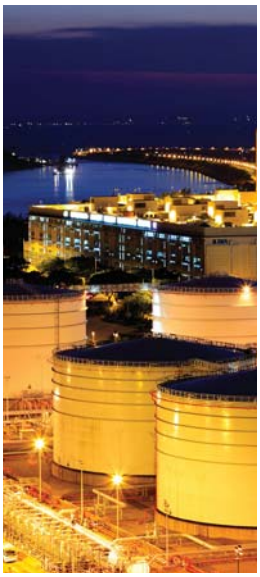

Draft Sampling and Analysis Plan

United Verde Soil Program
Clarkdale, Arizona

Freeport Minerals Corporation

GHD Services Inc.
7560 N. La Cholla Blvd. Tucson Arizona 85741
11102656 | 001 | WP1.10 | Report No 1 | July 06 2015

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Appendices

Appendix A GHD's Field Training Manual and Standard Operating Procedures

Acronyms

AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
AR	Analysis Request
As	Arsenic
BGS	Below Ground Surface
CD	Compact Disk
CL	Cleanup Level
COC	Chain of Custody
CIOP	Community Involvement and Outreach Program
Cu	Copper
DFAR	Daily Field Activity Reports
DQO	Data Quality Objective
DSR	Data Summary Report
EDD	Electronic Data Deliverable
EPA	United States Environmental Protection Agency
ER	Equipment Rinsate
ESI	Expanded Site Investigation
FDT	Field Data Tablet
FMC	Freeport Minerals Corporation
FQC	Field Quality Control
FSM	Field Site Manager
ft	feet
GIS	Geographic Information System
GPL	Groundwater Protection Level
GPS	Global Positioning System
ICP	Inductively Coupled Plasma
IDW	Investigation-Derived Waste
IEUBK	Integrated Exposure Uptake Biokinetic
LDVM	Laboratory Data Validation Manager
mg/kg	milligrams per kilogram
MS	Matrix Spike
MSD	Matrix Spike Duplicate
Pb	Lead
PDB	Project Database
PM	Project Manager
PPIN	Property Parcel Identification Number
QAPP	Quality Assurance Project Plan
QA	Quality Assurance
QC	Quality Control
QCM	Quality Control Manager
RI	Remedial Investigation
ROW	Right-of-Way
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedures
sq ft	square feet
TC	Target Constituent
UA	Use Area
USB	Universal Serial Bus
VRP	Voluntary Remediation Program

1. Introduction

The United Verde Copper Company (United Verde) operated a copper smelter northwest of Clarkdale, Arizona from 1915 to 1932. The smelter was reopened in 1935 when Phelps Dodge Corporation purchased United Verde and continued to operate until 1953. Freeport Minerals Corporation (FMC) is the successor to Phelps Dodge Corporation.

Because the copper smelter operated in an era before emissions control equipment was commonly used, historical air emissions from the smelter may have deposited metal-bearing particles on nearby soil. FMC has elected to enter into the Arizona Department of Environmental Quality's (ADEQ) Voluntary Remediation Program (VRP) to address the potential that historical smelter operations may have contributed to elevated metals concentrations in soil on properties near the former smelter operations. Under the VRP, FMC will perform a soil characterization and remediation program (the Soil Program) within the area shown on **Figure 1-1** (the Study Area).

The Study Area includes properties most likely to have been affected by historical air emissions (the primary off-site transport mechanism for metals associated with the United Verde operations) due to the properties' proximity to historical smelter operations. This study area was approved by ADEQ as part of FMC's VRP application. Provision is made in **Section 1.3** for adjustments in the Study Area if warranted based on the data collected under this Sampling and Analysis Plan (SAP).

The Soil Program will give owners of eligible residential, non-residential (e.g., commercial, etc.), and public properties (e.g., schools, parks, etc.) within the Study Area the opportunity to have the soil on their properties tested for certain smelter-related metals (i.e., target constituents [TCs]) and, if necessary, remediated (i.e., soil removed and replaced—hereinafter referred to as "cleanup").

Eligible properties are those properties within the Study Area that either are developed or planned for development[1] or meet one or more of the property category criteria provided in **Section 3.5** and have sufficient accessible area (as defined in **Section 3**) for both sampling and, if required, cleanup. Undeveloped properties, which are not eligible, generally include large (greater than one acre) properties that are used for agriculture (e.g., farming, pasture, etc.) or that are comprised of an open area that has not been planned for development. However, discrete portions of undeveloped properties that have a structure and use areas typical of a residential property will be included in the Soil Program (e.g., use areas adjacent to a farm house).

Industrial properties are not eligible for the Soil Program as they represent different exposure scenarios and human health risk considerations. In addition, industrial operations generally represent sources of metals and other contaminants that have no relation to or would be indistinguishable from the historical smelter operations.

[1] For the purposes of this SAP, a property will be considered to be "planned for development" if it is the subject of a development plan (e.g., plat) that has been approved by the applicable governmental authority (e.g., city, county, etc.).

Legend

- Clarkdale Study Area
- Clarkdale Parcels

DRAFT

1,000 500 0 1,000 Feet

UNITED VERDE SOIL PROGRAM

Figure 1-1

STUDY AREA

Sampling and Analysis Plan

Clarkdale, AZ

N W E S

Office	Revised By		Signed Date/Initial	As-Built Date/Initial	Comments
Waterloo	RM	5/22/2015			31952_(SAP)GIS_WA001

FMC has retained GHD to prepare and implement this SAP, which presents procedures for collecting and analyzing soil samples from those eligible properties where the owner has signed a property access agreement (**Section 2**). The sampling is designed to determine representative soil concentrations of TCs within designated use areas (UAs) (e.g., front yard, backyard, driveway, parking area, etc.) of individual properties located within the Study Area. The TC concentrations will be compared with health risk-based cleanup levels approved by the ADEQ (CLs) (**Section 1.2**) to determine if cleanup of that UA is required.

This SAP has been prepared as guidance for the execution of field sampling activities, laboratory analysis of soil samples for the TCs, sample data collection activities, and data reporting. All fieldwork will be performed in accordance with GHD's health and safety procedures and a site-specific health and safety plan. This document presents the site sampling and analysis procedures. Data quality objectives (DQOs) and analytical procedures applicable to the soil sampling activities are described in the Quality Assurance Project Plan, United Verde Soil Program (GHD, 2015) (QAPP). GHD's Field Training Manual and Standard Operating Procedures (SOPs), which will be used to support the sampling, are provided in **Appendix A**.

Applicable guidance from the Superfund Lead-Contaminated Residential Sites Handbook (EPA, 2003) (Handbook) was used in developing this SAP. The Handbook states that lead-contaminated sites may contain other metals of concern and the guidance provided in the handbook may be applied to investigation and remediation of lead and other metals (EPA, 2003). Use of the foregoing guidance in developing the soil sampling procedures and associated quality assurance/quality control (QA/QC) measures incorporated into this SAP ensures that the sampling approach meets regulatory guidelines, is technically defensible, and will achieve the sampling objectives by providing data of sufficient accuracy and sensitivity to compare with cleanup criteria.

1.1 Smelter Operational History

The United Verde mine in Jerome was the source of copper ore and concentrates smelted at the United Verde smelter in Clarkdale. Ores from the mine varied in type and quality over the life of the mine but typically contained copper (chalcopyrite), zinc (sphalerite), lead (galena), and iron (pyrite) sulfide minerals. Trace elements, such as gold and silver, were inclusion in the sulfide ores along with other minor metals.

The simplified smelting process included ore crushing, milling, and roasting before the actual smelting refinement process. The roasting and smelting processes produced sulfur dioxide emissions as the metals separated by the high heat of the furnaces. Iron and silica together with trace metals were separated into the slag which was discarded during the process. Copper matte was produced as the finished product of the smelter to be further refined elsewhere into other products. Zinc was recovered during the later years of the smelting process also.

Emissions testing available from the smelter in 1935 primarily indicated detectable concentrations of copper, zinc, lead, arsenic, and iron in emissions particulate. Iron and zinc are essential human nutrients at low concentrations and not considered hazardous to humans at low concentrations typically emitted at a copper smelter. Therefore, copper, lead, and arsenic were carried forward into the development of CLs for this soil program.

1.2 Target Constituents and Cleanup Levels

The primary objective of this SAP is to generate representative TC concentrations in soil within each UA of a given property for comparison to CLs. A human health-based risk assessment (Damian Applied Toxicology, 2015) was submitted to support a request for site-specific TCs and CLs for the Soil Program. The TCs and CLs approved by the ADEQ for the Soil Program are included in **Table 1-1**.

Table 1-1: Cleanup Levels

Target Constituent	Cleanup Level by Land Use (mg/kg)	
	Residential	Non-Residential
Arsenic (As)	30(1)	30(2)
Copper (Cu)	9,000(1)	41,000(3)
Lead (Pb)	425(1)	800(3)

(1) The residential CLs for As, Cu, and Pb are site-specific CLs that have been approved by ADEQ by letter dated May 1, 2015, for the Soil Program.
(2) The non-residential CL for As is set equal to the residential CL consistent with the approach used by ADEQ for pre-determined values.
(3) Pre-determined CLs specified in AAC R-18-7-205.

1.3 Groundwater Protection Level

FMC will verify through modeling that the CL developed for Pb will adequately protect groundwater, and if necessary, develop a groundwater protective soil cleanup level. The CL for arsenic (30 mg/kg) is lower than the minimum Groundwater Protection Level (GPL) protective of soil contaminant leaching to groundwater of 290 mg/kg, and a GPL does not exist for copper (ADEQ, 1996). Therefore, FMC will develop an alternative GPL for Pb once sufficient site-specific data has been collected. The development of the alternative GPL for Pb will be based on a mixing cell model and the ratio between the site-specific total and leachable metal concentrations.

1.4 Adjustments to the Study Area

Other common non-smelter-related sources within urban areas (e.g., lead paint, pesticides, herbicides, prior use of leaded gasoline, fertilizers, treated wood, other commercial or industrial sources, etc.) can result in elevated soil TC concentrations; therefore, elevated concentrations of TCs could be found outside of the Study Area regardless of any potential contribution from the historical smelter operations. The Study Area includes properties most likely to have been affected by historical air emissions due to the properties' proximity to historical smelter operations and may be expanded if warranted based on the Soil Program data.

The analytical data obtained from implementation of this SAP will be evaluated to determine if there is a trend or pattern in TC soil concentrations with distance from the United Verde smelter that indicates whether TC soil concentrations associated with historical operations would likely exceed applicable CLs outside of the Study Area. If necessary, this evaluation will consider multiple lines of evidence on possible emissions dispersion patterns, TC ratios, and spatial distribution. Any recommendation for expansion of the Study Area will be submitted to the ADEQ for review and approval.

2. Community Involvement, Outreach and Solicitation

This section addresses the Community Involvement and Outreach Program (CIOP) that will be undertaken in support of the Soil Program. The objectives of the CIOP include the following:

- Provide program information to local community leaders, the general public and property owners
- Coordinate with the owners of those properties that are eligible for sampling and, if necessary, cleanup under the Soil Program
- Obtain access agreements
- Report the results of sampling and, if applicable, details of cleanup activities to property owners

The CIOP will include a variety of activities designed to inform local community leaders, the general public, and property owners within the Study Area about the Soil Program and to obtain the necessary access agreements for the Soil Program activities. To facilitate implementation of the CIOP, a Community Outreach office will be established in Clarkdale and staffed as necessary to fulfill the CIOP objectives.

Requests for access and details about the Soil Program will be delivered to property owners within the Study Area in a variety of ways, including the following:

- Direct mail to every eligible property owner within the Study Area
- An open house event to explain and answer questions regarding the Soil Program
- Phone calls and door-to-door contact, if necessary

A minimum of two attempts (e.g., telephone, mailing, door-to-door contact, etc.) beyond the initial mailing will be made to obtain access from each property owner within the Study Area.

The CIOP materials and presentations will, at a minimum, provide the public with the following:

- Contact information for the Community Outreach office
- Summary information about the Soil Program
- Information to facilitate submission of soil sampling access agreements

Work Plans approved by the ADEQ as well as copies of the CIOP materials will be kept at a repository located at the Community Outreach office and the local library.

Periodic briefings regarding the status of the Soil Program will be provided to local community leaders, including the Town of Clarkdale and the tribal nations within the Study Area.

A fact sheet that describes the Soil Program has been prepared and distributed to local community leaders and will be sent to each eligible property owner. This fact sheet will be updated and redistributed when cleanup begins. The general public will be invited to open house events for the Soil Program that will provide information about the Program.

3. Sampling Approach

The procedures for the selection of sample locations and depth intervals within a property are provided in this section.

Eligible properties that are subject to the requirements of this SAP can be grouped into the following property categories: residential, non-residential, and unpaved rights-of-way (ROWs) (e.g., alley or street) that are a functional part of an adjoining UA. (Public properties will fall into one of these categories and are not discussed separately.) The accessible portion of these properties will be subdivided into separate UAs, and the representative soil concentration of the TCs will be determined within each UA using composite samples as specified in **Section 3.2**. For the purposes of this SAP, accessible areas are defined as those areas within a UA that represent a potential for direct contact with surface soil that is either bare or covered by grass or gravel. Accessible areas do not include the following:

- Paved or impervious areas, the area underneath stationary structures, creeks (or similar conveyances), and drainage ditches having either steep (>30%) sides or rip rap (or similar lining materials)
- Steep slopes that are generally inaccessible by young children[2]
- Those properties that have insufficient area for sampling after application of the criteria specified in **Section 3.5.2**
- Those areas that would present unacceptable safety concerns if remediated (e.g., an area behind a retaining wall that, due to age or condition, does not appear to be stable)

As indicated in **Section 1** , a property that does not have any accessible area would not be eligible for sampling.

Additional definition of property categories and the determination of UAs within those properties are described in **Section 3.5**.

3.1 Depth Intervals

Samples will be obtained from the depth intervals below ground surface (BGS) shown in **Table 3-1** at each sample location (whether it is an aliquot for a composite sample or a discrete sample). Sampling will likely not extend below 24 inches due to the low probability of potential human health-related exposure at lower depth intervals.

[2] Inaccessible areas generally include steep slopes (greater than 3:1). The primary population considered by the ADEQ in the development of cleanup criteria is pre-school age children. Integrated Exposure Uptake Biokinetic (IEUBK) guidance indicates that the home and its surrounding yard is the basic unit for risk analysis for Pb because exposure to Pb for pre-school children commonly occurs within this domain (EPA, 1994). Although steep slopes may be adjacent or close to such primary UAs, the steepness makes the potential for use of these areas by young children significantly different from other UAs.

Table 3-1: Sample Depth Intervals			
Interval	**Residential (Inches bgs)**	**Non-Residential (Inches bgs)**	**Purpose**
A	0 to 3	0 to 3	These two depth intervals will be obtained at each sample location to determine if remediation is required.
B	6 to 12	6 to 12	
C	12 to 18	12 to 18	Samples from the C and D depth intervals may either be obtained during the initial sample event or in a subsequent event. In either case, the C and D interval samples will only be submitted for laboratory analysis if TC concentrations in the sample from the 6- to 12-inch interval exceed a CL. In addition, it should also be noted that the D interval sample may not be analyzed unless the C interval sample exceeds a CL. Any samples of which analysis is not required will be disposed.
D	18 to 24	18 to 24	

3.2 Composite Sample Collection

The representative soil TC concentrations will be determined for each UA by the analysis of a composite sample from each depth interval specified in **Table 3-1**. Each composite sample will consist of one aliquot for each 400 square feet (sq ft) of UA, with a minimum of five aliquots per composite sample. Equal volumes of each individually homogenized aliquot will be taken and homogenized together in a separate, single, clean container to create the composite sample. Detailed procedures for obtaining each aliquot and creation of the composite sample are specified in **Section 5** and portions of GHD's Field Training Manual (**Appendix A**).

