle. Sample containers being submitted to the laboratory for volatiles analysis should contain zero headspace.

Soil from field vapour screening (e.g. soils in plastic bags or soil screening jars) should not be reused for laboratory analysis of organic parameters. A negative bias for VOC analysis may be obtained if the soil sample is submitted to the laboratory after measuring the headspace vapours during field screening. Photo-ionization detectors are typically used for chlorinated solvent screening and catalytic explosimeters are used for petroleum hydrocarbons. If there is insufficient recovery of soil for both vapour and chemical analyses, the soil should be submitted for chemical analysis without conducting a field vapour screening measurement. Soil previously used for field vapour screening can be submitted to the laboratory for the analysis of inorganic parameters (e.g. salinity, metals) or physical parameters (e.g. grain size analysis).
4.2.3.2 Sample Containers and Preservation

The analytical methods and quality control protocols set out in the Ministry publication “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” address matters such as sampling requirements, sample containers and preservation, quality control and quality assurance, the protocol for accepting analytical results, and reporting of data.

For storage of samples for organic analysis, it is recommended that refrigeration temperatures be maintained at <4°C, but it is recognized that many situations can occur where fluctuations to above this temperature are extremely difficult to avoid. Since temperatures slightly above 4°C for very short periods of time are unlikely to significantly affect sample quality, the maximum temperature is set at 10°C. Some microbiological activity occurs at the above temperatures, so the possibility of breakdown of organics exists. Analysis for both organic and inorganic parameters should occur within hold times specified in the Ministry publication “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” dated March 9, 2004.

4.3 Decontamination Procedures

Decontamination procedures are important for preventing cross-contamination between sampling areas.

Laboratory sample bottles should be stored in a clean environment in the field, away from potential contaminant sources. Chemical resistant gloves should be worn by sampling personnel during soil sampling activities. Gloves should be changed for each sample collected and submitted for laboratory analysis.

Soil sampling equipment should be properly decontaminated between each soil sample taken. Down-hole drilling equipment (e.g. auger flights) should be decontaminated between each borehole drilled. The Qualified Person should evaluate decontamination requirements on a site-specific basis.

The following presents a discussion of general practices for decontamination of manual sampling tools, down-hole sampling equipment, down-hole drilling equipment, and excavator buckets. The general decontamination procedures when sampling for trace organic chemicals are also described below.

4.3.1 Manual Sampling Tools and Down-Hole Sampling Equipment

The following decontamination procedures are for manual sampling tools, such as knives or spatulas, manual soil coring or augering tools, and down-hole sampling equipment:

• Visible soil debris should be brushed from the equipment;
• The equipment should be washed with phosphate-free detergent, until all soil adhering to the equipment has been removed and then rinsed with potable water;

• If organic residue cannot be removed from the hand tool using this methodology, the equipment should then be rinsed with methanol after the potable water rinse;

• The equipment should be allowed to air-dry before sampling. Alternatively, clean paper towels can be used to dry the equipment (this practice is especially useful in winter conditions, to avoid the problem of water freezing on the hand tool); and

• The soil and water residues generated by this decontamination activity should be disposed of appropriately.

4.3.2 Down-Hole Drilling Equipment

The following decontamination procedure is recommended for down-hole drilling equipment:

• Gross soil should be removed from all drilling equipment with a brush;

• The plug and any auger flights that may come into contact with groundwater should be thoroughly cleaned. In practice, this means that the plug and at least the first 2 to 3 auger flights need to undergo additional cleaning consisting of scrubbing the equipment with a brush and soapy water to remove organic residuals and soil. The equipment being cleaned should then either be steam cleaned or pressure washed with potable water; and

• If organic residues or residual soil are still adhering to the drilling equipment and cannot be removed, the contaminated equipment should be set aside and not used for the remainder of the drilling. The equipment should be properly cleaned before reuse.

4.3.3 Backhoe/Excavator Buckets

When advancing a test pit through a contaminated zone, the bucket of the backhoe or excavator (which is acting both as the soil removal equipment and sampling tool) may have contaminated soil adhering to the bucket. In order to avoid cross-contamination between different strata in the same test pit, or between different test pits, the bucket should be banged on the ground periodically to remove as much soil as possible from the bucket.

4.3.4 Decontamination Procedures When Sampling for Trace Organics

The general procedures for decontamination when sampling for trace organics are described below.

4.3.4.1 Control of Cross-Contamination

Soil sampling for trace organic contaminants requires special techniques in order to avoid contamination, both from other samples and from sampling equipment and containers. When potentially high concentrations dangerous levels of contaminants are suspected, protective gloves
made of solvent-resistant material (e.g. latex) should be worn. However, neither gloves nor bare hands should contact the sample directly. Rather than transferring the soil cores from the corer to the sample container with bare or gloved fingers, a stainless steel spatula or knife should be used. The sample tool selected should be cleaned between each sample collected and at the sample program conclusions.

4.3.4.2 Equipment Cleaning Procedure

As a minimum, sampling equipment should be washed with clean potable water and phosphate-free detergent using a brush, if necessary, to remove any particles or surface films. For equipment that cannot be adequately cleaned with a brush such as internal mechanisms or piping, the decontamination solutions should be circulated through the equipment. Equipment should be rinsed with potable water followed by deionized water.

The frequency of sampling to demonstrate the completeness of equipment decontamination is dependent upon the objectives of the project and will be determined by the Qualified Person.

If conducting sampling and analysis of highly contaminated soils, a more rigorous cleaning procedure may be required. This procedure may involve the use of an organic solvent, such as methanol.

All cleaning agents and rinse waters require capture, containment, and appropriate disposal in accordance with local and provincial requirements.

4.4 Field Records

Samplers should be diligent in taking field notes of sampling locations, vegetative cover at the sample site, sample depths, observed soil horizons and horizon depths. Any soil staining or unusual odours, or any other observations that could be of potential assistance in interpreting analytical results should also be noted.

Field notes should document all the events, equipment used, and measurements collected during the sampling activities. Field notes should be legible and concise such that the entire borehole installation and soil sampling event can be reconstructed later for future reference.

The information required to complete soil borehole and drilling logs should be collected in the field. Complete documentation of the drilling and/or sampling process should be accurately recorded in a field notebook and transferred to a borehole log. Notations about weather, drilling equipment, personnel on the site, sampling techniques, subsurface geology and hydrogeology should be recorded. Lithology descriptions should be based on visual examination of the cuttings and samples; these descriptions should be consistent with an industry accepted classification method. Each borehole should be individually logged.

In addition to borehole logs, test pit logs should be completed from field notes taken for all test pits dug as part of the Phase II ESA.
5. **Groundwater Sampling**

The primary objective of a groundwater sampling program in a Phase II ESA is to determine if the groundwater quality meets the applicable groundwater standards for the property. This is done by establishing existing groundwater quality at the property and comparing it to the applicable standards. The sampling locations for this assessment therefore need to be chosen in a manner which ensures that the maximum concentrations of contaminants, if any, are being measured. To do this, the Qualified Person should have information on potential sources of contamination, both on-site sources and off-site sources, and a basic understanding of the geologic and hydrogeologic setting of the property, commonly referred to as “hydrogeological conceptual site model.”

A preliminary understanding of potential contaminant sources and the regional geology/hydrogeology of the site can generally be obtained from the Phase I ESA, Phase II ESA work already conducted, and other available information. Field measurements of water level elevations and estimates of hydraulic conductivity are used to confirm or better characterize the site and groundwater flow (e.g. direction and rate of flow) and help direct the groundwater sampling program, particularly where there is evidence of groundwater contamination. All of this information will assist in determining the number, location and nature of groundwater sampling and in assessing the concentrations and extent of any groundwater contamination.

Groundwater sampling locations should also be chosen to include a determination of whether the contaminants, if present in the groundwater, are due to sources of contamination on the property, or from sources on adjacent or nearby properties. If the contamination is due to on-site sources, the groundwater assessment should include an assessment of the potential for the contaminants to migrate off-site. If the groundwater contamination is due solely to off-site sources, further detailed assessment of groundwater at the subject property (i.e. beyond determining maximum concentrations) may not be necessary for purposes of filing a record of site condition. In both cases, however, further assessment of the groundwater may be needed for purposes of conducting a risk assessment or for risk management measures.

The need for (and extent of any) groundwater sampling should be determined by the Qualified Person on a case-by-case basis. Groundwater sampling may not be needed if, in the opinion of the Qualified Person, there are no contaminant sources either on the subject property or adjacent/nearby properties that could potentially affect groundwater quality. The findings of the Phase I ESA, Phase II ESA soil sampling results, and other available information can help the Qualified Person in making this determination.

5.1 **Design of a Groundwater Sampling Program**

The number, location and nature of groundwater sampling is determined by the Qualified Person on a site-specific basis. In designing the sampling program, a staged approach is often useful to allow for modification and refinement of the field program as the investigation progresses. Generally, the sampling plans for soil and groundwater should be developed concurrently as
these media are often sampled together, keeping in mind that sampling plan(s) may follow a staged approach and may be influenced by the results of previous sampling. This should lead to the design of more efficient sampling programs through early and coordinated determination of the location of the sampling points and the choice of drilling and sampling equipment.

The Qualified Person should demonstrate clear reasons for each component of the field program, and understand the properties and potential distribution of the contaminants of concern in order to design the field program.