3.3 Confirmation Sampling

Every 20th sequential composite sample will be collected as a confirmation sample. Confirmation sampling will consist of shifting the yard sampling grids approximately 10 feet (ft) (space permitting). This will facilitate the collection of composite sample aliquots at different locations from those collected for the initial composite sample. This confirmation sampling approach will be used to determine if the initial composite sample obtained from a UA is representative of TC concentrations within the UA and to determine variability in soil concentrations.

Confirmation sampling will not be performed within any UA where there is insufficient space to allow for the shifting of grids. Such a circumstance will generally occur in greenways and alleyways. Greenways refer to those limited occurrences where the alley, or similar access, is generally covered in grass instead of gravel. Confirmation sampling will then be performed at the next available UA with sufficient space.

3.4 Discrete Samples

In addition to the composite samples, individual discrete samples will be taken from bare soil child-play areas (e.g., under swing sets) within residential properties. Samples will be obtained from the depth intervals specified in **Table 3-1** at each discrete sample location and progressively analyzed as specified in **Table 3-1**.

If the composite sample for the UA that contains the discrete sample location also exceeds the CLs, vertical delineation at the discrete sample location may not be required. However, if the discrete

sample location depth interval with a CL exceedance is deeper than the composite sample depth interval with a CL exceedance, the discrete sample will control vertical delineation within the area represented by the discrete sample. If vertical delineation is required at a discrete sample location due to a CL exceedance, such delineation will consist of collecting samples from the additional depth intervals specified in **Table 3-1**.

For the purposes of horizontal delineation, each discrete sample will be regarded as representing no more than 400 sq ft of area, consistent with the area represented by each aliquot of a composite sample. Additional discrete sample locations will be taken in a grid pattern around the discrete sample location. The maximum grid spacing between these horizontal delineation sample locations will be 20 feet. Structural boundaries such as pavement, buildings, boundaries of accessible areas, or property lines will be excluded from this grid pattern. The discrete sample location with a CL exceedance is considered horizontally delineated when it is surrounded by discrete sample locations without a CL exceedance and/or structural boundaries defined above.

3.5 Property Categories, Creation of Use Areas, and Sample Location Details

This section further defines property categories, procedures for segregating properties into UAs, and locations of composite aliquots or discrete samples within a given UA. An individual sampling plan (**Section 7**) based on aerial photography will be developed for each property showing the preliminary UAs and sample locations. These sampling plans will be modified based on actual field reconnaissance as necessary to ensure that the requirements of this section are achieved. Properties that are not representative of the types described within this section will be addressed on a case-by-case basis.

3.5.1 General Sample Location Requirements

The purpose of sampling is to determine the soil concentrations of TCs that could potentially be related to historical operation of the smelters. Therefore, sample locations (whether for a composite aliquot or a discrete sample) will be selected to avoid the potential impact from other sources of TCs including lead-based paints, lead-contaminated vehicle fluids, or prior emissions from leaded gasoline. The following guidelines will be used to implement these criteria:

- Sample locations will be selected no closer than 5 feet from existing structures (and at least 3 feet from the drip zone) to minimize any potential influence of lead-based paint.
- Sample locations will be selected at least 5 feet from existing roads and paved parking lots to minimize potential influence of lead from fuels, oils, and vehicle emissions. In addition, sample locations will be a minimum of 3 feet from driveways.
- Soil samples will not be collected in areas visually observed to be impacted by oil or other petroleum products.
- Soil samples will not be collected within paved or impervious areas or underneath stationary structures (inaccessible areas).
- Soil sampling locations will be no closer than 3 feet from in-yard garbage/compost piles; abandoned vehicles or vehicles in a state of disrepair; or other "junked" items.
- Soil samples will not be collected within drainage ditches having either steep (>30%) sides or rip rap (or similar material) lining.

Aliquot locations will generally be located visually to result in an approximate equal spacing within the UA as indicated on **Figure 3-1**; however, the aliquot locations will be adjusted as necessary to avoid those areas identified in the foregoing. The aliquots for long, narrow UAs (e.g., alleyways, street ROWs, driveways, etc.) will generally be located in an approximate "W" zigzag pattern with equal spacing down the length of the UA.

3.5.2 Residential

For the purposes of this SAP, the accessible areas of the following properties will be sampled under the residential category:

- Single- and multi-family residences
- Vacant lots that are planned for residential development as defined in **Section 1**
- Discrete portions of an undeveloped property that includes a structure and use areas typical of a residential property
- Houses of worship
- Community centers
- Child care facilities
- Schools
- Public recreational facilities, including ball fields, playgrounds, etc.

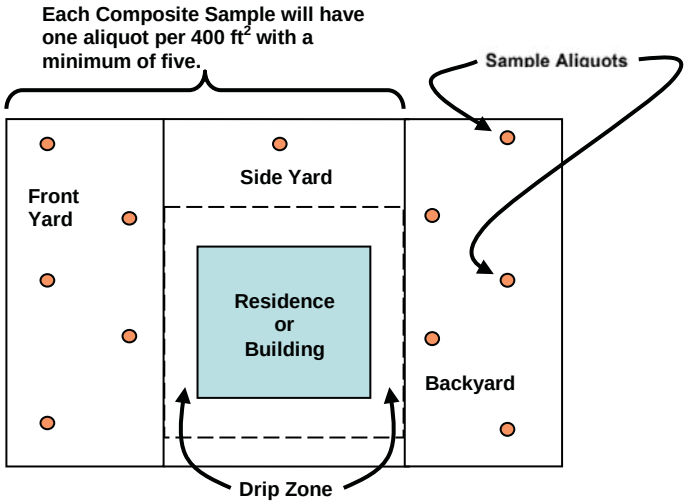
Vacant lots located adjacent to a property that matches any of the above definitions also may be considered for sampling on a case-by-case basis.

Residential properties will be divided into separate UAs as follows:

- Front yards and backyards will each be sampled as separate UAs provided that each UA is at least 10 feet in width measured from the drip line to the closest boundary of the accessible area. If either the front or backyard is less than 10 feet in width, that use area will be sampled as part of the larger UA.
- Individual side yards will each be sampled as a separate UA provided that the side yard is at least 15 feet wide, as measured from the drip line to the closest boundary of the accessible area. If a given side yard is less than 15 feet in width, that use area will be sampled as part of either the front or backyard UA.
- A gravel or earthen driveway/parking area will be sampled as a single UA.
- Any individual UA identified in the foregoing that exceeds 3,600 sq ft but is less than one acre in size will be subdivided into UAs approximately equal in size such that no individual UA exceeds 3,600 sq ft.
- Residential properties larger than one acre may either be sampled by continuing to sub-divide the property into 3,600 sq ft UAs or as a large area as described in **Section 3.5.5**.

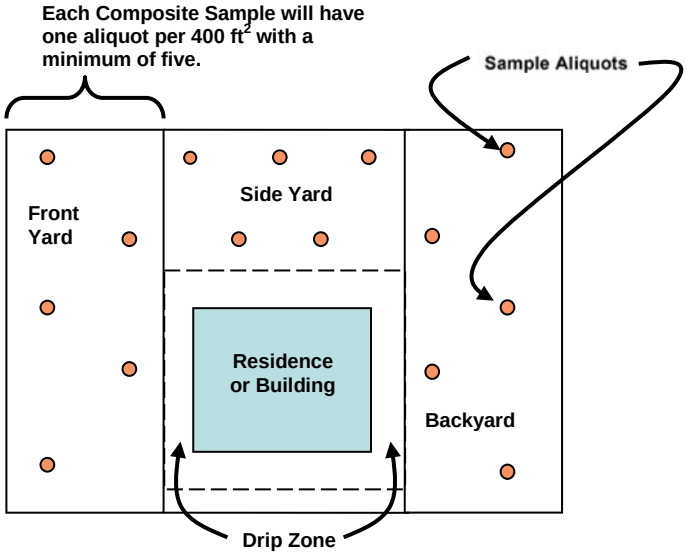
Figures 3-1 through 3-3 provide examples of the above scenarios.

Figure 3-1: Residential Property with a Front Yard, Backyard, and a Small Side Yard



In this example there would be 2 composite samples for each depth interval (no separate use area is > 3,600 ft^2).

Figure 3-2: Residential Property with a Front Yard, Backyard, and a Large Side Yard



In this example there would be 3 composite samples for each depth interval (no separate use area is > 3,600 ft^2).

3.5.3 Non-residential

For purposes of this SAP, non-residential properties will include properties that either have been developed or have been planned for development for a use other than residential, including vacant lots that are not sampled as a residential property in accordance with **Section 3.5.2**. Non-residential properties do not include industrial use properties.

The accessible area of non-residential properties that exceeds 5,000 sq ft but is less than one acre in size will be subdivided into UAs approximately equal in size such that no individual UA exceeds 5,000 sq ft. Non-residential properties larger than one acre may either be sampled by continuing to sub-divide the property into 5,000 sq ft UAs or as described in **Section 3.5.5**. FMC may, at any time, elect to conduct residential sampling activities (as outlined in **Section 3.5.2**) at non-residential properties.

Examples of non-residential UA scenarios are included in **Figures 3-4** and **3-5**.

Figure 3-3: Residential Property with a Front Yard, Backyard, and no Side Yard

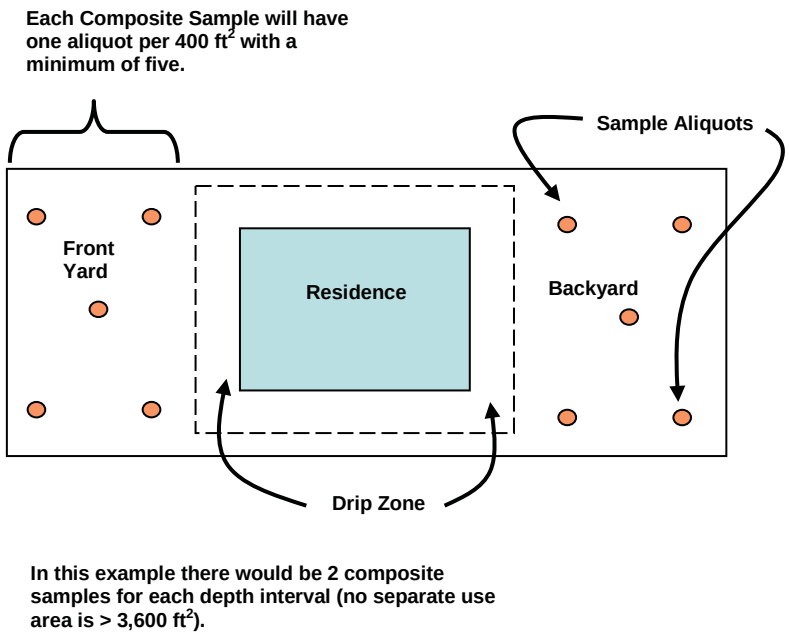
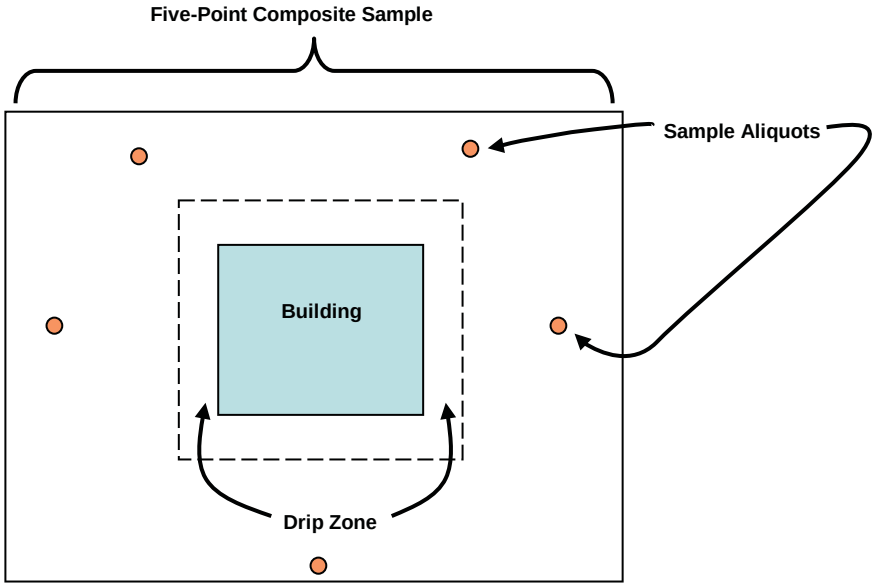
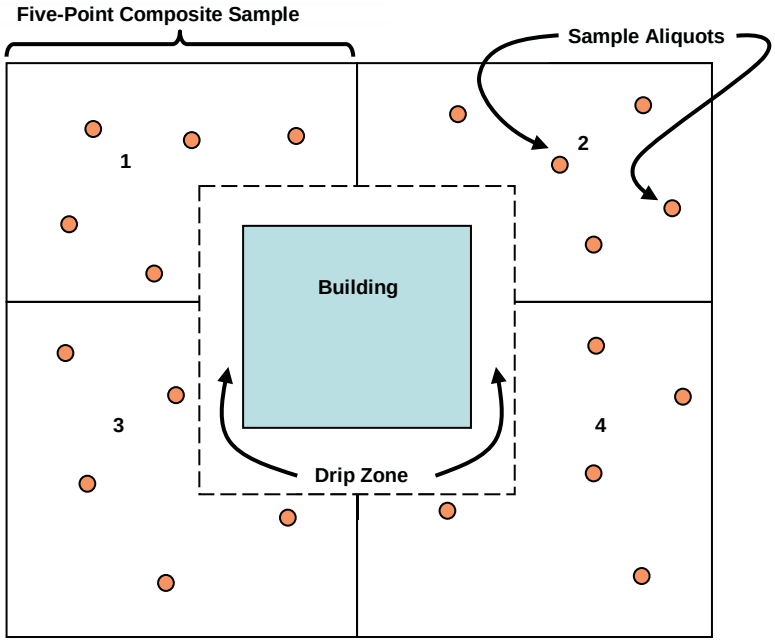


Figure 3-4: Non-residential Property that is less than 5,000 Square Feet in Size



In this example there would be 1 composite sample for each depth interval.

Figure 3-5: Non-residential Property that is Greater than 5,000 Square Feet and Less than One Acre in Size



In this example the property is larger than 15,000 ft^2 but less than or equal to 20,000 ft^2; therefore, there would be 4 composite samples for each depth interval.

3.5.4 Alley and Street ROWs

Alley and street ROWs will be sampled as follows:

- **Alleys:** Unpaved alleyways adjoining eligible residential and non-residential properties will be sampled as outlined within this section. The approach to sampling will depend on whether access has to be obtained from the adjacent individual property owners or owner of the alleyway. Depending on the access scenario, one or the other (not both) of the following approaches will be used to determine UAs within alleyways throughout the Study Area:
  - **The alleyway is sampled on an individual property basis.** The alleyway area that will be subject to segregation into UAs will be that portion of the alleyway that is adjacent to the property being sampled. If access has been granted by both adjacent property owners, the area will extend the full width of the alleyway; otherwise, the area will extend to the middle of the alleyway.
  - **The alleyway is sampled on a block basis.** The alleyway area that will be subject to segregation into UAs will be represented by the full length and width of the alleyway for the block (i.e., from street to street).
  - **I**f the alleyway area that is to be segregated into UAs exceeds 3,600 sq ft in a residential area or 5,000 sq ft in a non-residential area but is less than one acre in size, the alleyway will be subdivided into UAs of approximately equal size such that no individual UAs in residential areas exceed 3,600 sq ft or 5,000 sq ft in non-residential areas. Alleyways larger than one acre may be sampled by continuing to sub-divide the property into either 3,600 sq ft or 5,000 sq ft (as applicable) UAs or as described in **Section 3.5.5**.
- **Streets:** The portion of unpaved street ROWs that serve as a functional part of an adjoining residential or non-residential UA will be sampled as part of that UA providing that access for such sampling can be obtained from the entity that controls the rights to the ROWs for such access.

3.5.5 Large Residential and Non-residential Areas

This section is only applicable to eligible residential or non-residential property types and any associated ROWs. In most cases, the requirements of this section would only be applied to large parks, ball fields, school property, or other similar properties.

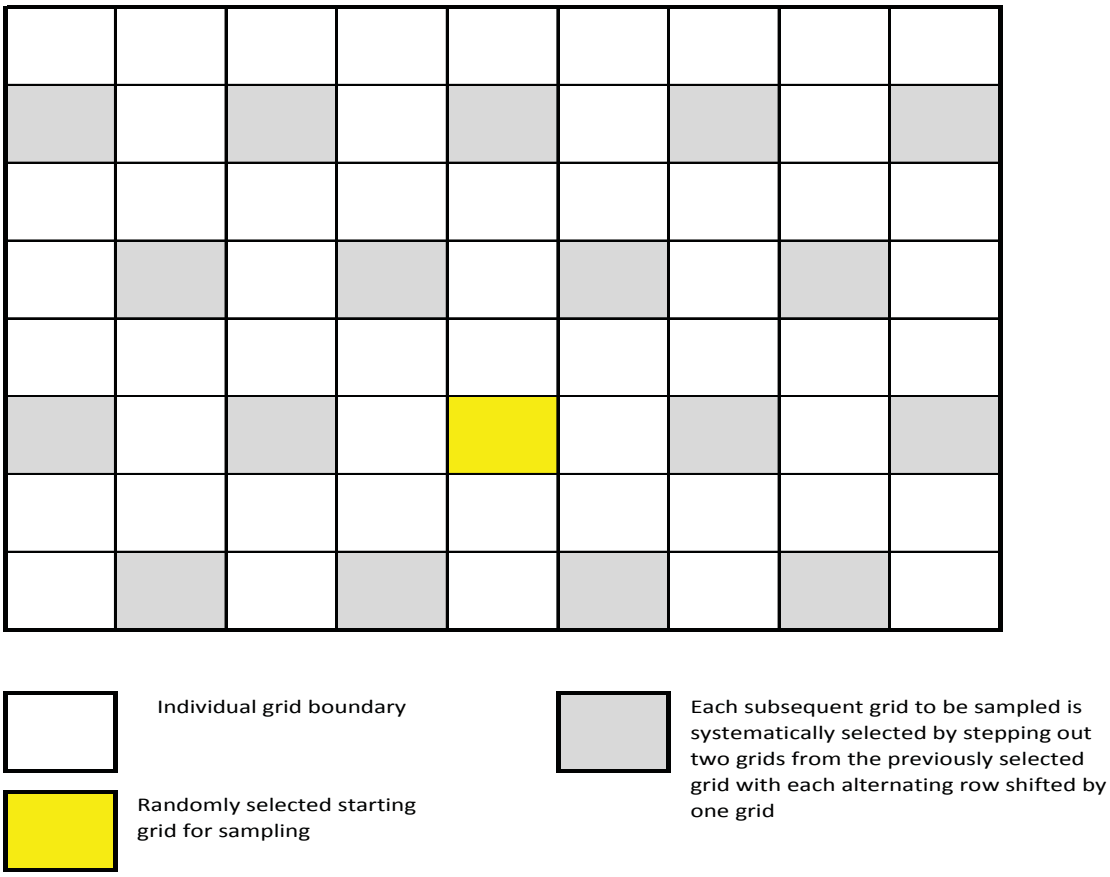
If the accessible portion of the property that is to be divided into UAs is larger than one acre, that property area will be divided into sub-areas (grids) that are approximately equal in size but no larger than 3,600 sq ft for residential areas or 5,000 sq ft for non-residential areas of the property. The larger count of 12 grids or 25 percent of the total number of grids will then be selected as individual UAs using a random start systematic sampling approach as follows:

- The first grid (i.e., UA) will be selected randomly using a random number generator.
- Then sampling will proceed by stepping out to every other grid from the first grid with the grids in alternating rows being shifted one grid.

This grid selection process is shown in **Figure 3-6**.

Figure 3-6

Large Residential and Non-Residential Grid Selection



A composite sample will then be obtained from each of the selected grids for each depth interval following the procedures specified in **Section 3.2**. If the concentration of one or more of the TCs in a composite sample from a given grid is above the applicable CL for that property's land use, then each of the four adjacent grids will also be sampled. If a composite sample from any of the adjacent grids is above the applicable CLs for that property's land use, then additional sampling will be conducted at adjacent non-sampled grids.

If the sampling process identifies the need for continued sampling on a given property after 50 percent of the grids have been sampled, the FMC will evaluate the applicability of this process to the property and discuss the results with ADEQ.

4. Analytical Methods and Field Quality Control Sampling

This section describes the analytical methods, sample containers, preservatives, holding time requirements, and field QC samples.

4.1 Analytical Methods

All samples will be analyzed for the TCs using analytical methods specified in the QAPP (GHD, 2015). The samples will be shipped to Microbac Laboratories, Inc. (Microbac) of Marietta, Ohio or comparable licensed laboratory for preparation and analysis. Microbac maintains a current license with the Arizona Department of Health Services.

4.2 Sample Containers, Preservatives, and Holding Times

Samples must be placed in sample containers certified by the laboratory to be pre-cleaned, compatible with the matrix and intended analysis, and properly prepared and preserved to maintain sample integrity. The sample containers, preservatives, and holding time requirements are identified in the QAPP.

4.3 Field Control Samples

Field QC is applied using a graded approach and depends on decisions required for individual tasks. Decisions must be based on procedures that are established to meet the objectives of the investigation defined within this SAP. Specific field QC procedures, including appropriate sample custody, documentation, and document control procedures are described in the QAPP.

Quantitative measures of field QC are produced through an analysis of shifted grid or sub-area composite confirmation samples taken on a specified frequency. Confirmation, duplicate, and split samples collected for soils are only approximate measures of field QC due to the heterogeneity of the soil matrix. Specific procedures and collection frequencies for field QC samples are provided in the QAPP.

5. Field Sampling

This section discusses the field sampling methods, sample handling protocols, and documentation requirements that will be required to complete the objectives of this investigation.

5.1 Utilities

After the identification of the property to be sampled and the verification of a signed property access agreement for that property, GHD will obtain utility clearances and applicable excavation permits for each property before sampling activities commence. The GHD utility clearance manager, or designee, will contact Arizona Blue Stake or the appropriate underground utility owner to ensure that the underground utilities located on the property are marked prior to sampling. The GHD utility clearance manager will confirm the availability of the property for sampling, make the underground utility marking requests, track the marking requests to verify all the public and private utilities are marked, and coordinate with the sampling teams on which properties are marked for sampling. Overhead utilities will be addressed as prescribed by FMC's overhead utility policies.

5.2 Soil Sampling Method

Soil samples will be collected using a stainless steel hand auger, core sampler, or hand trowel per GHD's Field Training Manual Section 5.0 for Soil Sampling SOPs (**Appendix A**) from the specified depth interval (**Table 3-1**). The soil samples will be collected as follows:

1. UAs (for composite sampling) will be laid out for each property by the sampling team. The UAs will be measured and compared with the sampling plan developed for each property (**Section 3.5**) and any adjustments noted. The individual aliquot sample locations for each composite UA sample will be marked using surveyor flags and noted on the site plan as part of the sample documentation process.

   Coordinate locations for ad-hoc discrete samples will be obtained and uploaded to the Project Database (PDB).

2. All sampling equipment including the sieve will be cleaned following the cleaning procedures outlined in **Section 5.3** before each composite sample aliquot or discrete sample is collected.

3. Where surface materials (such as mulch, gravel, etc.) have been placed on top of the soil, they will be removed from the sample location and placed next to the area to be sampled. Decorative rock (or similar, non-organic landscape material) found at the sample location will be added to the aliquot when placed on the sieve, such that any fine material from the rock that passes the sieve will be retained in the sample. Once the samples have been collected and the excess sample materials returned to the holes, the surface materials will be replaced in a manner as close to the original appearance as practicable. Sieving is discussed in more detail below in this section.

4. At each sampling point, the soil matrix will be excavated with a stainless steel auger, core sampler, or hand trowel to collect each sample aliquot. Sample aliquots will be excavated to the specified depth intervals specified in **Table 3-1**. Extreme care will be exercised during the excavation of sample holes to prevent any material from falling into the hole from upper intervals and potentially cause cross-contamination in the sample.

5. Sampling equipment that comes in contact with the sample will be decontaminated between each sample depth interval but not between each aliquot location for that depth interval.

6. The individual soil aliquots for each depth interval will be placed in separate containers, such as plastic bowls or zipper storage bags, and homogenized before combining into the composite sample.

7. A portion of each aliquot to be composited will be placed onto a standard No. 60 sieve[3] that will be placed over a plastic bowl of sufficient diameter to catch material that passes through the sieve. The sieve and bowl will then be gently agitated until nearly all of the fine material possible has passed through the sieve. Samples will not be ground prior to sieving, as this changes the physical structure of the soil and may bias the analytical results. Once all sieved aliquots of a given composite sample have been collected, the retained soil will be thoroughly homogenized in the bowl or transferred to a plastic zipper storage bag and homogenized.

8. Composite samples will be placed in an appropriately clean container provided by the analytical laboratory and appropriately labeled in accordance with the QAPP. Each sample will have a unique identification number that will be marked on the sample container and noted in the daily field sample form and chain-of-custody form.

9. Each sample will be sent to the project analytical laboratory following the sample handling, storage, and shipping procedures provided in the QAPP. All samples will be analyzed for

[3] A No. 10 sieve may be substituted for the No. 60 sieve provided that an extrapolation factor is developed following guidance provided by the Technical Review Workgroup (TRW) (EPA, 2000).

total TC concentrations. Sample analysis will be consistent with the methods identified in the QAPP.

10. Excess sample material and material removed when excavating the hole will be returned to the holes, leaving the sampling location as close to pre-sampling conditions as practicable (e.g., replacing any surface materials that have been removed). Sand may be added to the hole, as necessary, to bring the hole back to ground surface level.

5.3 Decontamination

All sampling and sample compositing equipment that comes in contact with samples and is not designated to be disposable will be cleaned prior to sampling. The standard cleaning protocol will include the following procedures:

- Removing any excess dust or dirt from the equipment with paper towels and/or wire brushes and distilled/deionized water, if needed
- Washing the equipment with a water solution containing a detergent, such as Alconox® or a similar laboratory-grade detergent
- Rinsing the equipment with distilled/deionized water

Equipment will be cleaned at the start of each day's sampling event and between each composite sample.

5.4 Wastewater Drum Samples

Field equipment decontamination fluids, such as investigation-derived waste (IDW) water, will be collected and stored in a 55-gallon drum or other appropriate container. If required, this wastewater will be sampled for a wastewater profile analysis to determine the disposal method for the wastewater. The wastewater samples from the holding container will be analyzed for the same TCs as the soil samples. Drum sampling procedures are described in GHD's Field Training Manual Section 7.0 for Water Sampling SOPs and provided in **Appendix A**.

5.5 Sample Documentation

All documentation related to sampling will be retained in the daily field activity report (DFAR), sample chain of custody (COC) forms, and other field information records according to procedures for documentation of sampling activities developed for the PDB as defined in **Section 7**. To the extent possible, sampling documentation will be collected electronically using an electronic field data tablet (FDT) and transferred directly into the PDB. Complete and accurate information is necessary for meeting the DQOs noted in the QAPP and the objectives of this SAP. Procedures for sample documentation are provided in the QAPP.

5.5.1 Sample Labels, Chain-of-Custody, Packaging, and Shipping

Procedures for sample labeling, COC, sample packaging, and shipping are provided in the QAPP.

5.5.2 Sample Information

Sample information will be recorded in the DFAR (described in the QAPP). The DFAR form is designed with data fields that prompt field sample personnel to capture relevant sample data and information for each sample. The forms will include a sampling plan for each property sampled and

will allow sample personnel to add or change sample locations and other pertinent information about the property.

The DFAR is designed to ensure that all necessary information is captured, documented in the PDB, and available for systematic QC review of the sample information. The DFAR will be completed by the sample team as the samples are collected and will be transferred to the PDB at a minimum, within 24 hours of the completion of the property's sampling activities. The DFAR and other related forms will provide the necessary information for documenting sample collection, tracking the samples through analysis, and allowing the data to be reported through multiple applications.

5.6 Global Positioning System Measurements

Where required, a handheld GPS will be used to capture location coordinates. GPS instrument operators will be trained in the use of the instrument and will operate the instrument in accordance with the manufacturer's operation manual.

5.7 Site Photographs

Digital photographs will be obtained for each sample location and transferred to the PDB. These photographs will document the presence of any features significant to the sampling activities, as well as any unusual soil samples observed at the properties. The photographs will be organized into meaningful sub-directories (i.e., by property area or activity).

For each photo taken, the following items will be noted in an electronic photographic field form:

- Name and address of property (or the parcel number)
- General direction faced
- A brief but accurate description of what the photograph shows (typically the UA location name; i.e., F01)
- Unique identification number of the photograph taken
- Reference point or reference scale, if appropriate

6. Analytical Quality Control Procedures

All samples identified for analysis at all depth intervals will be analyzed for As, Cu, and Pb. QA/QC project management and laboratory procedures, including data validation and usability, are specified in the QAPP.

7. Data Management

The data reduction, review, validation, reporting, and record keeping procedures described in this section will ensure that complete documentation is maintained, transcription and data reduction errors are minimized, the quality of the data is reviewed and documented, and the reported results are properly qualified.

The project will follow a systematic process for acquiring and managing data. The data flow from the laboratory and the field to the project team and data users shall be sufficiently documented to ensure that the data are properly tracked, reviewed, and validated for use. At the core of this process is the PDB. The PDB will be used for sample planning, collection of field documentation, sample management, organization of analytical results, reporting, and archiving of all project data and documents. The primary elements of the data acquisition and management process include the following:

- Sample planning
- Sample nomenclature
- Field data collection
- Chain-of-custody
- Laboratory data reporting
- Data review and validation
- Data reporting

7.1 Sample Planning

Sample planning for a given property will occur prior to the sampling team mobilizing to the property. The sample planning task will involve entering the identified property ownership and geospatial information into the PDB. Sample planning for each property will then be performed using GIS as follows:

- Overlaying the property geospatial data onto aerial photography and identify separate UAs for the property
- Making a preliminary determination if there is adequate space between the structure and property boundaries to allow for side yards
- Subdividing the UAs as necessary to meet the size limitations for a composite sample as specified in **Section 3.2**
- Determining the number of aliquots required for each composite sample based on the size of the UA area (or sub-divided UA area)
- Identifying a preliminary location for those aliquots on the sampling plan taking into account the criteria established in **Section 3.5.1**
- Identifying any discrete samples that may be required for verification by the field sampling team to the extent allowed by the resolution of the aerial photography
- Assigning UA designations and sample identification labels using the sample nomenclature specified in **Section 7.2**

7.2 Sample Nomenclature

A sample coding system will be used to provide a unique identification for each sample collected during the Soil Program. This sample coding system will allow for the retrieval of information concerning a particular sample and ensure that each sample and its location are uniquely identified.