The number and location of groundwater monitoring wells (i.e. sampling points) required at a site will vary, depending on the complexity of the geology/hydrogeology, and the location and extent of the contaminant sources or areas of concern identified. A determination of the required number and location of monitoring wells/sampling points could include the following considerations:

- An up-gradient monitoring well to characterize background groundwater quality (preferably at the property boundary);
- One or more wells within the contaminant plume (if present) to characterize the contaminants in relation to the applicable standards;
- Cross-gradient wells at either side of the plume, to define the lateral extent of contamination plume (if present);
- One or more wells at the down-gradient limit of the plume (if present) to monitor its migration;
- Well nests screened within the contaminated water-bearing zone, to assess the vertical extent of contamination, as deemed necessary by the Qualified Person; and
- One or more wells screened into lower (and down-gradient) water-bearing zones, to confirm the presence or absence of contamination in lower formations, if deemed necessary by the Qualified Person.

The above should be regarded as general guidance only. The actual number, depth and location of wells required to support the conclusions should be determined by the Qualified Person, depending on the site conditions.

5.2 Hydrogeologic Characterization

A basic understanding, or characterization, of the site hydrogeology is a first step in the assessment of groundwater quality and conditions at a property. The hydrogeologic characterization of a property helps ensure that groundwater samples obtained represent maximum concentrations and are suitable for comparison with the applicable groundwater standards for the property. Hydrogeologic comparison also helps in assessing the distribution of contaminants and the potential for off-site migration.
Initially, site stratigraphy and groundwater flow are often described in qualitative terms and/or shown in a conceptual diagram. Basic information such as the location of the assessment area and site boundaries, location of potential contaminant sources, soil types and (possibly) the estimated groundwater depth and flow direction may be known early on in the Phase II ESA process. An initial characterization should be established based on a review of the Phase I ESA and any other available information. Field measurements and analysis are used to confirm and refine the initial characterization as necessary given the particular situation and objectives of the groundwater sampling program.

An estimate of the hydraulic conductivity is required to provide quantitative estimates of the velocity of groundwater flow. Groundwater flow direction, and hydraulic gradient, can be estimated using a potentiometric surface map which can be constructed using the groundwater elevation data. Caution should be used when preparing potentiometric surface maps to ensure that only those wells which are screened in the same hydraulic zone and at similar elevations are included in deriving a potentiometric surface. Groundwater velocity can be calculated based on the hydraulic conductivity and hydraulic gradient.

5.2.1 Hydraulic Conductivity

It is rarely possible to determine a single value of hydraulic conductivity that is truly representative of the site due to the heterogeneity of formations frequently encountered. Usually, a range of hydraulic conductivities is considered acceptable.

Field measurements of hydraulic conductivity may be obtained using standard methods including single well response tests, well pumping and drawdown measurements, and field permeameters.

Hydraulic conductivity may also be estimated by laboratory methods through the use of laboratory permeameters and grain size analysis (i.e. sieve analysis). These methods however are generally not recommended, particularly for fine-grained soils, because the small sample sizes used may not be truly representative of the formation.

The Qualified Person should be aware of the inherent limitations of hydraulic conductivity measurements in determining a representative hydraulic conductivity for the site.

5.2.1.1 Single Well Response Tests

Single well response tests (slug or bail tests) provide only a point estimate (and order of magnitude precision) of hydraulic conductivity but are rapid and relatively inexpensive. Estimated hydraulic conductivity from slug tests can differ by an order of magnitude or more relative to the hydraulic conductivity value(s) determined from pumping tests. In many cases, however, single well response tests should be sufficient for purposes of Phase II ESAs since the objective of a Phase II ESA is rarely to conduct a detailed hydrogeologic assessment of a property. More detailed assessments may be needed in some cases outside of a Phase II ESA itself, such as when conducting a risk assessment or an assessment related to site impact and cleanup/remediation.
A single well response slug test involves the sudden removal, addition or displacement of a known volume of water and the monitoring of the changes in water level as it returns to equilibrium. The rate of change of the water level is a function of the hydraulic conductivity of the formation and the geometry of the well. Hydraulic properties determined by slug tests are representative of the material in the immediate vicinity of the well only, and therefore the test results may be affected by the filter pack of the well.

There are several methods to analyze data from single well response tests. These include the Bouwer and Rice slug test, Hvorslev slug test method and the Cooper method for determining hydraulic conductivity in a confined aquifer. The Qualified Person should decide on the most appropriate method given the site-specific conditions.

### 5.2.1.2 Aquifer Pumping Tests

Aquifer pumping tests are more time-consuming and expensive than single well response tests but provide more accurate estimates of hydraulic conductivity. Such tests however are used primarily for water well development and more detailed hydrogeologic assessments, and are generally not needed in Phase II ESAs.

Well conductivity tests should be performed a minimum of 24 hours after well development. Pumping tests are conducted by pumping at the pumping well at a constant or variable rate and measuring the changes of the levels of water at nearby observation wells during the pumping and the recovery.

### 5.2.2 Flow Direction and Hydraulic Gradient

At sites where groundwater contamination is suspected and hydrogeologic characterization is required, a sufficient number of wells should be installed to adequately assess the groundwater flow direction and gradient. The exact number of wells required will depend on the complexity of the site hydrogeology and should be determined by the Qualified Person.

Groundwater level measurements should be collected using accurate electronic instruments and at least one round of groundwater level measurements should be collected during the Phase II ESA. Water levels should be collected after a minimum of 24 hours have passed since well development, to allow for stabilization. At sites where longer-term assessment is required, multiple monitoring events should be scheduled to ascertain seasonal fluctuations in the groundwater levels.

More detailed characterization of vertical groundwater flow should be performed where vertical migration of contaminants in groundwater is suspected. Issues such as density of the contaminants, presence of water-bearing zones/permeable lenses beneath the zone of contamination, and the interconnectivity of hydrostratigraphic units should be considered when determining if the vertical component to groundwater flow should be assessed. The Qualified Person should determine whether assessment of the vertical component of groundwater flow
should be completed at a site. If required, nested wells or piezometers should be installed in separate, dedicated boreholes.

5.2.3 Groundwater Velocity

An estimate of the average linear groundwater velocity should be included in the groundwater characterization (either an average representative value for the site or a range of maximum/minimum values). Groundwater velocity can be calculated based on the hydraulic conductivity and hydraulic gradient. All sources of parameter estimates should be provided, with a clear listing of assumptions used in the calculations.

5.3 Groundwater Monitoring Wells

Groundwater samples are obtained by installing monitoring wells, or piezometers, in boreholes to obtain various types of data, including: groundwater elevations; groundwater quality; elevations and apparent thickness of light non-aqueous phase liquids (LNAPL); and samples of LNAPL or dense non-aqueous phase liquids (DNAPL).

Groundwater monitoring wells are designed to allow for monitoring within a specific hydrostratigraphic unit of interest, or within a specific portion of one hydrostratigraphic unit that may have varying chemical or hydrogeologic properties with depth.

This section provides a general description of the design, installation and development (i.e. preparation for use for groundwater monitoring purposes) of groundwater monitoring wells.

5.3.1 Monitoring Well Design

A monitoring well is comprised of two key elements: the well casing and the well screen. The well casing provides access from the surface to a sampling location (i.e. the well screen) in the subsurface. The well casing is also commonly referred to as the well riser. The well casing (and associated seals and grout) prevents collapse of the borehole and inter-zonal hydraulic connection. The monitoring well casing and screen provide access to the groundwater at the zone of interest in the subsurface.

The fundamental parameters associated with the design of a monitoring well include:

- Borehole and well diameters;
- Screen length and location;
- Well casing and screen materials; and
- Screen slot size and filter pack.

Other features of monitoring wells such as annular sealing around the well and completion of the well at ground surface are discussed in subsection 5.3.2 Well Installation.
5.3.1.1 Borehole and Well Diameters

The monitoring well is installed within a borehole drilled into the ground to allow for monitoring within a specific hydrostratigraphic unit of interest. The diameter of the borehole should be sufficiently large to accommodate the monitoring well casing, annular materials and tremie pipes used for filter pack or seal placement.

The diameter of the monitoring well (installed within the borehole) will be governed by the purpose of the installation. In general, wells installed for monitoring groundwater should be at least 2.5 centimetres (1 inch) in diameter, and are typically 5 centimetres (2 inches) in diameter. This allows small diameter bladder pumps, bailers, or inertial pumps to be installed. Wells of smaller diameter should be avoided unless they are solely used for hydraulic monitoring.

5.3.1.2 Screen Length and Placement

The monitoring well screen length should be consistent with the desired monitored interval and geologic conditions encountered (i.e. stratigraphy and water table elevation). Screens should not straddle multiple hydrostratigraphic units, and must be properly sized and placed to avoid creating preferential pathways for contaminants to migrate between hydrostratigraphic units.

Typical well screens are 1.5 to 3.0 metres (5 to 10 feet) in length. Issues that may require consideration when designing the length or placement of a well screen include:

- Monitoring for LNAPL above the water table may require longer well screens because of seasonal fluctuations in water table elevations;
- Monitoring for evidence of DNAPL in an aquifer typically involves placement of well screens at the bottom of the aquifer, directly above the aquitard;
- Monitoring for geochemical parameters may require shorter well screens in aquifers where geochemical conditions vary significantly with depth, to reduce the potential for mixing of water from distinct vertical geochemical zones; and
- Well screens that are excessively long in the saturated zone may misrepresent the chemistry of a dissolved contaminant plume by mixing impacted and non-impacted groundwater from different depths within the aquifer. The potential for well bore dilution should be considered by the Qualified Person in the design of all wells.

It is recommended that shallow water-bearing horizons be characterized first before drilling into deeper formations, if groundwater characterization of the deeper formations is required. It may be necessary to seal the shallower formations by grouting, casing or inflatable packers to prevent cross-contamination.
5.3.1.3 Well Casing and Screen Materials

It is important to choose well casing and screen materials that do not sorb or leach contaminants from the groundwater. Improper selection of casing and screen materials could lead to “false negative” or “false positive” results being reported for the chemical analysis of the groundwater.