To facilitate the use of the PDB and to maintain data consistency for the project, a sample nomenclature scheme has been developed consisting of several PDB fields that are used to identify a sample. Each of these data fields is described below.

- **Location Code** – Each location must be uniquely identified. This field refers to the unique location from which a sample is collected. The property parcel identification number (PPIN) will be used to designate the particular property location along with the lot number. The PPIN will be appended with the UA location within the property. (PPIN = 5512 and a front yard = F01 [Location Code = 5512-F01]). UA designations are provided in **Table 7-1**.
- **Sample Number** – Each sample collected must be uniquely identified. This field refers to the unique sample number assigned to each sample. The sample number will be a combination of the PPIN property and a unique sequential numbering scheme. (PPIN = 5512 and a sequential sample number = C0001 [Sample Number = 5512-C0001]).
- **Sample Type** – Each sample will have a designated sample type that corresponds to a particular type of sample and sample depth. The sample types are identified in **Table 7-2**.

7.2.1 Location Codes

Each location must be uniquely identified. As stated above, the PPIN, and the UA within the property will be used to establish the unique location for each sample. In order to query the PDB for all of the samples from a particular UA, a specific, consistent location code will be assigned to UAs as indicated in **Table 7-1**.

Table 7-1: UA Location Codes

Sample Types	Description
A	Alleyway
B	Backyard
C	Commercial
D	Driveway
F	Front Yard
G	Grid
IA	Inspection Area
L	Left Yard
R	Right Yard
U	Unsamplable Area
W	Rights-of-Way

7.2.2 Sample Numbers

The sample numbering system to be used in the field has been developed to uniquely identify each sample collected. All samples will receive a unique sequential number, including the QA/QC samples, except for matrix spike/matrix spike duplicate (MS/MSD) samples. The MS/MSD samples retain the original parent sample number and are given a distinct sample purpose that is appended to the number.

The field sample coordinator, or other project personnel, can use the unique sample numbers to query sample information in the PDB to sort, track, and guide the sampling activities until each sample task is completed. If planned samples are not collected or unplanned samples are collected,

the field sample coordinator can make adjustments to the sample information and document the final sample list for each sampling task. The unique sample number will be a combination of the PPIN and a sequential sample number that will be specific to the property and the category (composite, discrete grab, water) of sample collected. The sample number will be used sequentially for all the same sample categories collected at a property without regard to the UA location. Examples of the sample number are as follows:

- 4695-C0001-Soil composite sample collected at PPIN 4695
- 4695-G0001-Soil grab sample collected at PPIN 4695

7.2.3 Sample Type

An alpha character designation will be applied for each sample type. The sample types are indicated in **Table 7-2**.

Table 7-2: Sample Type

Sample Types	Description
AC	Soil Composite sample taken from the A interval identified in Table 3-1
BC	Soil Composite sample taken from the B interval identified in Table 3-1
CC	Soil Composite sample taken from the C interval identified in Table 3-1
DC	Soil Composite sample taken from the D interval identified in Table 3-1
AG	Soil Discrete sample taken from the A interval identified in Table 3-1
BG	Soil Discrete sample taken from the B interval identified in Table 3-1
CG	Soil Discrete sample taken from the C interval identified in Table 3-1
DG	Soil Discrete sample taken from the D interval identified in Table 3-1
IW	Investigation Derived Water
WQ	Field QC Water Sample (e.g., equipment rinsate)
UNK	Unknown/Other

7.2.4 Sample Purpose

Another PDB field that is part of the sample identification scheme is the sample purpose. An alpha character description for the purpose of each sample collected is shown in **Table 7-3**.

Table 7-3: Sample Purpose Nomenclature

Sample Purpose Description	Nomenclature
REG	Regular Field Sample
ER	Equipment Rinsate
FB	Field Blank
FD	Field Duplicate
FS	Field Split
CF	Confirmation Sample
MS	Matrix Spike
MSD	Matrix Spike Duplicate
WC	Investigation Derived Water Characterization

7.2.5 Combined Unique Identifier for Sample Name Identification

To ensure uniformity in the sample name identification of all of the samples collected for this sampling task, the following combination of fields will be used:

Table 7-4: Sample Name Identification

			Sample				
Examples	**Location Code**	**-**	**No.**	**-**	**Type**	**-**	**Purpose**
Non-QC composite sample taken from the A interval in a front yard UA	4405-F01	-	4405-C0001	-	AC	-	REG
Non-QC discrete sample taken from the B interval in a backyard that is > 3,600 sq ft and has been sub-divided – this sample is the 3rd discrete sample taken from the property	4509-B02	-	4509-G0003	-	BG	-	REG
Equipment rinsate (ER) water sample identification will not include a PPIN as part of the sample location code, but will use a generic field quality control (FQC) location code	99999-WQ	-	99999-W0001	-	WQ	-	ER
	Where the FQC has been assigned the generic number 99999 for the Project						
Wastewater sample for characterization will include the same generic field quality control (FQC) location code	FQC-WW	-	FQC-W0001	-	IW	-	WC

7.3 Field Data Collection

The PDB will be used to plan each day's sampling activities. A daily work list will be produced to direct each day's sampling effort. Along with the work list, the sample plan and pre-defined sample numbers will be electronically transferred to a FDT which will contain the DFAR and the sample plan.

To the extent practicable, completed sample collection records will be downloaded from the FDT to the PDB at the end of each day's sampling activity. They will be reviewed, approved, and processed in the PDB to produce the analysis request COC (AR/COC) form (example in the QAPP) that accompanies the samples to the laboratory. On the day the samples are shipped, copies of the AR/COC forms will be transmitted to the project chemist and PDB manager for review and tracking. During sampling activities, any variances (changes) to the sampling plan dictated by the actual field conditions will be recorded in the DFAR on the FDT. Both the transferred data and any manually entered data residing in the PDB constitute the complete record of field sampling information for each sample. The field data collection process will be routinely reviewed for completeness and accuracy.

The PDB will also be used to ensure that the frequency for field QA/QC samples specified by the SAP and QAPP will be collected and reviewed.

7.4 Chain-of-Custody (COC)

During field sampling activities, custody of the samples must be maintained from the time that the samples are collected until laboratory data are issued and samples are appropriately disposed. Information for the COC, transfer, handling, and shipping of all samples will be recorded in the PDB. An AR/COC form will be either be printed from the PDB or generated manually to accompany each set of samples from the field to the laboratory.

The field sample coordinator is responsible for verifying the accuracy and completeness of the AR/COC forms for the sample shipment being made. After the samples are shipped, the generated AR/COC forms will be transmitted to the project chemist and the associated laboratories for notification of sample shipment.

The field sample coordinator is responsible for documenting any variance or nonconformance to the SAP with respect to sample collection, preservation, packaging, documentation, and shipment in accordance with GHD's Field Training Manual Section 3.0 for Field Activity Support which is provided in **Appendix A.**

7.5 Laboratory Analysis and Data Deliverables

The laboratory will verify the receipt of the samples with the project quality control manager (QCM) and field site manager (FSM). Any sample integrity problems or discrepancies with the AR/COC forms are addressed at this time. If the issue requires that a location be re-sampled, the QCM notifies the FSM and the project manager (PM) of the problem so it can be resolved. Any problems encountered by the laboratory during the sample analysis program will immediately be brought to the attention of the QCM.

The laboratory data packages will be sent as an electronic data deliverable (EDD) to the laboratory data validation manager (LDVM) for review and inventory. The LDVM will acknowledge receipt of the EDD, review the information contained in the EDD for conformance with the QAPP, and send

the EDD to the PDB manager for data loading. Upon the successful upload of the EDD by the PDB manager, the project team is notified when the electronic portion of the deliverable is ready for evaluation and reporting.

All laboratory data generated will be provided in an electronic format that complies with the PDB specifications. The laboratory will be required to confirm sample receipt and login information. For each sample group, the laboratory will return copies of the completed AR/COC forms and confirmation of the laboratory's analytical login to the field sample coordinator and project chemist in a timely manner after sample receipt.

7.5.1 Receipt of Sample

When the analytical laboratory receives the sample coolers, a receipt of sample form will be initiated. This form will document the sample condition upon receipt. All receipt nonconformance situations will be sent to the QCM and FSM. If required, a nonconformance report will be completed to record the nonconformance and an appropriate corrective action will be implemented to prevent its reoccurrence in accordance with GHD's Field Training Manual Section 3.0 for Field Activity Support, which is provided in **Appendix A**.

7.5.2 Delivery of Data Packages

The laboratory will deliver a complete data package for each sample in either a hard copy or read only electronic format that will allow for the review or validation of the data by an independent organization. The report will have sequentially numbered pages and will contain a table of contents referencing individual sections in the data package, original AR/COC forms, a copy of all corrective action reports, and a case narrative documenting the resolution of all corrective actions and noncompliant events. All Level IV data packages will be assembled in the following sequence:

1. Cover page (with laboratory service identification number and GHD's project name and number)
2. Original AR/COC form
3. Sample receipt form (including cooler temperature)
4. Cross-reference table (laboratory sample number versus field sample number)
5. Case narrative
6. Summary data sheets
7. Raw data
8. Inorganic raw data sequence:
    - Sample results forms, including method blanks
    - QC summaries
    - Initial instrument calibration, daily calibration checks, including all related CCVs
    - Calibration blanks, including all related continuing calibration blanks
    - Interference check standards (A and B for inductively coupled plasma [ICP] only)
    - Sample raw data

- QC raw data
- Post digestion spike results
- Analytical spike results
- Method of standard additions
- ICP series dilutions
- Instrument run log
- Sample preparation log
- Standard preparation log

The laboratory is required to retain a full copy of the analytical and QC documentation throughout the duration of the Project. Such retained documentation will include any hard copies and other storage media (e.g., CD, USB key, mass storage devices, etc.). As needed, the analytical laboratory will make available all retained analytical data information.

7.6 Data Validation

Analytical data will be validated by the LDVM to ensure that method and procedural compliance are achieved and analytical data quality requirements are met. The data will be validated in accordance with the procedure identified in the QAPP.

All validated sample results will be entered into the PDB either by manual data entry or automatic upload during the validation process. The PDB has data fields for both the laboratory and the validation qualifiers, which allows both qualifiers to be retained. The PDB will also accommodate a reason code, which is descriptive information explaining the rationale for applying a particular validation qualifier. All manual data entry is subjected to a QC review to verify the completeness and accuracy of the data entry.

7.7 Data Evaluation

The valid analytical results for TCs will be compared to the CLs in **Table 1-1.** Once the validity and usability of the soil data has been determined, a series of standard and/or custom reports will be generated as required from the PDB for evaluation and reporting.

8. Reporting

Each property owner who participates in the soil sampling program will receive a property sampling report that provides the analytical results obtained.

Within two weeks of commencement of field sampling activities, monthly reports will be submitted to ADEQ. The monthly report will describe project status, including base project statistics and figures.

Upon the completion of the Soil Program, sampling and analytical results will be provided to the ADEQ in a Data Summary Report (DSR). The DSR will contain sampling results figures, tables of analytical data, and a summary of data validation and data quality.

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Appendices

Appendix A

GHD's Field Training Manual and Standard Operating Procedures

- GHD's *Field Training Manual*
  - *Section 3.0 for Field Activity Support*
  - *Section 5.0 for Soil Sampling Standard Operating Procedures*
  - *Section 7.0 for Water Sampling Standard Operating Procedures*

Disclaimer – Please note, Conestoga-Rovers & Associates (CRA) changed its name to GHD on July 1, 2015. The Field Training Manual and Standard Operating Procedures were originally prepared under the CRA name prior to this date.

CRA FIELD TRAINING MANUAL

SECTION 3.0:

FIELD ACTIVITY SUPPORT
STANDARD OPERATING PROCEDURES

(F100)

JANUARY 2011
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Revision 2 - January 3, 2011

PLEASE ADHERE TO THE FOLLOWING QUALITY SYSTEM TRAINING REQUIREMENTS:

- **Employees who are required to conduct a specific field activity must be properly certified to do the work.**
- **This involves reviewing the SOP and completing the online training course and exam.**
- **Employees must also conduct this field work under supervised conditions on at least three occasions, and must be certified by a qualified mentor. Only then can an employee conduct a specific field activity on their own. This is documented on a Field Method Training Record (QSF-021).**
- **A QSF-021 is not required for this SOP.**

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3.0 FIELD ACTIVITY SUPPORT STANDARD OPERATING PROCEDURES

3.1 OVERVIEW

The proper support of all CRA field activities is imperative to ensure that quality field work is performed in a safe, legal, and cost-effective manner at all times. Inadequate field support can and does have a significant impact on the conduct and outcome of our field activities.

All field activities, no matter how short in duration, require some form of support whether it be equipment and supply requisition, field log entry, or coordination for entry onto others' property.

With this in mind, this section presents basic field activity support tasks which are relevant to the majority of the field procedures detailed in this manual.

Due to the "phase" nature of most projects, it is expected that establishing a field site, with all its various support functions, may take place over time and in small increments. This section of the Field Manual should be reviewed, at the detail level necessary, for each phase of the work.

3.2 SITE PLANNING, SETUP, AND SUPPORT ACTIVITIES

Whenever possible, the site should be visited prior to the design of or planning for any field support activity. If a prior visit cannot be accomplished, current topographic mapping of the area or aerial photo imagery (of a usable scale) should be obtained to assist in the planning of and design of support structures or activities. At a minimum, appropriate personnel should be consulted to determine any physical, legal, or logistical obstacles which could hinder or otherwise impact the work.

3.2.1 PERMITTING

The planning process for establishing a field site for the first time or when planning the addition of any new support structure at an established site should include researching the codes, rules and regulations for the jurisdiction in which the work is being conducted. The same applies for planning the conduct of any new field procedure. It is not safe to assume that a particular field activity or aspect of that activity is unregulated. For instance, establishing a temporary entrance onto a site off of a local road for the purposes of installing a well does, in many cases, require special permitting regardless of the duration of the entrance's use. Permit requirements will vary from site to site depending on locale and regulatory constraints (i.e., Superfund sites). Careful review of all substantive requirements with the CRA Project Manager/Coordinator is necessary.

It is impossible to attempt a review of all governing code rules and regulations within this manual. In most cases, CRA's client contact can provide accurate guidance. Where a knowledgeable contact is not available, local code enforcement officials should be contacted. Keep in mind that client confidentiality is

of utmost importance and all such contacts with local officials should be done discretely and in writing with the permission of the client.

The following is a basic list, by category, of notifications, permits, licenses, etc. most often required for the conduct of CRA field activities:

Client Facility and Land Usage

- Site Pass
- Vehicle Pass
- Camera Permit/Pass
- Ignition Source Permit
- Property Pass
- Excavating Permit
- Confined Space Permit
- Hotwork Permit
- Tree/Flora/Fauna Removal Permit

Building and Construction

- Building Permit
- Permit for use of the Right-of-Way
- Road/Bridge Use Permit (generally required when heavy equipment will be moved through built-up areas on a frequent basis)
- Tree/Flora/Fauna Cutting Permit

Site Safety

- Dig Safe Permit
- Electrical Utility Hook-up Underwriters Inspection Certificate
- Certificate of Occupancy (all structures for human occupancy)
- Fire Inspection

Form SP-01 contains a basic checklist of site planning and setup considerations. This form should be completed during the mobilization phase of any field site work.

In many cases, CRA personnel are called upon to coordinate for, fill out and otherwise process permit applications. However, CRA personnel will not sign any applications or other legal documents unless otherwise instructed to do so by the CRA Project Manager.

Proper advanced research and planning should allow sufficient time for applications to be properly executed by CRA clients, client subcontractors, or other responsible individuals.

Where possible, all site permits, licenses, etc. should be visibly posted at the point where all site visitors must enter through to gain access to the site. In most cases, this will be the site contractor's field trailer.

3.2.2 SITE LAYOUT

For site work to be conducted efficiently, safely, cost effectively, and legally, proper layout of the site must be made during the work planning process. Inevitably, the layout of the site, no matter how well planned, will and should change as work conditions require. With this in mind, site planning should be completed in the office as much as practical. Detailed site layout will be completed in the field.

As previously discussed, site topographic mapping or aerial photo imagery should be obtained to assist in the site layout planning process. In most cases, up-to-date site surveying, completed prior to the start of any work, will be available. However, before any second-hand map or photo source is used for site layout planning, the credibility of the map/photograph must be confirmed. The credibility of the map/photograph source is defined by its accuracy and its date of production. Boundaries which may appear obvious on a second-hand map/photograph source should not be utilized for planning until they are confirmed.

There are times when a site sketch my need to be developed. In these cases, the following guidance should be utilized:

- Put a north arrow on the sketch (up on the page)
- The sketch is not to scale, but it should be proportional
- Sketch in and label all features which can impact our work or access to the site, including pavement, curbs, guard rails, fences, ditches, storm drains, manholes, meter boxes, existing wells, debris, power poles, sign posts, overhead utilities, roads, and streets adjacent to the site

Underground utilities are often difficult to locate with certainty. Look for tell-tale evidence, which may include:

- Water meter
- Sewer cleanouts in pavement
- At-grade electrical transformers
- Patches of new pavement
- Storm drains
- Manhole covers

- Assume that there are underground utilities in public road rights-of-way until proven otherwise
- A typical field-drawn sketch is included as Figure 3.1

The following subsections provide a generic list of site layout planning topics.

Vehicle Access and Parking

1. Access to the site should be made off of all rights-of-way by proper permitting
2. Access across the right-of-way should be properly posted from both directions and not disrupt any existing drainage along the right-of-way
3. Consideration should be given to the future use of the access in terms of vehicle weight, width, and height
4. Future requirements for two-way traffic should be considered
5. Turn-around swings of large vehicles should be considered
6. The effects of weather on roadways and parking surfaces should be considered
7. Size and location of personnel vehicle parking areas should be off site or away from heavy equipment traffic

Support Facilities

The following items should be considered:

1. Local pickup for site power and telephone should be made with respect to the location of site trailers and other facilities requiring power
2. Location of site office trailer such that all site visitors are easily directed to and through the trailer to gain access into the site
3. Locations of storage areas for hazardous chemicals
4. Location/size of vehicle decontamination pads
5. Location of non-hazardous waste storage
6. Location of drum staging area/construction for security and accessibility
7. Area lighting for support zone

3.2.3 SITE SECURITY

It is of the utmost concern that security and safety issues related to any field work which CRA undertakes, supervises, or oversees be evaluated. Proper planning/evaluation of these issues will ensure that the safety of site personnel and the general public, as well as the interest of CRA and our clients, are safeguarded. No site or site activity is too small to have its security and safety issues reviewed.

In many cases, CRA has no direct role in the planning or implementation of site security and safety matters. However, it is every CRA employee's responsibility to bring site security and safety deficiencies to the attention of responsible parties. All such notifications should be made in writing. At a minimum, verbal notification should be given with proper notation in the CRA daily field log.

Regardless of the phase of work being undertaken, the following are the generic considerations which should be reviewed for all work sites.

Security

1. Perimeter fencing is required where pre-existing conditions or future work conditions create any form of hazard to the general public
2. Fence construction must be sufficient in extent and materials for the level of security required
3. Warning signs must be posted on the site's perimeter to notify the general public
4. When site perimeter fencing does not extend to the access point of the site off the right-of-way, a site access gate/chain should be installed and posted
5. All keys to the site and its support facilities should be properly marked and maintained only by designated personnel
6. Adequate temporary barriers and signs should be available when perimeter fencing is temporarily removed for work
7. Area lighting should be utilized around support facility structures and storage areas to deter theft
8. A site sign-in log must be maintained to record the time of personnel entrance and exit
9. When site work is of short duration and does not warrant the installation of secure storage areas, alternate off-site storage should be arranged for CRA equipment
10. Notify local law authorities of activities to be conducted

Safety

1. The site-specific Health and Safety Plan (HASP) must be reviewed by all site personnel prior to entering the site.
2. All hazardous equipment and chemicals must be properly labeled and securely stored when not being used.
3. All personnel on site must have documented proof of training and medical surveillance as specified in the HASP. Such documentation must be maintained on site at all times.
4. Some form of emergency communications with local emergency response agencies must be available (i.e., cellular phone).
5. First aid equipment sufficient for the anticipated site hazards and number of personnel must be available (household first-aid kits do not generally satisfy this condition; commercial type kits are required). First aid kits must have a documented inspection weekly.

6. All new site personnel and visitors must receive adequate familiarization/training with the site HASP and sign-in acknowledging receipt of such training.
7. A site sign-in log must be maintained for personnel accountability in the event of a site evacuation.
8. Daily Tailgate Safety meetings must be conducted and documented in the HASP. At a minimum the Tailgate Safety meeting must include a review of the site conditions, weather consideration, the relevant topics from the HASP and a detailed review of the job.

3.2.4 SITE MAINTENANCE AND APPEARANCE

Proper site maintenance is indicative of a site which is properly supervised and safe. Additionally, the larger the work force on site, the more usage the site facilities receive, thus requiring more frequent maintenance.

CRA and contractor personnel must include site maintenance in the scope of the daily and weekly site activities.

Adequately sized storage areas should be provided for all equipment and supplies on site.

Personnel waste including Personal Protective Equipment (PPE) and clean site debris (i.e., cardboard boxes, packing materials, etc.) should be deposited in waste containers supplied by a local vendor. Waste containers should be clearly marked, "**NO PPE**". For some projects, the waste profile for the site will include PPE as a part of the waste profile. In these instances, the PPE can be commingled with the site wastes for off-site disposal. Stockpiling of bagged trash in open piles should be avoided. If waste materials are to be removed from the site by the contractor, the disposal facility being used should be noted in the field log.

Spent PPE must be disposed of in clearly marked containers intended solely for this purpose. Care must be taken to ensure PPE is not removed from the site by unauthorized haulers.

Contractors must be closely supervised to ensure that the site is kept free of food waste materials and personnel waste on a daily basis. Daily site waste trash must be cleaned up daily and stored appropriately to avoid rodents/animals. No less than weekly, a representative from CRA and the site contractor(s) should conduct a site inspection to ensure site facilities are in good order and that the site is free of unwanted debris.

3.3 SITE SUPPORT FACILITIES

3.3.1 GENERAL

The following section provides general guidance for the setup of various common site support facilities. The specific configuration of each facility will vary based on the nature of the site work, available space, and the intended duration of its use.

3.3.2 OFFICE TRAILER

CRA and contractor trailers should provide a clean and organized area where coordinating, planning, and recordkeeping activities can be carried out free of disturbances.

All visitors to the site will at some point enter the site office trailer. The trailer's appearance often provides visitors with their first impression of the site work. With this in mind, trailers should be kept clean and orderly at all times.

The following list contains general guidance for setup of site field trailers.

1. Trailers partitioned to include office space and storage space should be used and provide security should the office area be shared with others
2. Trailer should be equipped with a phone, trash container, chairs, lighting, and heating if winter work is anticipated
3. Emergency telephone numbers must be clearly posted adjacent to the phone Numbers posted should include fire, police, rescue, hazardous spill response, as well as CRA's incident hotline
4. Trailers should be installed on a stable base and properly leveled and should include points of safe access (e.g., hand rails, stairs, ramps)
5. Under no circumstance will unqualified personnel complete power wiring to the trailer
6. Trailer interiors should be organized to include areas for storage of supplies and personal property
7. Each trailer must be equipped with an ABC-rated fire extinguisher and first aid kit

3.3.3 DECONTAMINATION PAD

At all field sites where equipment and vehicles may come into contact with known or potentially hazardous substances, a decontamination pad will be constructed.

The purpose of the equipment decontamination pad is to remove and capture all known or potentially contaminated site soils from the tires/tracks and chassis of all vehicles exiting the site.

The size and durability of the decontamination pad will be determined by the size and weight of the equipment being used as well as the duration, location, and season of the work.

Most commonly, the decontamination pad is placed in line with the gate separating the Exclusion Zone (EZ) from the Contaminant Reduction Zone (CRZ). At sites where vehicle-borne soils and potential contaminants are expected to be minimal and no CRZ exist, the decontamination pad may be placed in line with the gate separating the Support Zone (SZ) from the EZ/work area.

Figure 3.2 outlines the components of the various decontamination pads for light, medium, and heavy duty applications; Figures 3.3, 3.4, 3.5, and 3.6 show examples of these various decon pads.

In general, equipment decontamination pads should be installed and operated under the following guidelines:

1. Sized for the width and weight of the heaviest equipment expected, leaving sufficient room for decontamination equipment, personnel, and waste fluid storage drums.
2. Provide an impermeable barrier capable of containing all decon liquids.
3. Durably constructed to withstand the wear and tear of equipment tires/tracks.
4. Provided with a low point sump where all decon fluids can be collected and pumped out.
5. Be constructed such that a minimum amount of materials will require special disposal when the decontamination pad is decommissioned. The use of granular fills or stone as the primary load bearing surface should be avoided.
6. The length of the decontamination pad need not be sufficient to contain the entire vehicle. The vehicle can be decontaminated in sections as it passes over the pad.
7. If possible, vehicle access into the work zone should be made around the decontamination pad rather than over it. This will reduce the wear and tear on the pad. If such access is made possible, the pad should remain blocked whenever it is not in use.

3.3.4 DRUM STORAGE AREAS

Wastewater containing detergents and or solvents will be generated at all field sites where the decontamination of heavy equipment, personnel, or sampling equipment will take place. These fluids must be collected and stored until they can be properly disposed of. When waste fluids are collected and stored in drums, such drums must be staged within an area which provides secondary containment for the drums. Most often a temporary or permanent type drum storage pad is constructed for this purpose.

The storage pad's primary purpose is the containment of all fluids which may inadvertently be released from the drums due to spillage during handling or rupture of the drums. Rupture may occur due to thermal expansion or an increase in the drum's internal pressure due to a reaction of the drum's contents.

At field sites located in built-up areas such as industrial zones, existing structures may offer adequate containment for the drums with a minimum of modification. The use of existing structures may prove to be cost effective. If existing structures are used, they should be configured and operated to the minimum standards listed below.

Figure 3.7 illustrates the construction of a typical drum storage pad.

In general, a drum storage pad should be installed and operated under the following guidelines:

1. Pads should be sized with the following factors in mind:
   - Drums must be stored on standard pallets
   - A walk-way 2 feet wide (minimum) must be left between pallets
   - Unless drum handling equipment has sufficient reach to remove any drum within the pad when it is operating from outside the pad, room must be provided within the pad for equipment access
2. Pads must provide containment of all fluids which could be stored within the pad
3. If equipment access is provided over the pad's perimeter wall, the wall must be capable of supporting the vehicles weight, even with repeated usage
4. The floor of the pad must be durable enough to withstand the movement of drums, pallets, heavy equipment, and personnel over the course of a yearly freeze-thaw cycle
5. The pad should slope to a low point "sump" where spilled fluids can be easily collected
6. Precipitation must not be allowed to collect in the pad; some form of structure or device should be installed around/over the pad to allow for easy and secure installation of a protective tarp capable of covering the entire pad, regardless of how many drums are on the pad
7. Protective tarps must be inspected often for rips and tears
8. Pads must be properly barricaded and posted to prevent unauthorized entry
9. Drums must be stored within the pad on wooden pallets, maximum four drums to a pallet
10. Drums should be positioned on the pallet such that the bung or lid clamp bolt are facing to the outside for easy access
11. Pads should be constructed using a minimum of imported fills or other materials (e.g., synthetic liner) which will have to be disposed of after use

3.4 SUPPORT FUNCTIONS

3.4.1 FIELD NOTES

All field work activities performed or overseen by CRA field personnel must be accurately recorded in bound field log books (preferred), Quality system Field Data Forms (QSF-200, 400, and QSF-500 Series D), or in some other CRA-approved format (i.e., electronically, loose paper).

Field notes will be used in the compilation of project reports, assist in various design activities, and provide a legal record of the work.

Although CRA uses a number of different types of formats to record field notes, all share certain common information and usage requirements. These are (and not limited to):

1. Field notes must be neat, legible, and detailed.
2. Information must be factual and complete.
3. Date, name, and project number must be on all documentation.
4. Weather conditions.
5. All pages must be consecutively numbered.
6. Names of personnel performing sampling or measuring.
7. Times of personnel arrival and departure.
8. Sample collection/measurement locations, performance of sample collection, and general visual observations of samples collected (i.e., colour, visual/olfactory evidence of contamination, turbidity, sediment presence, sheen/product presence, etc.)
9. Field measurements collected.
10. Factual descriptions of site features such as buildings, utilities, creeks/streams, site construction, etc. If necessary, sketches of property layout.
11. Variations in work completed to Scope of Work and why.
12. Be objective; keep your personal feelings off of the notes, do not make slanderous statements.
13. Reference to CRA equipment control number. If field equipment is rented, record the name of the rental company, serial number, and reference to the certificate of calibration.
14. Field calibration of equipment, including lot numbers and expiry dates of gases/solutions (if required).
15. Errors must be lined out with a single line, initialed, and dated.
16. At the end of each day, any remaining space on the page should be "closed out" by crossing out the space and signing your name.
17. Each day's work must start on a new page.

In order for field notes to be used and easily interpreted by various individuals within CRA, they must have common formats regardless of which office the work is being supported from. Examples of the following standard field notes have been included as Figures 3.8 through 3.14.

It is understood that in many cases field projects have needs which require variations in the format and extent of the information recorded.

At sites where CRA personnel rotate support time, field books should be handed over in person or secured in a location accessible by multiple/controlled keys.

Section 3.7 provides additional guidance with respect to the transfer of work responsibilities between CRA personnel.

Whenever work is completed, send field notes (or copy) and/or QS documentation to the Project Field file. Communicate to the Project Coordinator or Project Manager that the field notes are in the Project Field file and provide key details of field activities.

3.4.1.1 GROUNDWATER, SURFACE WATER, DOMESTIC WELL SAMPLING LOG

The groundwater, surface water, domestic well sampling log provides a common format for recording the specific field measurements and quality assurance measures used when collecting these types of samples.

Figure 3.8 shows a typical water sample log entry.

3.4.1.2 PHOTOGRAPH LOG

Certain field projects require regular photographic documentation of all aspects of the project or key portions of the project. The Project Manager/Coordinator or field personnel should obtain approval from the client regarding their policy with respect to photographs at the site. Whenever a large volume of photographs are generated, or as required by certain Work Plans, a photograph log must be used to record data for each photograph. Section 3.6 outlines the recommended photographic documentation procedures for field activities.

In many cases, photographs can be documented directly in the daily project diary using the same information requirements specified in the example photograph log.

The CRA Quality System addresses photograph filing and storage procedures within the Filing of Project-Related Material Work Instructions (QSWI-004).

Figure 3.9 shows a typical photo log entry.

3.4.1.3 DRUM LOG

The drum log provides a common format for recording the observations and safety monitoring measurements made during the conduct of drum removal activities, as well as tracking the drum's handling from discovery to final disposition.

The drum log can be used for recording surface or subsurface drum investigative activities.

Figure 3.10 shows a typical drum log entry.

3.4.1.4 DAILY PROJECT DIARY

The daily project diary is used to record a detailed description of the sequence and nature of all work performed on the site each day work is conducted.

The daily project diary is generally not used for recording detailed field measurements/readings but may be if no other field log format is suitable for such data.