The monitoring well casing and screen should maintain their structural integrity, should be resistant to chemical and microbiological degradation and should not chemically alter the groundwater (in particular, with respect to potential contaminants of concern). The main classes of materials used for monitoring well construction are thermoplastics, metallics (e.g. stainless steel) and fluoropolymers.

Polyvinyl chloride (PVC) is a thermoplastic material most commonly used for well construction in Ontario. It is made of sturdy, lightweight construction and can easily be threaded for joining casing sections.

High (parts-per-thousand) concentrations of some organic chemicals may degrade PVC. In cases where conditions are too harsh to use PVC casings, the Qualified Person should consider the use of stainless steel or polytetrafluoroethylene (Teflon) casings (the choice will depend on subsurface conditions).

5.3.1.4 Well Screen Slot Size and Filter Pack

The well screen slot size should be designed based on the materials used in the filter pack (also referred to as a sandpack) adjacent to the screen. The filter pack is intended to minimize the entry of soil particles into the well during sampling and is selected based on the geologic materials in which the monitoring well is screened. The filter pack is an inert granular material with a grain size and gradation selected to stabilize the hydrogeologic unit adjacent to the screen. ASTM Standard D5092-90 (ASTM, 2001) provides specifications for designing the well screen slot size and filter pack.

The elevation of the top of the filter pack is to be selected in the field based upon the geologic conditions encountered. For shallow overburden wells, it is common to extend the filter pack to above the top of the water table to account for the anticipated fluctuation of the water table due to seasonal effects. In deeper overburden wells, the filter pack should span the length of the specific hydrogeologic unit that will be monitored. The filter pack should not extend through a confining layer, causing two or more separate permeable layers to become connected. Where practical, the filter pack should extend a minimum of 0.6 metre (2 feet) above the top of the well screen.

As a general practice, filter socks should not be installed over monitoring well screens. The filter sock may reduce the measured hydraulic conductivity (especially when performing slug tests) in coarse-grained formations and can physically entrap contaminants with high viscosity. Filter socks should only be used when fine particulates are adversely affecting analytical results and all other methods of reducing these fines in the groundwater sample (e.g. optimizing the sand filter pack/well screen slot size combination, trying alternate well development methods or using low-
flow sampling methodologies) have failed. In general, the proper installation and development of a well is a much more effective method of ensuring that the amount of solids entering the wells screen is minimized, rather than the use of a filter sock.

5.3.1.5 Well Nests

In some cases, sampling from multiple discrete intervals at a given location may be required. Monitoring wells may be installed as well nests (multiple boreholes with one well installed in each closely-spaced borehole), multi-level wells (multiple sampling tubes placed within the well casing, isolated with packers or grout), or configurations with a series of single-riser wells within one borehole. Alternatively, consideration should be given to installing separate wells.

Monitoring well nests are the preferred method for sampling at multiple levels at a given location. The other two methods (i.e. multi-level wells and multiple risers within a single borehole) may have problems due to improper placement or settlement of seals or filter packs.

Where well nests are used and the direction of groundwater flow is known or can be estimated, the shallower wells should be placed hydraulically up-gradient of the deeper wells. This will minimize the potential for the grout seal from the deeper well to chemically influence the formation water sampled by the screen or the disruption of groundwater flow patterns, which are possible when the deeper wells are installed hydraulically up-gradient of the shallower wells.

5.3.2 Well Installation

The truck-mounted hollow stem auger drilling method is the most commonly used drilling technique for installing groundwater monitoring wells in a Phase II ESA. This method is preferred because it is simple to use and does not require any drilling fluids or air that could affect groundwater quality. Portable, solid stem drilling rigs or direct push drilling equipment can be used for shallow sampling or when truck-mounted drilling equipment cannot be used.

Other drilling methods include air/water/mud rotary drilling techniques. These methods may be used in difficult conditions (e.g. bouldery terrain) or for bedrock investigation, but their use for a Phase II ESA is less common. These methods introduce air and fluids which can affect groundwater quality, hence the monitoring wells should be properly developed prior to sampling. In addition, air rotary drilling may result in the stripping of VOCs and further migration of contaminants.

Whichever borehole drilling method is used should be compatible with the groundwater monitoring wells to be installed and should ensure that future data measurements or samples collected from the well are representative of the zone of interest.

If monitoring wells are installed in grossly contaminated areas, suitable drilling and well installation measures should be implemented to prevent migration of contamination from the soil to the water table and further into lower hydrostratigraphic units.
Well construction materials should not be stored directly on the ground, nor in the vicinity of potentially contaminating materials (e.g. soil cuttings, waste drums, near idling site vehicles, etc.). To minimize the potential for well material contamination prior to completion of the monitoring well, keep monitoring well materials (e.g. PVC risers and screens) in the original manufacturer’s plastic sleeves as long as possible during installation. Latex, nitrile or cotton gloves are recommended for use while handling monitoring well materials and should be discarded if they become contaminated.

A typical well installation procedure is described below, based on the use of a hollow stem auger drill rig.

5.3.2.1 Well Casing and Screen

The borehole should be drilled as close to vertical as possible unless the well is intended and designed to be angled (e.g. to access beneath a building or other structure).

Prior to insertion into the augers or borehole, the well assembly (i.e. well screen and riser components) should be measured to record its exact total length, and the length of each component. Once this length is known, well placement may proceed.

If the borehole is significantly deeper than the desired well screen interval, then the base of the borehole should be filled with bentonite chips to an appropriate depth below the bottom of the well screen. Hydration of the bentonite is not required because this section of the borehole should be saturated.

Before the casing and well screen are placed on the bottom of the borehole, at least 0.15 metre (6 inches) of filter pack material should be placed at the bottom to serve as a footing. An exception to this configuration may occur when DNAPL is being monitored.

The well casings and the well screen should be placed into the borehole and plumbed. Where critical, centralizers may be used to aid in the well installation. If centralizers are used to plumb the well, then they should be placed so that the placement of the filter pack, bentonite seal, and annular grout will not be hindered. Monitoring wells less than 15 metres (50 feet) deep do not require centralizers. If centralizers are to be used, they should be placed below the well screen and above the bentonite seal.

No lubricating oils or grease should be used on casing threads. Teflon tape may be used to wrap the threads to insure a tight fit and minimize leakage. No glue of any type should be used to secure casing joints. Welded joint construction is also acceptable.

An end cap should be used at the bottom of the monitoring well screen and should be constructed of the same material as the well screen. If the well screen installed is of a standard length, then the use of a screw-on end cap is recommended. If the well screen length should be cut to a non-standard length to accommodate its installation, slip-on end caps will need to be installed. It is also recommended that any well cap being installed should be equipped with a weep hole at the bottom, to allow perched water to drain from the well screen if the groundwater level drops.
below the bottom of the well screen, due to seasonal fluctuations in groundwater levels or other factors.

5.3.2.2 Filter Pack

When placing the filter pack into the borehole, a minimum of 0.15 metre (6 inches) of the filter pack material should be placed under the bottom of the well screen to provide a firm footing. In cases where DNAPL is present, it may not be desirable to have a filter pack “sump” beneath the well and therefore this requirement may be deleted. The elevation for the top of the filter pack should be selected in the field based upon the geologic conditions encountered.

A tremie pipe (a 25-millimetre diameter rigid tube) may be used to introduce the filter pack to the well annulus. In this situation, the tremie pipe is placed at the bottom of the borehole and the filter pack is added through a funnel to the pipe; this minimizes bridging or void formation within the filter pack. The tremie pipe is raised periodically to allow the filter pack material to evenly fill the annular space.

If filter pack materials are added using gravity free fall, then the materials should be added slowly to minimize bridging or void formation within the filter pack. Periodic sounding of the annular space with a weighted tape measure is recommended as a method to ensure that bridging of the sand is not occurring in this space.

Filter pack placement should be carefully performed concurrent with the removal of the augers when collapsing borehole conditions exist. The filter pack level should be maintained within the augers or temporary casing to ensure a proper filter pack “envelope” around the well screen.

Filter pack placement is typically a delicate operation, requiring a careful balance between:

- Placement of too much sand and locking the well components within the augers; and
- Placement of an insufficient amount of sand which then allows formation materials to collapse around the well screen area.

On occasion, it may be necessary to add potable water and/or drilling muds within the augers to maintain a positive pressure head on the formation materials, which (when certain conditions are encountered) will flow into the auger string in an effort to equilibrate with exterior levels. If potable water or drilling mud is added, the volume used should be recorded and additional purging volumes may be required.

5.3.2.3 Bentonite Plug and Annular Seal

After the filter pack has been installed, a bentonite plug should be placed directly on top of the filter pack to prevent water draining from the annular seal into the well screen and affecting the monitoring results. The annular seal is a low permeability material which is placed above the bentonite plug between the well casing (i.e. riser pipe) and the borehole wall to maintain alignment of the well.
5.3.2.3.1 Bentonite Plug

The bentonite plug consists of hydrated bentonite chips/pellets and should be placed above the filter pack to the specified depth or a minimum of at least 0.6 metre (2 feet) above the filter pack. Bentonite chips can be added to the annulus using gravity free fall in shallow boreholes (less than 15 metres (50 feet)) where the annular space is large enough to prevent bridging. Sounding measurements using a weighted tape measure to confirm that the bentonite has been placed at the proper depth/intervals. Care should be taken to add the bentonite chips slowly to prevent bridging.

It is necessary to allow the bentonite to hydrate before installing the annular seal. If the water table is temporarily below the bentonite seal interval during well installation, potable water should be used to hydrate the bentonite. Potable water should be added for every 50 to 100 centimetres of bentonite added to the annular space. The bentonite plug should be allowed to hydrate for a reasonable amount of time. For deeper boreholes, the tremie method should be used to place the bentonite plug.

5.3.2.3.2 Annular Seal

The annular space above the bentonite plug should be filled with a bentonite/cement grout (recommended) or hydrated bentonite chips. Silica sand or soil cuttings from the existing borehole should not be used in any portion of the annular space.

If bentonite chips are being used, the chips should be added carefully to the annulus, so that bridging (and leaving a void space in the annulus) is avoided. If installed above the water table, potable water should be added for every 50 to 100 centimetres of bentonite added to the annular space, in order to hydrate the bentonite chips.

Gravity free fall is only applicable for bentonite chips. If gravity free fall is used, then periodic sounding of the annular space with a weighted tape measure is recommended to ensure that bridging of the sealant material is not occurring in this space.

A tremie can be used for bentonite or cement/bentonite grout. If the tremie method is used, the end of the tremie pipe should always be submerged in the grout to ensure positive displacement.

Addition of a bentonite slurry is not recommended. The water associated with this slurry can cause chemical alteration of the adjacent formation water and bring into question the representativeness of water samples collected from the well.

If a bentonite/cement grout is used as the annular sealant, the top 1 metre (3 feet) of the borehole should be sealed with bentonite clay chips. Again, potable tap water can be used to hydrate the bentonite and should be added for every 50 to 100 centimetres of bentonite added to the annular space. This section of bentonite acts as a seal, to prevent surface water from entering the monitoring well annulus.
Temporary casings or augers should be removed in short increments, as the annular sealant (or filter pack) is added. This will prevent borehole collapse or material sloughing from the borehole wall from mixing with the filter pack or annular sealant.

For unconsolidated materials (i.e. non-cohesive soils), the temporary casing or hollow stem auger should be withdrawn until the bottom of the auger or casing is approximately 0.3 metre (1 foot) to 0.6 metre (2 feet) below the annulus material being filled.

For consolidated materials (i.e. cohesive soils), the temporary casing or hollow stem auger should be withdrawn until the bottom of the auger or casing is approximately 0.6 metre (2 feet) to 3 metres (10 feet) below the annulus material being filled.

5.3.2.4 Surface Completion

The ground surface around the monitoring well should be sloped to drain surface water away from the well. A protective casing and lockable well cap should be installed to protect the well and prevent unauthorized access.

Above ground installations (monument casings) and flush mount casings are available. Leaving an unprotected PVC riser sticking above the ground surface is not recommended, unless the site is secure and has no vehicular traffic in the area of the monitoring wells.

5.3.2.4.1 Monument Casings

Above ground installations, such as monument casings, are often preferred. These offer the advantages of better visibility, less maintenance, and fewer problems associated with water intrusion and freezing within the casing. Monument casings can be installed to a greater depth below ground surface, and are therefore less susceptible to frost heave.

Above ground risers should be protected by steel monument casings that have been sealed into the ground with concrete. The steel monument casing should have a lockable cap. The PVC riser should be capped inside the monument casing.

5.3.2.4.2 Flush Mount Casings

Flush mount installations are usually necessary in areas with vehicular or pedestrian traffic. They are also preferred in some sites for aesthetic reasons. A lockable cap should be installed atop the riser, inside the flush mount casing. This will discourage vandalism of the monitoring well. When installed in the street or any other area with high vehicular traffic, the flush mount casing should have sufficient strength to avoid being damaged.

Flush mount well installations are typically more problematic and maintenance intensive than above ground installations. Aluminum installations and steel installations are available. Steel installations are easily detected with a metal detector when snow or ice cover exists. Aluminum covers are not detectable by a metal detector.
5.3.3 Wells in Confined Aquifers (Unconsolidated)

If a monitoring well is being installed in an unconsolidated confined aquifer, the following additional criteria are recommended for the design and installation of the well:

- The well screen should not extend into the confining layer;
- A permanent steel casing should be considered to isolate the confined aquifer if groundwater is encountered above the confining layer, or if a contaminated zone is encountered above the confining layer. The steel casing should be set a minimum of 0.6 metre (2 feet) into the confining layer;
- Cement or cement/bentonite grout should be allowed to cure a minimum of 24 hours before drilling continues below the confining layer; and
- Annular grout should be placed the entire length of the casing, up to approximately 0.3 metre (1 foot) below ground surface.

5.3.4 Well Development

Monitoring wells should be developed after installation prior to taking groundwater samples or conducting hydraulic conductivity or other testing. If wells are not developed properly, sample or test results will be suspect and not properly reflect existing near-well groundwater/aquifer conditions.

Well development should not be initiated until at least 24 hours after the well has been installed, to allow for curing and settling of annular grout.

The objectives for well development include:

- Rectify clogging or smearing of formation materials that occurred during drilling of the borehole;
- Stabilize the formation and filter pack materials;
- Retrieve lost drilling fluids;
- Improve well efficiency (i.e. the hydraulic connection between the sandpack and the formation);
- Restore groundwater properties that may have been disturbed during the drilling process; and
- Grade the filter pack to effectively trap fine particles that may otherwise interfere with water quality analyses.

The three primary factors that influence the development of a monitoring well are the type of geologic material; the design and completion of the well; and the type of drilling technology employed.
5.3.4.1 Well Development Methods

Monitoring well development methods include pumping and over-pumping, surging, bailing, airlift pumping and air or water jetting. The most typical methods used for well development are:

- Pumping and over-pumping;
- Bailing;
- Surging; or
- Combinations of the above.

Methods that use one-directional flow (pumping or over-pumping) may produce bridging of particles within the filter pack. Methods that induce flow reversal (surging, bailing, jetting) are preferred and will produce a stable filter pack. Any standard well development method is considered acceptable provided that the goal of obtaining representative formation water is achieved.

The use of air jetting as a well development method is not recommended for sites where sampling of VOCs or geochemical parameters is to be conducted. Air jetting will introduce air into the formation water, which can cause volatilization of VOCs and changes to groundwater geochemistry.

5.3.4.1.1 Pumping and Over-Pumping

The easiest, least expensive, and most commonly employed technique of monitoring well development is some form of pumping.

Pumps that may be used for well development include submersible pumps, centrifugal pumps, or manual inertial pumps. During development by pumping, the pump intake is raised and lowered through the length of the screened interval. This will ensure that the sandpack surrounding the entire length of the well screen is properly developed.

During the development process, the initial water removal should be slow and gentle. Water should be removed with increasing vigor as the well is developed. Well development requires a sufficient application of energy to disturb the filter pack, freeing the fine particles and allowing them to be drawn into the well. The coarser fractions then settle and stabilize the well screen. The well should ultimately be pumped at a rate that is higher than the anticipated sampling rate.

Limitations to pumping and over-pumping include:

- Pumping or over-pumping alone may not adequately develop a well. Only one-directional flow is produced which can cause bridging in the filter pack and formation; and
- The presence of fines in well purge water may damage some types of pumps.
Due to its low cost and simplicity, pumping and/or over-pumping is the well development methodology that is typically used during the development of groundwater wells in most Phase II ESAs.

5.3.4.1.2 Bailing

In relatively clean, permeable formations where water flows freely into the well, bailing can be an effective development technique. The bailer should be of sufficient weight to free fall through the water column. The bailer is allowed to fall freely through the monitoring well. The displacement caused by the bailer produces an outward surge of water proportional to the volume of the boiler. This tends to break up bridging that has developed within the formation.

As the bailer fills and is rapidly withdrawn, the drawdown created in the borehole causes the particulate matter outside the well intake to flow through the well intake and into the well. Subsequent bailing removes the sand and other particulate matter from the well. Bailing should be continued until the water is free from suspended particulate matter, or until the level of particulates ceases to change.

5.3.4.1.3 Surging

Surge blocks can be used to destroy the bridging of the fine formation particles and to create the agitation that is necessary to develop a monitoring well. A surge block is used alternatively with either a bailer or pump, so that material that has been agitated and loosened by the surging action is removed.

The surge block assembly should be of sufficient weight to free fall through the water in the well and create a vigorous outward surge. Surging begins at the top of the well intake so that sand or silt loosened by the initial surging action cannot cascade down on top of the surge block and prevent removal of the surge block from the well.

Surging however is not commonly used to develop monitoring wells. Not all drill rigs have the capability to move the surge block at progressively increasing speeds (which is required when developing a well) and additional time and care is needed to thoroughly clean the surge block to prevent cross-contamination between use at different wells.

5.3.4.2 Monitoring the Well Development Process

The primary goal of well development is to ensure that water extracted from the well and any hydraulic testing of the groundwater is representative of groundwater in the adjacent formation. Monitoring is conducted during the well development process through evaluating whether stabilization is occurring for various properties of the water being removed from the well.

Well development typically requires the removal of three to ten well volumes of groundwater (or if low yielding, pumping the well until dry) up to three times over a one to two-day period (i.e. typically 10 to 30 well volumes). The groundwater elevation in the pumped well should be allowed to reach static equilibrium before a subsequent round of pumping is initiated.
The removal of a maximum of 10 well volumes is often considered the cut-off for development efforts unless monitoring indicates that continued pumping will improve the representativeness of the water being pumped from the well.

Field measurements of stability parameters such as turbidity, pH, temperature, and conductivity should be recorded during the well development process (typically after the removal of each well volume). Development is considered complete once the groundwater is relatively silt-free (or no further improvement is observed), and/or the temperature, pH, turbidity, specific electrical conductance have stabilized to within ±10 per cent of successive readings. Silt-free water may not be attainable in wells screened in fine-grained soils, in which case the well development should continue until the other properties have stabilized.