The daily project diary focuses on personnel, equipment and material quantities, safety, all significant events and all other matters of financial or legal concern to CRA and its clients, etc.

Other than a few common headings within the daily project diary, entries can be made in a "free format".

Figure 3.11 shows an example of a typical project diary entry.

3.4.1.5 TEST PIT LOG

The test pit log provides a common format for recording the observations and air monitoring measurements made during the conduct of test pitting activities.

Test pit log section diagrams need not be artist renditions but should be neat and use common symbols to represent the vertical and horizontal features of the pit.

Figure 3.12 shows an example test pit log entry.

3.4.1.6 SAMPLE LOG

The sample log provides a single location where sequential entry of all samples, regardless of matrix, can be made.

The sample log provides a means of easily tracking the sample's number, date, time, source, sampler, and analysis required for every sample collected throughout the duration of the work.

The sample log provides a quick reference source to determine the Quality Assurance/Quality Control (QA/QC) sample preparation frequency.

Figure 3.13 shows an example of a typical sample log entry.

3.4.1.7 BOREHOLE/SOIL/SEDIMENT SAMPLING LOG

The borehole/soil/sediment sampling log provides a common format for recording specific field measurements, observations, and quality assurance measures used when collecting any soil/sediment sample.

Figure 3.14 shows a typical soil sample log entry.

3.5 FIELD EQUIPMENT

CRA has an extensive inventory of field equipment for monitoring, sampling, transportation and health and safety related activities. Prior to setting out for a field activity, it is very important that prior planning of the equipment needs be undertaken and appropriate selections and arrangements made. The following sections outline the protocols and procedure guidelines for field equipment acquisition, use, return, and care.

The control and administrative procedures for field equipment are described in detail in Section 7.6 Control of Monitoring and Measurement Equipment of the CRA Quality System Manual.

3.5.1 AVAILABLE EQUIPMENT - INTER-OFFICE INVENTORY

Appendix A - Section 1 presents a summary of the CRA Interoffice Equipment inventory and the respective charge-out rates for each item. These rates have been established and standardized for both the U.S. and Canadian offices. Yearly updates of these inventories and charge-out rates will be issued to each CRA office and distributed accordingly to the appropriate personnel.

In addition to the capital equipment listed in Appendix A - Sections 1, 2, and 3 present the typical inventories held at CRA offices for personal protective equipment and field supplies. Charge-out rates differ from area to area for expendables and, as such, U.S. and Canadian rates have been developed.

In order to assist field staff in properly preparing for various projects, CRA-Waterloo has assembled a number of prepackaged kits associated with specific field equipment and for specific field oversight roles. The purpose of the kits is to provide all reasonably foreseeable parts/supplies needed for the proper operation of the piece of equipment you have requisitioned (i.e., calibration equipment, tubing, expendables, etc.). Also included in the kits will be basic tools and spare parts that will allow you to perform minor repairs and servicing. Equipment in need of major or complicated repairs should be arranged in conjunction with the Field Equipment Manager. This should be taken care of at the time that replacement equipment is ordered from the Field Equipment Manager. Use of these kits should ensure

that CRA field personnel are properly equipped and can professionally complete the assigned tasks. Lost time due to improper preparation is inexcusable and will not be tolerated by CRA or its clients.

Kits that are available include the following:

1. Pump Kits for Groundwater Sampling (each type of pump is outfitted differently)
2. Hydraulic Monitoring Kit
3. Drill Rig Supervision Kit
4. Photoionization Detector (PID) Kit
5. Groundwater Stabilization Kit
6. Flow Meter Kit

It is to be noted that not all offices will have all of the above-listed kits available. Only those kits that have an identified need in each office will be available.

3.5.2 EQUIPMENT REQUISITION PROCEDURE

Once the equipment needs are identified, an established simple procedure of equipment requisition is to be followed to permit equipment tracking, preparation, and charging.

This procedure involves having the requisitioner complete the Field Equipment Requisition Form (QSF-014), having it initialed by the Project Coordinator and forwarding it to the Office Field Equipment Manager. QSF-014s can be located under the Quality System tab of My Portal.

The Field Equipment Requisition Form (QSF-014), must be filed with the Office Field Equipment Manager, for equipment scheduling.

Apart from the information in the header, including the proper "branch" name, the requisitioner enters the following for each item:

- Description
- Quantity ordered

It is imperative that the description of the items ordered match exactly with the descriptions of items provided in Appendix A. This will ensure that:

- The proper items are arranged (especially important when more than one type of an item is available)
- CRA's clients understand what equipment and the quantities that have been used on their job. (CRA's clients often receive photocopies of the Field Equipment Requisition Form/charge-out sheets with their invoices from CRA)

For projects where lots of cased supplies have been ordered on the Field Equipment Requisition Form (QSF-014), the number of units in a case must also be recorded, again for proper accounting of the charges to clients.

For larger jobs it is requested that, to the extent practicable, supplies be ordered directly from the supplier on a job-by-job basis. This provides CRA's clients with a clear understanding of the supplies ordered/consumed for their project since they will then receive an actual copy of the supplier's invoice to CRA.

The Field Equipment Manager readies the requisitioned items, ensuring that they are in good working order, and hands them over in time to meet the stated "Job Date". The Field Equipment Requisition Form (QSF-014) is then filed in an "Open Requisitions" file, until the items are returned.

If a requisitioned item is not available in the branch, the Field Equipment Manager may source it from another branch. After checking its availability, the Field Equipment Requisition Form (QSF-014) is faxed to the providing branch, which will send the item(s) to the requesting branch via Federal Express or other appropriate delivery service. The providing branch documents all loan information, including the name of the receiving branch.

3.5.3 EQUIPMENT RETURN/REPAIR PROCEDURE

Upon return of the items, the Field Equipment Manager dates and signs for receipt at the bottom of the form. At least twice per month, and not later than the 21st day of each month, the Field Equipment Manager prepares requisitions of returned equipment for accounting/billing purposes.

Equipment loaned to other branches will be returned after use to the providing branch, again by Federal Express or other appropriate delivery service. If an item needs repair or maintenance, it is the providing branch's responsibility to have the item repaired and to document the recovery and repair costs of that particular item.

It is also the responsibility of the providing branch to ensure that the charges are being billed to the client and to receive credit for equipment use. The name of the providing branch must therefore be entered on the Field Equipment Requisition Form (QSF-014) prior to it being sent to the Accounting Department.

Note:	*Items which have to cross the U.S./Canadian border will need Customs documentation (green ticket, in the case of equipment of Canadian origin) which may delay its forwarding to the requesting branch.*

The Customs documentation must stay in the equipment case at all times. When the item is returned across the border, it must be accompanied by this Customs document.

Equipment must be decontaminated **before** removal from the site to ensure that chemicals are not transferred to other sites. It is the responsibility of the person who requisitioned the equipment to ensure appropriate cleaning before returning the equipment. Equipment decontamination procedures are typically site specific for unique site compounds. Failure to appropriately clean equipment and return equipment for others to use can have **disastrous** effects on other programs.

Note:	*Equipment Decontamination cannot be performed at the CRA offices since CRA does not have the proper facilities for decontamination and has no way to properly dispose of/treat the spent decontamination fluids (it would require CRA to become a waste generator). CRA field personnel who fail to comply with this requirement may be terminated from CRA employment.*

If repairs to, or maintenance on, an inventory item are required after use on a job site, the requisitioner must return the item and attach a red label, as shown below, (labels provided in equipment return area). The requisitioner identifies the user on the red label. The Field Equipment Manager will contact the individual identified, and will provide any necessary service or repair to the equipment.

CRA

Equipment Requires Servicing
DO NOT USE

Name: _____

The Field Equipment Manager initiates the required action, documents any necessary information in the Field Equipment Manager's file, and returns the equipment to the storage area for future use.

The Field Equipment Manager will be responsible for tracking equipment performance and repair costs to evaluate future equipment purchases and determine the appropriate charge rates for recovery of capital and maintenance costs. Personnel utilizing equipment are encouraged to provide feedback regarding equipment operation, whether positive or negative.

3.5.4 EQUIPMENT CALIBRATION AND MAINTENANCE

Equipment calibration and maintenance will be performed by the Field Equipment Manager at the respective CRA office prior to release for field use. The responsibilities of the Field Equipment Manager for each CRA office are described in detail in the Inspection, Measurement, and Test Equipment Work Instruction (QSWI-003) of the CRA Quality System Manual. In the event that equipment utilized requires frequent calibration or the equipment used is for an extended period away from the branch office, it will then be the responsibility of the person who requisitioned the equipment to ensure proper calibration and maintenance. In most cases, this can be simply accomplished by returning the equipment to the administrator for regular maintenance. A white label is attached to every piece of CRA-owned equipment, identifying when the next calibration/maintenance is due. Calibration and maintenance can

only be performed by following manufacturer's guidelines, which will accompany all equipment when requisitioned. A complete file of owners" manuals is also maintained by the Field Equipment Manager.

When utilizing analytical equipment which requires frequent calibration, such as a pH meter or organic vapor analyzer, it is essential that a record of calibration be kept, documenting each calibration event and the results obtained. For small programs, the calibration record must be kept in the Field Log Book (as described in Section 3.4.1). On larger programs, a log book dedicated to calibration records may be warranted. Quality System Field Data Record Forms (QSF-200, 400, and 500 Series PMC) are also available to record field calibrations.

Equipment care is generally guided by common sense (i.e., regularly check oil levels) or, in many programs, is a mandatory aspect of the Quality Assurance Project Plan (QAPP).

Equipment rental from outside sources must also be handled in a manner which is consistent with CRA's existing policy, ensuring cleanliness upon return and following appropriate calibration/maintenance schedules. When renting equipment, it is important to initially evaluate the equipment received to determine proper operation (quick return is critical if equipment is not operating correctly) and to note existing damage/condition of rental equipment. Equipment rental may be arranged through the CRA Field Equipment Manager to acquire and return rental equipment (or by CRA personnel themselves when location or timing dictates). Procedures identified in Section 7.0 of the CRA Quality System Manual should be followed when renting equipment.

When CRA personnel arrange rental equipment themselves, reimbursement for payment and invoicing to the client is accomplished by entering the rental invoice on your weekly timesheet (expense section).

3.5.5 EQUIPMENT TRANSPORTATION AND SHIPMENT

CRA's policy, at this time, is to ship equipment via Federal Express, UPS, or Purolator-type courier utilizing the appropriate delivery options available. Overnight delivery in some cases may be necessary, but it is more appropriate and cost effective to utilize regular 2-day service, thereby avoiding costly rush deliveries.

The person sending equipment is responsible for proper packaging and protection for the shipping event. Common sense dictates that fragile/glass components must be well cushioned and protected accordingly. Equipment administrators or office personnel designated for shipping will perform the shipping tasks when required and pack equipment properly. To the extent practicable, the kits for equipment will be custom designed with cushion packing to eliminate/minimize the use of loose packing material (e.g., styrofoam peanuts).

Flammable, corrosive, or shock-sensitive materials, fuels, calibration gases or solvents/acids must NOT be shipped via common courier (e.g., Federal Express), unless special arrangements and documentation

(i.e., Hazardous Material Shipping Manifests) have been prepared. Alternative arrangements can be made for shipping sensitive materials. These are:

- Ground transportation via local courier, with appropriate labeling/bill of lading
- Employee acquisition and transportation, once at the project area
- Distribution or delivery, once at the project area
- Have materials arranged through CRA's client

The regulations/laws differ from state to state, province to province, and country to country regarding shipping/transportation labeling and documentation. Local Field Equipment Managers and/or office shipping personnel will advise or direct inquiries to the appropriate resources regarding special shipping needs. When shipping instruments or equipment, the operation/calibration manuals will be included as part of the kit.

Note:	*All CRA shipped Goods (i.e., Equipment) and Services (i.e., Reports) are covered under CRA's General Insurance Carrier. When shipping items via Federal Express, it is required to list the "Declared Value for Carriage". This amount is typically $100 or less ($100 is the maximum amount for damage or loss per shipment that Federal Express is liable for). Reporting Declared Values above $100 is not required, and will incur additional charges.*

3.5.6 SECURITY/KEY CONTROL

CRA vehicles and/or equipment, when on loan to CRA personnel, should be kept locked or in locked areas when unattended or not in use for extended time periods. CRA personnel who requisition equipment or vehicles are responsible for the care and return of the equipment or vehicle allocated.

Equipment marking/encoding to identify that the equipment is CRA owned will be performed by the Field Equipment Manager.

Keys for CRA vehicles and equipment will be controlled by the respective Field Equipment Managers for each office. Duplicate keys will be stored at the respective CRA office which maintains/controls the equipment/vehicle. All keys and key duplicates will be tagged, showing the appropriate information for identification.

Each CRA office will maintain a key box to secure keys and key duplicates. The Field Equipment Manager will be responsible for security of the office key box.

All site keys will be duplicated as soon as practical after installation of any lock. Duplicate key sets will be distributed under cover letter to any outside organization whom it is deemed necessary to have such a key set. All keys will be properly tagged with durable tags on which can be placed site, key #___ of ___ and lock name data. Keys will be placed on a durable key ring.

Keys will be provided to the Field Equipment Manager as soon as possible after completion of the work. If required, the Field Equipment Manager will re-tag the keys with permanent, standardized key tags if necessary.

If a lock must be cut off, it is imperative that all keys sets be updated as soon as possible so as to avoid confusion and delay by other CRA personnel or outside organizations at a later date.

3.5.7 EQUIPMENT USE BY OTHERS

CRA vehicle or equipment use non CRA employees is not permitted. Only CRA personnel are permitted to requisition and use CRA owned equipment. Insurance coverage only applies to CRA personnel.

3.5.8 VEHICLE RENTAL

CRA's policy at this time regarding vehicle rental is that, whenever practical, CRA personnel will use personal vehicles and claim the appropriate mileage expenses on the weekly timesheet. When the use of personal vehicles is not practical (i.e., flying to the location of the work site or the requirement of a different type of vehicle, e.g., box van), the following rental policies will apply:

- The vehicle, with the exception of when a special vehicle (e.g., box van) is required, will be a compact automobile (upgrades will be at the personal expense of CRA personnel)
- When multiple CRA personnel are working at the same site, vehicle rentals will be minimized to the extent practical
- When possible, the gasoline tank of the rental vehicle will be filled just prior to returning the vehicle to the rental agency (gasoline prices charged by rental agencies are often exorbitant)

Arrangements for rental vehicles are the responsibility of individual CRA personnel. Reimbursement of vehicle rental costs and invoicing to the client is accomplished by attaching the original rental invoice to the weekly timesheet.

Upon receipt of the rental vehicle, CRA personnel will thoroughly inspect both the interior and exterior of the vehicle and report any damage to the rental agency and ensure that such damage is noted on the rental agreement, initialized, and dated by an agent or representative of the rental agency prior to leaving the agency lot.

CRA currently has discount arrangements with most major vehicle rental agencies.

Recent changes to CRA's insurance policy, with respect to vehicle rentals, do not require either Canadian or U.S. CRA personnel to purchase the ADI or AWI insurance coverages offered by the rental agencies.

3.5.9 EQUIPMENT PURCHASES

When a capital asset is required for a project, or as a result of a general demand, the Field Equipment Manager will initiate the acquisition. The purchase orders for the purchase of capital equipment are issued by the Accounting Department in Waterloo, and approval is documented on the Purchase Requisition Form A or B (depending on cost). Purchase Requisition Forms are located under documents within the Contracts tab of My Portal. Non-capital assets and field supplies are purchased by the Office Field Equipment Manager, as required, upon approval from the Branch Office Manager. All purchases must be documented, using the Purchase Order Form (QSF-024) or another format.