If water is introduced into the formation during the borehole or well installation processes, then sufficient water should be purged to also ensure that all water added to the formation has been removed and representative groundwater samples can be obtained.

5.3.5 Well Survey and Documentation

Once the well is installed, a survey should be conducted to define the position of each new monitoring well location. In addition, complete documentation of the monitoring well installation and development process should be kept.

5.3.5.1 Well Survey

A well survey should be conducted to define the monitoring well location and the vertical elevations of the ground surface and top of casing. A well survey referenced to an established geodetic benchmark is preferred, although an arbitrarily chosen site benchmark is often used and is also considered acceptable. When an arbitrary site-specific benchmark is used, its location should be described in detail.

A permanent survey mark (e.g. a notch in the riser piping) should also be placed at the top of each well casing and used as the reference point for all groundwater level measurements. All elevations should be expressed relative to this mark and to the survey benchmark.

5.3.5.2 Documentation

Documentation of the monitoring well design/installation and development activities should be completed in the field. Documentation recorded during the well installation should include information such as: monitoring well identification, date, depth of borehole, well completion details, and ground/well reference elevations. Documentation of the well development process should also include well volumes removed (or similar relevant information if a different development process was used) and field measurements for stability parameters.
Complete documentation of the monitoring well installation and development process should be accurately recorded in a field notebook. This information should be transferred to an “as-built” construction diagram or logs, which should be provided for each monitoring well.

5.4  Sampling Methods

Sampling methods should consider the type of material likely to be encountered on the site, the depth of sampling and the parameters being sampled for and match this with the appropriate sampling equipment/devices and sampling procedures. Certain pre-sampling activities are also normally required prior to obtaining a groundwater sample for analysis.

5.4.1  Sampling Equipment

The choice of sampling equipment or devices will be based partly on availability, cost, portability and ease of decontamination. However, certain devices are less suited to certain parameters and/or well depths. Important factors that play a role in the collection of representative groundwater samples include:

- Groundwater sample device (choice of pump or sampler, and flow rate used);
- Care and skill used in sample handling/transfer to sample bottle; and
- Use of suitable pump and tubing materials.

The most important consideration in designing and completing a successful groundwater investigation program may be the choice of the sampling device. The sampling device has the potential to alter the chemical composition of the groundwater sample, and as such the materials used, method of operation, ease of maintenance and field operation are some of the considerations which go into determining which sampling device is appropriate.

5.4.1.1  Inertial Pump (Foot Valves)

Inertial pumps can be used for groundwater well purging and sampling. They are inexpensive, can be used in wells as small as 1.25 centimetres (0.5 inch) diameter, can be dedicated to each monitoring well and do not require a power source (unless a mechanical actuator is used).

Inertial pumps can be used for development of low to moderate yield monitoring wells by over-pumping. The typical manual purge rate is 2 to 8 litres per minute. However, inertial pumps are labour-intensive, the foot valve is prone to clogging from silt or fine sand and they are mainly suitable for shallow well installations (<20 metres).

5.4.1.2  Bailers

Bailers are inexpensive, easily portable, can be decontaminated and require no external power source. Their disadvantages are that they are labour-intensive, and can alter the groundwater sample from degassing, volatilization, or aeration. Loss of VOCs can occur when bailers are
used, they produce more variability in VOC sampling results and results may be more operator-
dependant than with other devices (e.g. mechanical pumps).

The lines used with bailers can be a source of cross-contamination if the bailer is not dedicated to the well.

Bailers should be constructed of inert material. Single or double check-valve bailers can be used for LNAPL and DNAPL sampling, respectively. It is preferable to use a bottom emptying device with a valve to minimize aeration. Bailers should never be dropped into a well, but lowered slowly to prevent aeration or disturbance of the water.

In general, bailers can produce good results for VOCs in shallow wells with careful operation and handling. However, they have been shown to bias results for volatile analytes and analytes that are readily oxidized, if used without due care.

5.4.1.3 Small Diameter Submersible Centrifugal Pumps

These pumps were developed for contaminated site applications and can be used in small diameter monitoring wells. Higher flow rates can be used for well development and lower flow rates (0.1 litre per minute) for well sampling.

Care and control of pumping rate is a critical factor in sample quality. Pumps must be thoroughly cleaned between uses at different sampling locations to avoid potential issues with cross-contamination. Although there is potential for cross-contamination from metals from pump materials, these types of pumps are considered applicable for most contaminants of concern at Phase II ESA sites.

5.4.1.4 Bladder Pumps

Bladder pumps are typically used in applications where a low-flow rate is required. Often, low-turbidity samples can be obtained without filtration. Flow rates higher than 100 millilitres per minute can increase the loss of volatile constituents. Use of bladder pumps reduces the water-purge volume requiring treatment but they can also be time-consuming for low-flow applications. In addition, the pumps are difficult to decontaminate between sampling locations. Bladder pumps are suitable for sampling a wide range of contaminants at Phase II ESA sites.

5.4.1.5 Tubing and Accessories

Numerous (flexible) materials are available for use with groundwater samplers. Tubing of some kind is required for all pump devices.

Polyethylene tubing is commonly used with submersible pumps and inertial pumps. Although polyethylene, in particular low density polyethylene (LDPE), does adsorb organics to a greater degree than Teflon, and some other materials, representative samples are obtained using this material. Polyethylene is commonly used in the industry and is considered an acceptable material for well sampling. If utilizing LDPE tubing when sampling for VOCs, acceptable
results can be obtained if the precaution of first flushing the tubing with groundwater from the well is taken.

In general, all sampling tubing should be dedicated to a single groundwater monitoring well. Alternatively, it should be disposed of after one use at a monitoring well.

### 5.4.2 Pre-Sampling Activities

A number of pre-sampling activities or measurements are often required prior to obtaining a groundwater sample for analysis.

#### 5.4.2.1 Headspace Monitoring

Field vapour measurements may be taken from inside the casing of a monitoring well using a combustible vapour detector (operated in methane exclusion mode), to indicate the potential for contamination of the groundwater by VOCs. These data are only semi-quantitative and should not be used for risk assessment (e.g. for human health, ecological or explosive risks) or compliance reporting purposes. The results do not truly represent the concentration of volatile hydrocarbons in the headspace above the air/groundwater interface. At some sites, the presence of natural gas in the formation can cause high vapour concentrations measured in the well headspace that are unrelated to groundwater quality.

Vapour measurements (in monitoring wells) should be done to alert field staff to their potential exposure to volatiles while sampling the wells, allowing them to take the proper safety precautions. They should also be performed at sites where there is an explosive risk due to the collection of volatile organic vapours in a confined space (e.g. a nearby basement or sewer). The potential for explosive risk in the actual monitoring well is generally considered to be low.

The vapour concentration is measured by placing the combustible vapour detector nozzle inside the monitoring well casing no less than 15 centimetres (6 inches) below the top of pipe (TOP). The combustible vapour detector reading should be taken immediately after the cap has been removed from the top of the monitoring well casing in order to minimize the loss of volatiles from within the casing. The peak reading should be recorded.

Also, as described for soil sampling in subsection 4.2.2.4, portable gas chromatograph equipment is available which could be used for VOCs screening in groundwater.

#### 5.4.2.2 Water Level Measurement

Static water levels should be obtained prior to monitoring well sampling each time the monitoring well is sampled. Water levels in piezometers or monitoring wells should be allowed to stabilize a minimum of 24 hours after well construction and/or development before measurement.
Water levels should be accurately measured, using an industry accepted electronic water level detector, measuring tape or other device with similar accuracy.

Groundwater levels should be measured from the permanent water level measurement location mark at the top of pipe (TOP) which has been surveyed as the well reference elevation point. The top of the well casing should be notched to indicate the exact point of measurement. To ensure reproducible data, all subsequent readings should be taken from the same notched point in the well casing.

Water level measurements should start at wells located in uncontaminated areas first. Then measurements should be made from wells in contaminated areas, with wells containing the least contaminated groundwater being sampled first and wells containing the most contaminated groundwater being sampled last.

Measurement of the groundwater level should be conducted prior to purging of the monitoring well. Monitoring well water levels rarely return quickly to the original water level after purging of the monitoring well so the measurement after purging would not represent the true equilibrated water table elevation.

If possible, all water level measurements used to define a water table or potentiometric surface should be collected within a 24-hour period in order to minimize the effects of changing barometric pressure. Water levels taken during a sampling event determine the height of the water table (relative to top of pipe) prior to sample collection. The measurement is converted to a groundwater elevation and compared with data from other wells in the monitoring program.

Decontamination of water level measurement equipment, using the manufacturer’s recommended cleaning method for the probe, should be completed after each measurement in order to prevent cross-contamination between each reading and/or each monitoring well.

Latex gloves should be worn during use of the groundwater level measurement equipment. Contact between the latex gloves and the measurement probe should be minimized. Any hydrocarbon contaminated gloves should be disposed of.

5.4.2.3 NAPL Layer Detection

At sites with potential NAPL contamination, NAPL and its thickness can be detected in conjunction with water level measurement by using an industry accepted interface probe. NAPL monitoring should be performed at these sites every time that a monitoring well is sampled. Measurements of NAPL thickness and water level should be completed twice at each location to confirm initial readings.

The interface meter should be properly cleaned after each measurement to prevent cross-contamination between each reading and/or each monitoring well.
A transparent bailer fitted with a bottom-draw valve and lowered slowly into the well to withdraw a sample form the top of the water column can be used to provide visual confirmation of the presence of NAPL. This method is often superior to the interface probe in detecting the presence of a very small thickness of NAPL or sheen. The bailer should however only be used after the interface probe measurement is taken. The bailer is used to confirm the negative interface probe reading or, if a positive reading is obtained, to give a rough estimate the thickness of the free product.

Monitoring well measurements of NAPL should include depth to the NAPL phase, depth to water table and the thickness of the NAPL layer. This measurement should be performed before the NAPL is removed or the monitoring well is purged.

5.4.2.4 Well Purging

Water standing in a well may not be representative of the conditions within the water-bearing formation. Standing well water in contact with the well construction materials for an extended period of time may have differences in temperature, pH, redox potential and contaminant of concern concentrations compared to the formation water. Well purging is used to eliminate the potential for an effect from these factors.

During purging of the monitoring well, water that is geochemically representative of the formation water enters the well through the screen and is available for sampling. After purging and prior to sampling, the groundwater should be allowed to recover to at least 90 per cent of static levels (whenever this is practical). If the well is sampled before static levels are reached (i.e. the groundwater is stressed), inaccuracies in determining the actual concentrations of chemical parameters in the formation water may occur.

Options for purging wells include:

- Removal of a suitable number of well volume equivalents;
- Continued removal until certain field measured parameters have stabilized (e.g. pH, temperature, turbidity, dissolved oxygen, oxidation-reduction potential (ORP), and specific conductance); or
- Allowing hydraulic performance of the well to dictate purging volumes and rates.

It is not possible to pre-determine a specific purge volume for all situations. This depends on the objective of the sampling program, the chemistry being dealt with and the purge technique being employed. Numbers may vary from 1 to 20 bore volumes, although 3 to 5 bore volumes is generally considered to be acceptable. Purging may be done at the static level elevation or at the screen base elevation when pumps are used. The location of the purge point may influence the number of purge volumes needed to obtain representative samples.

Wells screened in formations with low transmissivity will likely go dry before the required water volume can be removed. It is recommended that the well be purged dry and the sample be collected after the well recovers enough to provide the water volume required for sampling.
The measurement of only field parameters may cause an excessive volume of water to be purged where groundwater is slow to stabilize. Alternatively, if the groundwater is very quick to stabilize, the purged water volume will be quite low and the water sample may not be representative of groundwater quality in the formation. Field measurements may not be indicative of representative sampling conditions when volatile organic chemicals are the contaminants of concern.

5.4.2.4.1 Low-Flow Purging

Low-flow purging and sampling refers to sampling methodologies that minimize the velocity of the formation water entering the well screen. Drawdown flow rates will depend on the formation. They can range from 1 litre per minute in very coarse-grained formations (e.g. gravels), down to 0.1 litre per minute in fine-grained formations (e.g. silts and clays). The goal is to ensure that water inside the well screen and in the formation is minimally disturbed while obtaining representative formation water. This helps to minimize losses of volatile contaminants in groundwater samples compared to samples taken using conventional purging and sampling.

In certain circumstances, the solids associated with highly turbid samples can result in false positive results for dissolved PAH, extractable hydrocarbon, or metals concentrations in the groundwater sample. To minimize the potential for this positive bias, the sampling method chosen should minimize the turbidity of the sample collected. Note that silt should not be filtered out of samples that are being sent for organics analysis.

In addition, volatile losses in groundwater samples can be observed with the conventional purging and sampling of medium to high transmissivity formations (i.e. volatiles are lost as groundwater trickles down the interior of the well screen as the water level is depressed within the well screen by pumping activities).

Low-flow purging and sampling should be considered in critical situations, where the positive biases caused by high turbidity samples or negative biases due to volatile losses may impact upon regulatory compliance. Low-flow purging is generally done for geochemical analysis when it is necessary to evaluate reduction oxidation conditions.

The differences in the analytical results for groundwater samples obtained by conventional purging and sampling compared to the low-flow method may however not be significantly different to affect the overall conclusions about the groundwater quality. It is therefore up to the Qualified Person to decide which purging and sampling method is appropriate given the specific conditions at the site. Whichever method is chosen, it should be consistently used throughout the sampling program.

5.4.3 Sampling Procedures

The key objective of groundwater sampling is to obtain a representative sample. Decisions about sampling methodology and procedures should consider the properties of the contaminants of concern, well configuration (screen depth and length) and should be designed to mitigate potential effects on the integrity of the groundwater sample.
5.4.3.1 Equilibrium Conditions

The monitoring well should be allowed to reach 90 per cent of static water level equilibrium before sampling, whenever this is practical.

Low recovery wells (e.g. clay formations) should be sampled at the end of the day, whatever percentage of the static water level equilibrium has been reached. The exception to this practice is when the field technician is returning to the site the next day. In this case, sampling of the monitoring well the next morning is also acceptable (this will give the well more time to recover) even for volatile organic parameters.

5.4.3.2 Sample Collection

The groundwater sample should be taken from the centre of the saturated zone within the monitoring well screen interval. This will ensure that the groundwater sample will be representative of the entire screened water column.

Aspiration of the groundwater sample should be kept to a minimum when sampling for volatiles. When using inertial pumps, a split VOC sampling tube for the inertial pump should be used when sampling volatiles in order to minimize volatile losses from the sampling process.

Any odours (e.g. petroleum hydrocarbon or solvent odours) that are observed in the normal course of collection of the groundwater samples should be recorded. For health reasons, samples should not be deliberately smelled in order to further quantify or distinguish the odours. Similarly, any reported concerns with objectionable taste from possible contaminants should be noted, but for health reasons, samples should not be tasted at any time in order to identify the presence of contaminants.

If the volume of water recovered from the groundwater well permits, all groundwater sample bottles (even those submitted for semi-volatile and non-volatile parameters) are to be filled to zero headspace.

The collection of groundwater samples from water seeping into excavations or test pits and submitting these samples for laboratory analysis is not a recommended practice. These samples are generally not representative of the quality of the formation water.

LNAPL sampling should be completed with a bottom-filling bailer equipped with a check-valve. This should be performed with minimal disturbance, to prevent emulsion or re-mixing of the oil layer with water. DNAPL should be sampled using a bottom-filling bailer, a dual check-valve bailer, or a bladder pump.

Groundwater samples should be placed in an ice-chilled cooler immediately after sampling and kept at 0 to 10°C (target of 4°C) until delivery to the laboratory. Collecting the samples throughout the day and then placing them all in a cooler at the end of the day is not an acceptable practice.
5.4.3.3  Field Filtration

There are situations for which sample filtration is required prior to analysis, and there are circumstances where samples should not be filtered. Filtration may affect the chemical composition of a sample by alteration of the physical state through removal of particulate and any adsorbed material. On the other hand, dissolved phase components may be the only feature of interest in the sample and low turbidity samples may be essential to the analytical technique being used.

For Phase II ESAs being performed in Ontario, the generic groundwater standards have been derived for dissolved metal concentrations. Thus, groundwater samples submitted for metals analysis should be field-filtered. Groundwater samples being analyzed for organic parameters should not be field-filtered to remove turbidity.

Sample filtration leads to additional atmospheric contact and to the potential for loss of volatile components and sample oxygenation. The filter papers or filtration devices may also serve to influence the integrity of the sample.

In-line, positive-pressure filtration should be used. Vacuum-filtration is not considered acceptable due to degassing effects. The standard filtration device is the 0.45 µm filter, commonly used with an inertial pump (foot valve) and tubing. The manufacturer’s instructions for filters should be followed. If sufficient groundwater is available, conditioning the 0.45 µm disposable in-line filter with groundwater before taking the sample is a recommended practice.

In general, a volume of twice the capacity of the filter should be flushed through the filter and discarded before the sample is collected. Filters should be used to draw one sample from one sampling location and then they should be discarded. After filtration through the in-line filter, the groundwater sample should be directly introduced into the sample bottle which should already have the proper preservative added.

If filtration (for metals) cannot be completed in the field, or filtration has not been properly performed (resulting in high silt levels in the sample bottle), the nitric acid preservative contained in the metals sample bottle will lower the pH to between 1.5 and 2. This can cause dissolution of sorbed or precipitated metals into the unfiltered sample and a positive bias to the reported metals concentrations.

5.4.3.4  Sample Splitting

Sample splitting is usually done for field QA/QC samples, or for peer-review/second party verification of sampling results. Splitting of water samples should be done as follows:

- For non-volatile or semi-volatile parameters, the first sample container should be partially filled, then the second container. Continue to fill by alternating back and forth between bottles, repeating the procedure until both containers are full; and
• For VOC samples, each sample bottle should be completely filled and capped. Then the split or duplicate sample bottle should be filled. This methodology will minimize volatiles losses from the groundwater samples during the sampling process.

5.4.4 Sample Containers and Preservation

The preservation of samples is a measure designed to stop or slow the ongoing effects of chemical and biological change once a sample has been collected. Since sample analysis is very specific, the preservation techniques required to ensure sample integrity are also specific. Preservation methods should be determined in consultation with the analytical laboratory and should be done in accordance with the requirements set out in the Ministry publication “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” dated March 9, 2004.