After the acquisition of a new Capital asset, a copy of the invoice and the new log sheet must be sent to the Purchase and Maintenance Group in Waterloo by the Field Equipment Manager. The proper charge-out rates will be established and the central inventory list will be updated by this group. These updates will be distributed to the branches on a yearly basis.

CRA personnel can purchase equipment when required for project field activities or operations. The procedures for purchasing goods and services are described in Section 7.4 (Purchasing) of the CRA Quality System Manual. Approval for such purchases must be obtained from the Project Manager who will consult with the client.

3.6 PHOTOGRAPHIC DOCUMENTATION

3.6.1 GENERAL

Project Manager and/or field personnel should obtain approval from the client regarding their policy with photos/videos of their facility. In addition to the log book entries specified for various field activities, photographic documentation may be required. Photographic documentation should never be the sole means of documenting any field activity due to the potential for unrecoverable film damage, exposure, etc. If done properly, photographic coverage can greatly enhance report preparation, and the resolution of potential financial/legal matters. The CRA Quality System addresses photograph filing and storage procedures within the Filing of Project-Related Material Work Instruction (QSWI-004).

At a minimum, photographic documentation should be made of the following subjects:

1. Whenever specifically called for as part of the documentation process for a specific Field Procedure
2. If any uncorrected field condition or action originating from site contractors or other on-site parties which is unsafe, illegal or in conflict with a published document (CRA or client) for which CRA is tasked with enforcing
3. The chronological progress of all construction activities

4. Panoramic views of the site depicting the site layout both prior to mobilization, during the conduct of work, and upon permanent or temporary demobilization from the site

3.6.2 USERS OF CAMERAS

Only high quality cameras should be used. Unless it is otherwise unavoidable, standard throw-away type cameras should be avoided.

When requisitioning a camera from CRA inventory or purchasing one specifically for a job, ensure that the camera has the following minimum features:

- Date-package
- Auto-exposure
- Auto-flash
- Weather resistant
- Auto-rewind
- An automatic or semi-automatic lens shield

If available and not inordinately expensive, cameras with zoom capability are useful.

Each photo should be documented in the photo log as specified in Section 3.4.1.2. However, to insure that the subject of every photo can be easily identified at a later date, a data placard should be held in the field of view when taking each photograph. A small wipe-off dry marker-type "memo board" can be purchased at most office supply stores and is well suited for this task. If possible, choose a non-white board since a white one will reflect the cameras flash and "wash-out" the data on the board. Use the thickest black dry marker available.

Information written on the data placard should include: the direction you are facing, subject name (i.e., "TP-01" for test pit number one) and the date, if your camera does not have a date package.

Every picture taken on each roll should be logged no matter what the subject or quality of the photo is. This is necessary to preserve the "chain-of-photographs" in the log book.

Advance consideration should be given to camera protection, operation, and loading/unloading when one will be used inside a site exclusion zone. Nitrile or other heavy outer gloves can make camera operation difficult as well as interrupt the field of view or the camera's sensors.

When extended periods inside the site EZ are anticipated, the amount of film required should be estimated. In some cases, two pre-loaded cameras may be necessary to avoid having to unload/load a camera wearing gloves. This also applies to conditions which could contaminate the interior of the camera during loading/unloading.

When working in areas of known contamination potential where full decontamination of all personnel and equipment is mandatory, some means of protecting the camera must be devised. In some cases, the disposable type "waterproof" cameras can be used.

Immediately upon removal from the camera, every roll of film must be marked with the roll sequence number. If the film tab has not been fully retracted by the camera during rewinding, manually retract it so that the film cannot be accidentally reloaded and double exposed.

Exposed film must be given the same security and confidentiality considerations as project log books. However, exposed film must be given additional physical protection to insure it is not damaged by exposure to water or excessive heat.

All film should be developed as soon as possible so that exposure quality can be checked. Photographs should be developed in duplicate in the 3 1/2 by 5-inch format.

3.6.3 VIDEO PROCEDURES

Video documentation applies to the same subjects as noted above.

Video documentation is better suited for the continuous documentation of a site activity, a site panoramic visual record and where a voice narrative in necessary. Video documentation has the distinct advantage of allowing for advance testing of the equipment as well as the opportunity to check/re-record images immediately after filming.

In most situations, video cameras will be used on internal power. Sufficient battery packs should be charged and on hand for the anticipated amount of daily filming.

As with still photography, photograph logs and data placards should be used. When filming, the date/time and elapsed film time should be on display in the view finder.

Since video records will generally involve movement of the camera with frequent stops and starts in the filming of a single activity/subject, care must be taken to properly note the change in subject, viewing direction, etc. This is best accomplished by using the audio recording capabilities of the equipment. To check the audio portion of the video in the field you will require an inexpensive set of stereo headphones.

As with cameras, advance planning considerations for the use of video equipment in a site exclusion zone include equipment protection and operation.

Used videos must be given the same security and confidentiality considerations as project log books. However, videos must be given additional physical protection to insure they are not damaged.

3.7 TRANSFER OF FIELD SUPERVISORY/OVERSIGHT RESPONSIBILITY

Whenever circumstances call for a change in the CRA personnel providing field supervisory or site oversight responsibility at any site, proper transfer of site-specific information is essential. Untimely or incomplete transfer of critical site information can result in duplicated efforts, conflicts with previously issued instructions, and improper conduct of the work. Every effort must be made to provide sufficient advance notification to potentially substitute personnel to allow them to properly prepare for their duties.

The Transfer of Field Supervisory/Oversight Responsibility Checklist (Form SP-04) provides a basic checklist to be used whenever the transfer of work responsibility is required. Whether completed by phone, in person or by written correspondence, current site personnel should provide the applicable information and materials noted on Form SP-04 to substitute personnel. Completion of the form by third parties for the current site personnel should be avoided as this tends to dilute the quality and quantity of information.

3.8 ACCURACY, PRECISION, UNCERTAINTY, AND SIGNIFICANT FIGURES

Much of CRA's work involves measurements of some feature or parameter (e.g., distance, depth, meter readings, etc.), interpretation of those measurements, and presentation of the data. Interrelated, but separate, factors (accuracy, precision, uncertainty, and significant figures) are also involved; and are important to understand at the field level and the office level where the data may be utilized in a calculation. This section is not intended as a mathematically rigorous development of the concepts of accuracy, precision, uncertainty, and significant figures; rather it is an introduction to underscore the importance of properly representing the data which has been collected. These factors can be summarized in concept as follows:

- **Accuracy:** The closeness of a measured value to the "true" value. As an analogy to throwing darts, accuracy is how close a dart lands to the bulls eye.
- **Precision:** The degree of mutual agreement, or grouping, of measured values; there is no implied relationship to the accuracy of the values. Again relating to throwing darts, if five darts are thrown at the target and they all land within a 1 1/2-inch diameter circle, then the precision of the dart throwing is very high.
- **Uncertainty:** The degree of inherent error that may be associated with a measured value. This is a function of the measuring device. How "close" can the device be read?
- **Significant Figures:** In the recording of a measurement or reading, those digits necessary to correctly express the uncertainty of the reading are considered significant figures.

3.8.1 ACCURACY AND PRECISION IN READINGS

Two things affect the accuracy and precision of field readings. One is the nature of the measuring device. The proper calibration and maintenance of field equipment is critical to collecting accurate data. The other factor affecting accuracy and precision is human error. This may result from improper reading of the instrument/device, improper recording of the data, or other factors. Care must be taken in all steps to reduce the chance of human error.

3.8.2 ACTUAL UNCERTAINTY

If a measuring device is graduated into increments of one-hundredth of a foot, then the actual uncertainty of that instrument is plus or minus one-hundredth (±0.01) of a foot. The device can not be read with any less uncertainty than 0.01 foot. This is NOT a lack of accuracy or precision; rather, it defines the limit, or resolution, of the measurement.

3.8.3 IMPLIED UNCERTAINTY

The manner in which a measured value or reading is expressed implies the degree of uncertainty of that measurement; the implied uncertainty must correctly reflect the actual uncertainty of the measurement. In general, the implied uncertainty of a value is plus or minus the last digit to the right (i.e., significant figure). The field recording of data MUST correctly reflect the actual uncertainty of the reading based upon the instrument/meter being used. The value measured or read by/from the instrument must not be rounded off, nor estimated beyond the accuracy of the instrument.

3.9 FIELD AND LABORATORY QA/QC

3.9.1 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, not lost, broken, or exposed to conditions which may affect the sample's integrity.

Often, due to weather or time constraints, the entry of sample data into the sample log or labeling of the sample containers does not occur immediately following sample collection. Additionally, the secure sample storage location on site may be distant from the actual area where sampling is being conducted. These are only a few of the many undesirable situations which may be encountered. Field personnel must creatively adjust to field conditions to ensure that good sample management practices are maintained. All sample submissions must be accompanied with a chain-of-custody (COC) document to record sample collection and submission. Section 3.9.1.4 describes the COC requirements in detail.

The following sections provide the minimum standards for sample management.

3.9.1.1 FIELD HANDLING

Prior to entering the field area where sampling is to be conducted, especially at sites with defined exclusion zones, the sampler should ensure that all materials necessary to complete the sampling are on hand. This includes a review of the laboratory supplied bottle order against the sampling and analysis plan and the simplified scope of work (SSOW) verifying sufficient quantity of appropriate containers are provided. Parameter holding times should be reviewed during planning as very short holding times (24 hours) may impact sampling schedules.

Most environmental samples must be maintained at a specified temperature (4 $\pm$2°C) after collection which requires that shipping coolers and ice be brought out to the field. Consideration should be given to bringing reserve ice into the field if sampling events will be of long duration or as replacement coolant for shipping on hot days. Conversely, when sampling in extremely cold weather, proper protection of water samples, trip blanks, and field blanks must be considered.

Personnel performing groundwater, surface water, or effluent sampling tasks must check the sample preparation and preservation requirements to ensure compliance with the project QAPP and/or appropriate method/regulatory requirements. Typical sample preparation may involve pH adjustment (i.e., preservation), sample filtration and preservation, or simply cooling to 4 $\pm$2°C. Sample preparation requirements vary from site to site and vary depending upon the analytical method for which the samples will be analyzed. Laboratories typically provide sample containers with the preservative already in the bottle; caution should be used to not overfill these containers.

The sampling personnel must also confirm before the sample event, the amount and sequence of bottle filling required for the respective sample containers. Volatile Organic Compound (VOC) samples must not have any headspace within the sample collection vial; whereas when collecting select analytes (i.e., metals) a headspace must be provided to allow addition of the required preservative, if necessary.

3.9.1.2 SAMPLE LABELING

It is imperative that sample labels correctly reflect the sample identification number associated with the sample location on all sample containers. Samples must be properly labeled as soon as practical after collection.

Quite often the analytical laboratory supplying the containers will provide blank sample labels. These labels are inconsistent and rarely include all of the information required in a consistent manner, therefore they should only be used as a last resort. Some CRA offices maintain computer software which can preprint basic project data on sample labels. When a large sampling program is anticipated, the use of these software programs to print out bulk labels is advantageous.

Under certain field conditions it is impractical to complete and attach sample labels to the container at the point of sample collection. However, to ensure that samples are not confused, a clear notation should be made on the container with a permanent marker indicating the last three digits of the sample number. If the containers are too soiled or small for marking, the container can be put into a "zip-lock" bag which can then be labeled.

Sample Labels

Note that the information shown below is the minimum information required on the sample label.

1. Project name
2. Project number
3. Sample identification (Sample ID)
4. Date of sample collection
5. Time of sample collection (in military or with AM/PM)
6. Sampler's name
7. Analysis requested
8. Preservatives

The project QA/QC specifications should be reviewed to determine any additional requirements.

An example sample label is provided below for clarity.

CONESTOGA-ROVERS & ASSOCIATES

PROJECT NAME: _____ **PROJECT NO:** _____

SAMPLE ID: _____

SAMPLE DATE: _____ **TIME:** _____

SAMPLER NAME: _____

ANALYSIS REQUEST: _____

_____

PRESERVATION: **NONE**☐ **HNO_3**☐ **HCl**☐ **H_2SO_4**☐ **NaOH**☐

NaOH/ZnOAc☐ **MeOH**☐ **Other:**_____

Labels should be secured to the bottle and should be written in indelible ink. It is also desirable to place wide clear tape over the label before packing in a cooler for label protection during transportation. Sample labels should not cover any pertinent laboratory information.

Sample Identification

No one sample identification (ID) format is adequate for every type of sampling activity. Prior to the start of every project or sub-sampling event within the project, Project Managers (PM) and field personnel should devise a sample ID format. Sample IDs **must be unique** and formats should be as simple and consistent as possible. Simple sample IDs will reduce transcription errors by both CRA and lab personnel. The sample ID format should be comprehensive enough to allow for easy location of detailed sample data within the CRA log books. This information and other related information should be entered in the field sample key (FSK) (see Section 3.9.1.6) which will facilitate entry into CRA's project database.

The unique sample ID may follow one of the two formats recommended below, or a specific sample protocol for labeling may be specified in the project Work Plan or QAPP.

a. MC-34767-mmddyy-XXX-001

or

b. MC-34767-ddmmyy-XXX-001

where:

1.	MC (Matrix Code)	=	GW-groundwater, SW-surface water, S–soil, SD-sediment
2.	034767	=	Project reference number
3a.	mmddyy	=	Date in month/day/year (US projects)
3b.	ddmmyy	=	Date in day/month/year format (Non-US projects)
4.	XXX	=	Sampler's first, middle, and last initials
5.	001	=	Sequential number for an event or project

This format has been selected to maximize the information content of the sample ID. Minor modifications are certainly reasonable.

1. Series letters designate a group of samples. This will typically identify sample matrix (e.g., sediment, soil, groundwater, surface water, air, etc.), or sample source. For example, "GW" means samples of groundwater, "SW" means samples of surface water. Letters should be used, not numbers. The sample ID matrix code is not the same as the matrix code identified in the FSK or CRA database, it is a simple two letter code used to define matrix as established for the project.
2. Project reference number together with the series number will allow easier tracking of samples.
3. Sample date will allow monitoring of actual holding time of samples and should ensure that all sample numbers are unique, even if sample location designation is used in a system, as opposed to assigned at random.
4. Sampler's initials will allow identification of the sampler and so allow all project personnel to contact the correct person for information regarding that sample and its collection. The use of

three initials is preferred. Special arrangements will need to be made if two individuals have the same initials.

5. The sequential number designation will identify the sample, and can be any numerical or letter designation. With multiple sampling crews collecting samples it is advantages to assign blocks of sequential numbers to each thereby avoiding repetition.

Field QC samples should be identified in the following manner:

1. Field blank samples – Field blank samples including equipment blanks, equipment rinsate blanks, media or bottle blanks, and ambient blanks should be identified in the same format as investigative samples with no indication that they are QC samples. The field logbook and FSK should identify them as QC samples.
2. Field duplicate samples – Field duplicate samples including field replicates, splits and full duplicates should also be identified in the same format as investigative samples. The field logbook and FSK should identify them as QC samples.
3. Trip blank samples – Trip blank samples are used during the collection and transportation of samples for VOC analysis (including light range TPH). Trip blanks are primarily for water samples but may include soils if field preservation is performed. Trip blanks should be identified with a TB for trip blank, the date (mmddyy or ddmmyy), and a sequential number if multiple trip blanks are submitted on a given day (e.g., TB-090909-001).
4. Matrix spikes and matrix spike duplicates – These are technically laboratory QC samples but typically require additional volume (triple volume). They should not be assigned separate sample IDs from the investigative sample as they are just additional volume.

The decision of how to assign sample numbers should be made at the beginning of a job or phase, and should be consistent throughout the job. Effort should be made to eliminate use of the same sequential number on a project.