5.5 Field Records

Documentation of the field activities undertaken in conducting the Phase II ESA, such as water level measurement, well purging and well sampling activities, is an important part of conducting a Phase II ESA. Field records and documentation should include the following type of information, as appropriate:

• Sampling field personnel;
• Well identification;
• Sampling date/time/weather conditions when static water level determined;
• Physical condition of the wells;
• Well vapour measurements (if taken);
• Static water level;
• Equipment used for measuring the static water level;
• Decontamination methods used on this equipment;
• The depth to water in each well, and relative elevation to a reference point of known elevation (either geodetic datum or an arbitrarily assigned benchmark);
• Well depth (historic or actual measurement);
• Sampling date/time/weather conditions when NAPL measurements performed;
• Presence/thickness of immiscible layers of NAPL;
• Equipment used for measuring the presence/thickness of NAPL;
• Decontamination methods used on this equipment;
• Sampling date/time/weather conditions when purging performed;
• Well purging details, including the calculated purge volume of the well (specify casing only, or including sandpack), number of volumes purged, the total volume of water removed (indicate if the well was purged to dryness), field measurements (if performed)
during purging (pH, temperature, conductance, turbidity, dissolved oxygen), visual observations during purging (i.e. turbidity, odour, discolouration);
- The type of equipment used to purge the well;
- Well recovery rate (slow, fast);
- Sampling date/time/weather conditions when sampling is performed;
- Equipment used to take samples;
- Decontamination and QA/QC checks for non-dedicated sampling equipment;
- General appearance of sample (e.g. turbidity, colour);
- Method of filtration and filter specifications (if applicable);
- Any problems or unusual events during sampling;
- Identifiers for samples and field QA samples;
- Parameters requested for analysis;
- Method and time of sample shipment; and
- Type and number of shipping containers.
6. Quality Assurance/Quality Control Program

Quality Assurance/Quality Control (QA/QC) measures are an essential component of Phase II ESA sampling programs. A QA/QC program is described as the overall “management system” that ensures defined standards of quality are met within a stated level of confidence. Quality control (QC) consists of the day-to-day activities (in the field or laboratory) used to control the quality of the product or service so that the needs of the users are met. Quality assurance (QA) consists of the measures or checks that are put in place to confirm that the quality control (QC) activities are effective.

A well-designed QA/QC program will:

- Ensure that data of sufficient quality is obtained, for proper site management decisions or cleanup/remediation design;
- Allow for monitoring of staff and contractor performance; and
- Verify the quality of the data for the regulatory agency.

While this section provides recommended guidelines for managing the QA/QC program, it is important to note that a QA/QC program should be developed on a site-specific basis.

Reference should also be made to the Ministry publication “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” dated March 9, 2004.

6.1 Field Sampling Management

Sample management is the continuous care given to each sample from the point of collection to receipt at the analytical laboratory. Good sample management ensures that samples are properly recorded, properly labeled, and not lost, broken, or exposed to conditions that may affect the sample’s integrity.

The following subsections provide guidelines for field sample management.

6.1.1 Field Handling

Prior to entering the field area where sampling is to be conducted, the sampler should ensure that all materials necessary to complete the sampling are on hand.

If samples must be maintained at a specified temperature after collection, proper coolers and ice/cool-packs should be brought to the field. Consideration should be given to keeping reserve cooling media on hand if sampling events will be of long duration. Conversely, when sampling in extremely cold weather, proper protection of water samples, travel blanks, and field blanks from low temperatures should be provided.
Personnel performing groundwater sampling tasks should check the sample preparation and preservation requirements to ensure compliance with the project QA/QC requirements. Typical sample preparation may involve pH adjustment (i.e. preservation), sample filtration and preservation, or simply cooling to 0 to 10°C (target of 4°C). Sample preparation requirements vary from site to site, depending upon the analytical parameters being assessed. Sample preservation techniques are discussed in the Ministry publication “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” dated March 9, 2004.

The sampling personnel should also confirm before the sample event, the amount of bottle filling required for the respective sample containers. For example, VOC soil or groundwater samples should not have any headspace within the sample collection vial.

Prior to the field sampling program, a bottle order should be sent to the laboratory specifying the parameters and number of bottles required for both soil and groundwater sampling. Enough lead time should be given to the laboratory to prepare and ship the bottle order, packing materials and coolers. Long-term storage of these bottles (i.e. for more than a few weeks) is not recommended because sample bottles may contain chemical preservatives which have a limited shelf life. QA/QC requirements should be discussed with the analytical laboratory.

### 6.1.2 Sample Labeling

Samples should be properly labeled as soon as possible after collection. The minimum data to be included on a sample label should include:

- Project name
- Sample number
- Sampler’s initials
- Date of sample collection
- Time of sample collection
- Analysis required
- Preservatives.

For transportation of potentially dangerous or hazardous materials (i.e. potentially flammable, explosive samples, or compressed gases, etc.), the packaging or documentation requirements of the courier company, Workplace Hazardous Materials Information System (WHMIS), Transportation of Dangerous Goods (TDG), Ontario Ministry of Labour, and any other applicable standards should be followed.

### 6.1.3 Packaging

When possible, sample container preparation and packing for shipment should be completed in a well organized and clean area, free of any potential cross-contaminants. Unless weather
conditions do not permit it, sample containers should not be prepared for shipment in a field office trailer due to the risk of breakage and the potential for personnel exposure.

All sample containers should have sample labels and clear, wide packing tape may be placed over the sample label for protection. The sample containers should be placed in sealable plastic bags to keep the labels legible, should melting ice in the cooler come into contact with the sample containers.

While there is no one “best” way to pack samples for shipment, samples should be properly packed in order to avoid breakage and potential cross-contamination. Typically, loose ice is used as the cooling media.

Dry ice should never be used to cool samples during shipment as the bottles can break, field personnel can be burned when handling dry ice, and the shipment of an asphyxiating material in a cooler that will be in an enclosed space (a delivery truck) is considered a dangerous practice.

6.1.4 Chain-of-Custody Records

Chain-of-Custody (CoC) forms must be completed for all samples collected. The chain-of-custody form documents the transfer of sample containers from the field to the laboratory.

The chain-of-custody form, completed at the time of sampling, should contain at least the sample number, date and time of sampling, and the name of the sampler. Contact information should also be provided. The chain-of-custody document must be signed and dated by the sampler when transferring the samples.

Each sample cooler being shipped to the laboratory should contain a chain-of-custody form. The chain-of-custody form should consist of multiple copies that can be distributed to the shipper, laboratory and client.

Completed chain-of-custody forms are considered to be legal documents. They should be completed and handled accordingly.

6.1.5 Shipment

“Holding time” refers to the period in time between the collection of the sample, and the analysis of the sample in the laboratory.

When quick turn-around-times have been requested, holding time conflicts do not usually occur. Problems can happen when samples are not delivered to the laboratory for several days (e.g. at remote sites) or when sampling is done prior to a weekend or holiday, and standard turn-around-times are requested (for many laboratories this is 10 to 12 calendar days).

Samples should be delivered to the analytical laboratory as soon as possible after sampling.
6.2 Field QA/QC Sampling

All field QA/QC project sampling tasks should be outlined in the project work plan.

Table 2 provides a summary of the field quality control samples considered appropriate for soil and groundwater sampled during Phase II ESAs. These frequencies should be considered as minimums and may need to be increased at some sites. Quality control samples are typically not collected for soil samples because of the greater variability in chemical concentrations in soil materials.

Table 2: Types and Frequency of Field QA/QC Samples

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Travel Blank</th>
<th>Field Blank</th>
<th>Equipment or Rinsate Blank</th>
<th>Field Duplicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
<td>Optional</td>
</tr>
<tr>
<td>Groundwater</td>
<td>Yes</td>
<td>Yes</td>
<td>Optional</td>
<td>Yes</td>
</tr>
<tr>
<td>Recommended Frequency</td>
<td>A minimum of one sample per site(^{(a)}), with sample shipment</td>
<td>A minimum of one sample per site(^{(a)}), with sample shipment</td>
<td>A minimum of one sample per sample shipment, if dedicated equipment not used, for each matrix sampled</td>
<td>A minimum of 5 per cent of all samples, with a minimum of one per sample shipment</td>
</tr>
</tbody>
</table>

The sampling plan should specify the number and type of field QA/QC samples that field personnel should submit to the laboratory. A field duplicate sample will be taken by the field personnel and submitted to the laboratory for QA/QC.

6.2.1 Travel Blanks

Travel (or Trip) blanks are prepared before the sampling event and sent to the site in the shipping containers designated for the project. These samples are intended to be kept with investigative samples and be submitted for analysis with the project samples. The samples should not be opened and are intended to determine if the sample shipping or storage procedures influence the analytical results.

Travel blanks are submitted to the laboratory without identification as a blank. The frequency of travel blank submissions will be determined by the project QA/QC requirements.

\(^{(a)}\) The recommended frequency of use of the field QA/QC types is one QA/QC for each matrix sampled, with additional blanks as required (i.e. rinsate blank). The use of field and travel blanks is recommended where VOCs, TPH (gas) or SVOCs are the analytes of interest.
6.2.2  Field Blanks

A field blank is collected to evaluate the influence of field ambient conditions on the sampling process. Field blanks are collected using water of the proper quality which is poured directly into the sample container. Field blank collection is performed at the sampling site to evaluate if ambient site conditions influence sample results.

Field blanks are submitted to the laboratory without identification as a blank. The frequency of field blank submission will be determined by the project QA/QC requirements.

6.2.3  Equipment Blanks

Equipment field blanks are defined as QA/QC samples used to determine if field equipment cleaning procedures are effective and adequate. Equipment field blanks are prepared by collecting water of the proper quality that has been “run through” or “poured over” the cleaned sample collection equipment. Equipment blanks are typically collected at the sample preparation area of the project site and submitted to the laboratory without identification as a blank.

Field personnel should be aware of the various qualities of water that may be used to rinse sampling equipment or used as QA/QC samples. These include:

• **Potable tap water.** This water is often used for the final rinse of sampling equipment. This water usually contains inorganic and/or organic parameters (often at significant concentrations). While this material is usually suitable for the final rinsing of equipment to be used in the field, it is not suitable for use as a field QA/QC sample.

• **Distilled or de-ionized water.** This water is sometimes used for the final rinse of sampling equipment (usually just clean tap water is used). This water usually contains trace amounts of ions and/or volatile organic parameters. While this material is suitable for the final rinsing of equipment to be used in the field, it is typically not suitable for use as a field QA/QC sample.

• **RODI (reverse osmosis de-ionized) water.** Typically, this is chlorinated tap water that has been passed through an activated carbon filter, purified by reverse osmosis membrane and then passed through deionization cartridges. This water is supplied by the contract laboratory. It is suitable for use for equipment blanks, field blanks and travel blanks for inorganic, non-volatile organic and semi-volatile organic parameters, but is not suitable for these uses for volatile organic parameters.

• **Purged RODI water.** This is RODI water that has been purged by nitrogen or air to remove the last vestiges of trace volatile organic parameters (e.g. chloroform and trihalomethanes) that are residuals of the chlorination process which are not completely removed by RODI treatment. This water is supplied by the contract laboratory. It is suitable for use as equipment blanks, field blanks and travel blanks for volatile organic parameters.
Use of the inappropriate grade water quality when preparing a blank sample in the field can lead to false positive results with field QA/QC samples. Care should be taken by field personnel to avoid this issue by diligent use of the proper material when preparing field QA/QC samples.

Equipment blank samples are usually not collected if groundwater samples at the site are collected using dedicated sampling equipment (e.g. these samples are not collected if groundwater samples are procured using inertial pumps and tubing dedicated to each monitoring well). One equipment field blank is typically collected for each batch of samples submitted to the laboratory when dedicated groundwater sampling equipment is not used.

Preservation or filtration (if required) is completed on the respective equipment blank samples to ensure that every step of the sampling procedure is evaluated.

### 6.2.4 Field Duplicates

A field duplicate sample is a second sample taken from a sample location and submitted along with the initial sample. Field duplicates are collected and submitted to assess the potential for laboratory data inconsistency and the adequacy of the sampling and handling procedures. A duplicate sample is collected from the same source utilizing identical collection procedures. Higher than expected variability is usually an indication of either poor field sampling techniques or a very heterogeneous sample matrix. The potential for laboratory inconsistency however should also be considered.

Field duplicates are typically submitted without identification as a duplicate to the laboratory by providing a false identification number. The sampling “key” to ensure proper sample identification should be submitted to the appropriate personnel to enable completion of the QA/QC review process.

Whenever possible, field duplicate samples should be taken where field observations indicate that the presence of contamination is suspected. Limited information on field duplicate reproducibility may result when samples containing non-detectable levels of the parameters of concern are submitted for analysis.

### 6.3 Laboratory QA/QC

Laboratory QA/QC procedures are dealt with in the Ministry publication “Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act” dated March 9, 2004.

Laboratory QA/QC samples include laboratory duplicates, method blanks, spiked blanks, and matrix spikes. For organics parameter analysis of a sample, chemical surrogates are added and surrogate recoveries calculated for each individual sample. The laboratory should indicate on the Certificate of Analysis (CoA) that the test method was in statistical control when the analysis was performed. The CoA should also flag any other quality issues with the analyses (e.g. results
for QA/QC samples during the analytical run being outside the acceptance criteria specified by the test reference method).

Laboratory QA/QC results should be included with the analytical laboratory report and should be reviewed carefully as part of the overall data assessment. Due to rigorous implementation of QA/QC protocols and establishment of standard operating procedures, it is expected that the contribution to overall variability of the results reported for samples analyzed by an accredited laboratory will be relatively small.

Only laboratories accredited to the ISO/IEC Standard 17025 by an internationally recognized accreditation body can be used for Phase II ESA analytical work. Accreditation is given only to laboratories that demonstrate competence in their field of testing and conform to ISO/IEC Standard 17025 – General Requirements for the Competence of Testing and Calibration Laboratories.

In addition to quality system accreditation, the accreditation process provides accreditation for unique combinations of analyte, matrix and method. For analyte/matrix combinations which are commonly performed, e.g. metals in soil, the accreditation body usually requires successful participation in a proficiency testing (PT) program as a requirement of accreditation. Only laboratories that have current accreditation to analyze these parameters should be chosen to perform the analysis of samples collected for purposes of a Phase II ESA and filing a record of site condition.

Section 47 of Ontario Regulation 153/04 sets out the regulatory requirements concerning the use of an accredited laboratory for the analysis of soil, groundwater and sediment (refer to subsection 3.3.5.2 Laboratory Accreditation of this guideline).

6.4 Assessment of QA/QC Sample Results

Analytical results are considered acceptable if standard operating procedures have been followed and the results of laboratory quality control samples (method blank, laboratory duplicate, spiked blank, matrix spikes) are within acceptance limits defined by the test method by which they were analyzed. For organic contaminants, the reported recoveries of all surrogates should be within the acceptance limits specified by the test method.

When assessing quality control samples, action should be taken when the expected variability or concentration is outside of the expected bounds. The original sample results should never be “corrected” or results mathematically manipulated to overcome quality control issues.

A discussion of the quality control results should be provided in the Phase II ESA report. Sample results should be qualified, if necessary. It is recommended that results be assessed in consultation with the analytical laboratory.
7. Phase II ESA Report

This section discusses the interpretation of the site assessment and sample results, and describes the type of information and conclusions which should be included in the Phase II ESA report.

7.1 Data Interpretation

A Phase II Environmental Site Assessment (Phase II ESA) is undertaken to determine the nature and extent of any potential contamination of soil, groundwater or sediment at a property. The assessment of soil quality is a fundamental component of a Phase II ESA and a Phase II ESA must include soil sampling and analysis. Soil sampling and analysis will indicate whether soil conditions are appropriate for the site use or whether site cleanup/remediation (or a risk assessment) is necessary. The results of the soil sampling will also help indicate, along with the results of the Phase I ESA, if the groundwater (or sediment, if any) at the property may be contaminated and should also be sampled.

Data interpretation should seek to ensure that the conclusions derived from the results of the study are consistent with and address initial aims of the Phase II ESA. For most studies, the primary goal of data interpretation is to establish the existing conditions with respect to the concentrations of contaminants of concern. The data must be compared to the applicable standards and parameters with concentrations above their respective standard should be discussed in the report. The source of standards used for comparison (i.e. the Ministry publication “Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act” dated March 9, 2004) should be clearly stated in the report. The methods used to process or interpret the data should be described in the Phase II ESA report.

Hydrogeological reporting should also include a brief discussion and interpretation of the hydrogeologic site setting including a description of local aquifers and local groundwater flow directions. The potential for the off-site migration of contaminants should also be discussed.

7.2 Report Content

The Phase II ESA report should stand alone and describe all aspects of the Phase II ESA program. The report should include the following information:

- The results/findings of the Phase I ESA;
- A summary of all preliminary work and field activities conducted at the site as part of the Phase II ESA study;
- The information and results from the site investigation;
- The interpretation and evaluation of the information and results from the site investigation; the focus of this being to identify and describe any contaminants (and wastes) found at the site, including location, possible sources for this contamination and concentration. Results
of all analyses conducted must be reported and assessed along with a rationale for the standards selected to compare these results to and a discussion of the QA/QC results generated as part of the assessment. Any contaminants remaining at the site, including location and concentration must be identified and described; and

• Conclusions of the Phase II ESA.

With respect to the hydrogeological aspects of the Phase II ESA, the following information should be included:

• Borehole stratigraphic and monitoring well instrumentation logs;
• Groundwater elevation measurements (typically reported in tabular format) should include: hydrostatic zone monitored, elevations of well screen and sandpack, surveyed reference point elevation, depth to water measurement, calculated water surface elevation, thickness of immiscible layers, and where appropriate, corrected hydraulic head measurement (with discussion of correction method);
• Hydrogeologic cross-sections are recommended for larger or more complex sites, as they illustrate the geologic materials, groundwater levels, hydraulic flow paths and contamination zones. Typically, cross-sections parallel and perpendicular to the direction of groundwater flow are prepared. However, cross-sections may not be needed are often not useful for smaller or less complex sites. The decision as to whether or not cross-sections would be prepared would be the decision of the Qualified Person; and
• Groundwater contour maps are also useful in depicting groundwater flow directions and gradients for all groundwater systems found at the site.

The Phase II ESA report provides documentation of the completed work, presents and interprets the findings, and provides conclusions and recommendations (if requested by the client) that are drawn from those results. The report should be a stand-alone document, but should reference any previous investigations performed (e.g. Phase I ESA or initial screening sampling). A suggested report format is presented in Table 3.

<table>
<thead>
<tr>
<th>Table 3: Suggested Phase II ESA Report Format</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Section</strong></td>
</tr>
<tr>
<td>Title Page</td>
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<td>Executive Summary</td>
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| Introduction | - Background information on site  
- Summary of Phase I ESA findings (including any previous Phase II ESA or other investigations at the site)  
- Description of any identified environmental issues  
- List any contaminants of concern identified in Phase I ESA  
- Description of the scope of work  
- Basis for choosing applicable site standards |
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| Field Methodology | - Description of buried utilities clearances  
                     - Description of all field work, including equipment used, methods of sample collection, when work was performed, field observations, summary of samples collected and analyses performed, laboratory used  
                     - A rationale table for the samples collected. All sampling locations and depths should be clearly indicated on a scaled drawing |
| Findings          | - Presentation and discussion of analytical results (including use of graphical and tabular form, as appropriate)  
                     - Analytical results tables, with comparisons with applicable site standards  
                     - Provide information on contaminants of concern discovered at site, their concentrations, their spatial extent (horizontal and vertical)  
                     - If possible, describe contaminant origin/source (including whether on-site or off-site source)  
                     - Describe potential for off-site migration of contamination  
                     - Discussion of laboratory and field QA/QC results, including inconsistencies and/or anomalies in the data |
| Conclusions       | - Conclude whether contaminants of concern are present on the property above applicable site standards and identify which contaminants these are  
                     - Describe the known physical extent of contaminants of concern on the property that are present above applicable site standards |