It is imperative that sample IDs be unique, use of sample locations (well numbers or boreholes numbers) that may repeated will cause problems when data is entered into the database (e.g. data may be overwritten). Unless specifically instructed, sample IDs and sample labels should not contain specific names of the sample source (i.e., "Well No. 16"). Provision of such specific data on the label can produce biased lab results and the afore mention database issues.

3.9.1.3 CHAIN-OF-CUSTODY (COC) RECORDS

Chain-of-custody (COC) is the sequence of possession of an item. An item (such as a sample) is considered to be in custody if the item is in actual possession of a person, the item is in the view of the person after being in his/her actual possession, or the item was placed in a secure area by that person. The integrity of analytical data is dependent in part on a legally defensible chain of custody of the

samples collected. Therefore; COC records must be completed and handled in accordance with the procedures defined in this section.

Note:	*Custody is not maintained if samples are dropped off at the office with notes for someone to fill out the COC record.* *Custody is not maintained if the shipping cooler is left outside in the hot sun awaiting FedEx or courier pickup.*

COC records will be completed for all samples collected. The COC documents the transfer of identified samples for the specified analysis. The COC record must be signed and dated by the sampler when transferring the samples. An example of a typical COC is provided as Figure 3.15.

The COC record, completed at the time of sampling, will contain, but not be limited to, the sample number, date and time of sampling, and the name of the sampler. The following items must be addressed on the COC record:

1. Company name and address of sampling firm
2. Project number (Phase and Task Code if defined)
3. Project name
4. Project location
5. Sampler(s) name
6. Laboratory name and location
7. COC number
8. Sample ID
9. Date sample collected
10. Time sample collected
11. Sample matrix
12. Sample method (grab or composite)
13. Container quantity and preservation
14. Sample analysis
15. SSOW reference number
16. Transfer (relinquish/received by) signatures

Additional items that should be included on or added to the COC record:

1. Chemistry contact
2. Shipping carrier
3. Air bill number

4. Date shipped
5. Cooler number
6. Turnaround time (TAT) required

The preferred method of COC record management is that each sample cooler being shipped to the laboratory will contain a COC record identifying the samples contained in the cooler. This is the preferred method, and should be mandatory for all Superfund projects conducted under a legal order or any projects that may be in litigation. Any uncertainty regarding this practice should be clarified with the CRA Project Manager. If individual samples are split into multiple coolers by parameter, these samples and associated containers/parameters should be entered on multiple COC records. Although not preferred, if a single COC record is used to ship more than one cooler, additional measures should be utilized to assist in tracking that cooler association with the COC that is being used. These methods are later described below.

The COC record will consist of a four-part form with color coded copies distributed as follows: the shipper (sampler) will maintain the goldenrod copy, the pink copy is provided to the Project Chemist while the other two copies (white and yellow) will be enclosed in a waterproof envelope within the cooler with the samples. The cooler will then be sealed properly for shipment. The laboratory, upon receiving the samples, will accept sample custody by completing the "received by" section of the COC. The laboratory will maintain one copy for their records. The original white COC page will be returned to the Project Chemist or contact identified on the SSOW by the laboratory with the final data deliverables package.

The following items provide guidance for the completion and handling of all COCs:

1. COC records used should be the CRA standard form or the specific program COC form which may include those supplied by the analytical laboratory. Use of laboratory forms is discouraged unless they contain all of the required information. Do not use any COC forms from other labs, even if the heading is blocked out.
2. COC records must be completed in indelible ink only.
3. COC records must be completed neatly using printed text.
4. If a simple mistake is made, line out the error with a single line and initial and date next to it.
5. Each separate sample entry must be sequentially numbered and should occupy a single line.
6. Do not skip lines and any unused lines should crossed out.
7. The use of "ditto" or quotation marks to indicate repetitive information in columnar entries should be avoided. If numerous repetitive entries must be made in the same column, place a continuous vertical arrow between the first entry and the next different entry.
8. When more than one COC form is used for a single shipment, each form must be consecutively numbered using the "Page ___ of ___" format.

9. If necessary, place additional instructions directly onto the COC record. Do not enclose separate loose instructions. Reference to project documents such as the SSOW by reference number should be included for clarification.
10. Include a contact name and phone number on the COC in case there is a problem with the shipment. This contact is typically the CRA Project Chemist that contracted the lab services and is identified on the SSOW.
11. CRA's copy of the COC must be maintained in the project field file.
12. Do not indicate the source of the sample as this may produce a biased lab result.
13. Before using an acronym on a COC ensure that this acronym is as defined on the referenced SSOW and or the back of the COC record, if not define clearly the full interpretation of your designation (i.e., polychlorinated biphenyls [PCBs]).
14. Additionally, the last COC from a sampling event must indicate that the last sample for that batch has been collected and shipped to the laboratory by writing "Batch Complete" on the COC. This will enable the CRA Project Chemist to track the samples as a group and confirm the laboratory has met the analysis turnaround time requirements of the program. This will also eliminate extended report due dates by the laboratory due to open batches.

When a single COC record is used to ship more than one cooler, one of the following additional measures should be utilized to assist in tracking that cooler association with the COC that is being used:

1. A photocopy of the completed COC should be placed in each cooler identifying the samples included in the cooler (with the lab cooler number if available) adding a notation consecutively numbering the cooler using the "Cooler ___ of ___" format.
2. A tracking sheet is enclosed in each cooler identifying the samples included in each cooler, the lab cooler number (if available), and the consecutive number of each cooler using the "Cooler ___ of ___" format. This tracking sheet should also note the COC number and the contact information for the person signing the COC or the CRA Project Chemist.

3.9.1.4 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 never be prepared for shipment in the field office trailer due to the risk of breakage and area/personnel exposure.

Sample containers should be prepared for shipment as follows:

1. Containers should be wiped clean of all debris/water using paper towels (paper towels must be disposed of with other contaminated materials)
2. Clear, wide packing tape should be placed over the sample label for protection

While there is no one "best" way to pack samples for shipment, the following packing guidelines should be followed:

1. Plan time to pack your samples (and make delivery to shipper if applicable). Proper packing and manifesting takes time. A day's worth of sampling can be easily wasted due to a few minutes of neglect when packing the samples.
2. Always opt for more coolers and more padding rather than crowd samples. The cost associated with the packing and shipment of additional coolers is usually always small in comparison with the cost of having to re-sample due to breakage during shipment.
3. Do not bulk pack. Each sample must be individually padded in bubble wrap bags for example.
4. Large glass containers (1 L and up) require much more space between containers.
5. Ice is not a packing material due to the reduction in volume when it melts.

The following is a list of standard guidelines which must be followed when packing samples for shipment:

1. When using ice for a cooling media, always double bag the ice in zip-lock bags.
2. The entire cooler contents should be in a large plastic bag (most labs supplies these).
3. Double-check to ensure trip and temperature blanks have been included for all shipments containing VOCs, or where otherwise specified in the QAPP or Work Plan.
4. Enclose the chain-of-custody form in a zip-lock bag.
5. Ensure custody seals (two, minimum) are placed on each cooler. Coolers with hinged lids should have both seals placed on the opening edge of the lid. Coolers with "free" lids should have seals placed on opposite diagonal corners of the lid. Place clear tape over custody seals.
6. Seal any drain holes and the lid with packaging tape.
7. Ensure that all "Hazardous Material" stickers/markings or any prior shipping labels have been removed from coolers being used which previously contained such materials.

Note: Never store sterile sample containers in enclosures containing equipment which use any form of fuel or volatile petroleum based product. An alternate means of secure storage must be planned for. When conducting sampling in freezing conditions at sites without a heated storage area (free of potential cross contaminants), trip blanks and temperature blanks not being used in a QA/QC role should be isolated from coolers immediately after receipt. Trip and temperature blanks should be double-bagged and kept from freezing.

3.9.1.5 SHIPMENT

In all but a few cases the QA/QC or Work Plan for the field work will require shipment of samples on a daily basis by overnight carrier. A great many problems can be avoided by proper advance planning.

Prior to the start of the field sampling, the carrier should be contacted to determine if pickup can be made at the field site location. If pickup at the field site can be made, the "no-later-than" time for having the shipment ready must be determined.

If no pickup is available at the site, the nearest pickup or drop-off location should be determined. Again, the "no-later-than" time for each location should be determined.

Verify courier shipping and laboratory receiving schedule during holidays. Saturday deliveries should also be verified and typically require additional labeling.

Sufficient time must be allowed not only for packaging but also for delivery of samples if this becomes necessary. Driving at high rates of speed or talking on the cell phone to make arrangements with the Project Chemist/laboratory in order to make the drop time is unacceptable.

Sample shipments must not be left at unsecured or questionable drop locations (i.e., if the cooler will not fit in a remote drop box do not leave the cooler unattended next to the drop box).

Some overnight carriers do not in fact provide "overnight" shipment to/from some locations. Do not assume; call the carrier in advance before the start of the field work.

Copies of all shipment manifests must be maintained in the field file.

3.9.1.6 FIELD SAMPLE KEY (FSK)

A field sample key is required for each sampling event. The main purposes of this document are:

1. To ensure proper association of sample data with sample locations, Area of Interest (AOI), etc., in the database
2. Provide a means of accurately transferring field data to the database

Several varieties of sample keys can be employed to meet these purposes including a copy of the COC with sample locations added or a simple excel spreadsheet, but the preferred approach is the use of the FSK (see Figure 3.16). The CRA standard FSK procedures are described in this section.

The FSK should be initiated during the sample event planning stage and submitted to the Project Chemist during the SSOW development (the latest version of the FSK can be obtained from the Field Methods training Peer to Peer Groups section of MyPortal: \\myportal\portaldoc\P2P Groups\Field Methods

Training Program\Sampling Documents). The document name will automatically be created from the information populated in the FSK as follows:

FSK_SSOW Ref Code_yyyy-mm-dd

Where yyyy-mm-dd reflects the last sample collection date recorded in the FSK. It is critical the SSOW Reference Code is input correctly on the FSK.

It has been determined that many problems are compounded further in the process when the FSK is inaccurate or incomplete. For this reason, the FSK will be initiated by the PM during the planning stage to ensure that FSK requirements are communicated to the field staff and that sample locations are carefully inputted.

The PM or designee will determine which worksheets from the FSK will be required, which field data will be imported into the database, and if possible, enter sample locations and matrix codes on the FSK prior to sampling. In this way, the FSK can be used as an effective tool to communicate sample locations to the field staff and to ensure sample locations are entered in a format consistent with the existing database (if applicable). The PM is responsible for providing the FSK to the person that will complete the form.

The FSK includes the following forms:

- **FSK Instructions –** The instruction spreadsheet outlines the details for completion of the FSK. Each consultant is urged to review these instructions and review with the field staff.
- **Field Sample Review Form –** Section A of the spreadsheet is mandatory. This section of the spreadsheet is used by the PM to identify the components of the project and select the FSK forms that are warranted for the project. Once the FSK is complete and returned to the Project Chemist, Sections B and C are used by the FSK Reviewer to check the completeness and accuracy of the FSK versus the SSOW, the COC and the lab's sample confirmation receipt (SCR) to ensure that the proper analyses are scheduled by the lab. Deficiencies identified in the FSK are recorded in Sections B with and C.
- **Sample Key** - This is a mandatory document all sampling events. This spreadsheet is used by the Data Analysts to associate sample data with sample locations. It is critical that the sample locations be entered in a consistent manner (e.g., MW-1 and MW1 would be considered different locations upon import). Note that if e:Monitor is used to collect sample information, the sample information must still be exported from e:Monitor Desktop to the field key sheet after the data are verified.

The field sample key should be completed and emailed to Project Chemist in a timely fashion. There are several client programs in place with detailed procedures that must be followed in regards to FSK completion and processing, these will be identified by the PM or designee.

For MS/MSD samples, one entry only should be made on the FSK (i.e., the MS/MSD samples should not have unique IDs differing from the parent sample). The sample type should be 'N' for Normal Environmental Sample. In the Notes field for that sample, "MS/MSD" should be written.

On the Sample Key (the main FSK worksheet) there is a section for selecting analysis/parameter that is populated with common analyses/parameters. This section can be modified as needed by the sampler.

3.9.2 FIELD QUALITY CONTROL/QUALITY ASSURANCE (QA/QC)

Generally, all project sampling tasks are outlined within the project-specific QAPPs which identify the QA/QC sampling requirements.

The following is a brief discussion defining the common types of field derived quality control samples which may be required for a groundwater sampling program. It should be noted that specific-project QAPPs may include all or only some of the following quality control procedures.

3.9.2.1 EQUIPMENT BLANKS

Equipment blanks are defined as QA/QC samples used to determine if cleaning procedures are effective and adequate. Equipment blanks are prepared by collecting deionized water which has been "run through" or "poured over" the cleaned sample collection equipment. Equipment blanks are typically submitted to the lab "blind". Equipment blanks are typically collected at the sample preparation area of the project site.

One equipment blank is typically collected for each batch of samples submitted or at a prescribed frequency (i.e., one field blank for every 20 samples).

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

Note:	*Samplers must be aware of the various qualities of "deionized water" and the impact the use of non-ultrapure deionized water may have on the program analysis results. For example, the CRA Waterloo laboratory has two grades of deionized water available: "rinse deionized water" intended for use as an equipment rinse water, and "ultrapure deionized water", intended to be used for the preparation of field blanks. Sampling staff are urged to check with the Project Manager or the Project Chemist to verify the deionized water needs; in most instances only ultrapure deionized water is acceptable for preparation of analytical blanks.*

3.9.2.2 FIELD BLANKS

Similar to equipment blanks, a field blank is collected to evaluate the influence of field ambient conditions on the sampling process. Field blanks are collected using deionized water poured directly into the sample container. Field blank collection is performed at a typical sampling site (re: well location) to evaluate if ambient site conditions influence sample results.

Field blanks are submitted to the lab "blind". The frequency of field blank submission will be determined by the project QAPP.

3.9.2.3 TRIP BLANKS

Trip blanks are prepared by the analytical laboratory upon request, before the sampling event and sent to the site in the shipping container(s) designated for the project. These samples are intended to be kept with investigative samples, then 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.

Trip blanks are usually submitted for VOCs only. The frequency of trip blank submission will be determined by the project QAPP.

3.9.2.4 FIELD DUPLICATES

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.

During groundwater sample aliquot collection the original and duplicate sample are collected simultaneously by partially filling the original and then the duplicate and alternating back and forth until both samples have been fully collected. This will provide two representative samples for analyses. Transferring the sample aliquot from a bulk container to the respective sample containers is typically not permissible.

Field duplicates are typically submitted "blind" to the laboratory by providing a false identification number. The sampling key to ensure proper sample identification must be submitted to the appropriate personnel to enable completion of the QA/QC review process.

The frequency of field duplicate submission will be determined by the project QAPP.

3.9.2.5 LABORATORY QA/QC SAMPLE VOLUMES

Matrix Spike and Matrix Spike Duplicate (MS/MSD) sample volumes are additional sample aliquots provided to the laboratory to evaluate the accuracy and precision of the sample preparation and analysis technique.

Typically three times the normal sample aliquot is required to conduct MS/MSD procedures. Sample collection is identical to the technique described for collection of field duplicates. Sample labeling identifies the respective sample location and each additional container which is labeled as the "MS/MSD" volume.

3.9.3 LABORATORY QA/QC SAMPLES

Laboratories analyze a variety of QA/QC samples internally to monitor the analytical procedure with regard to accuracy, precision, and contamination. A description of some QA/QC samples follows.

3.9.3.1 MATRIX SPIKES (MS)

Matrix spikes (MS) consist of an aliquot of the sample which is spiked with a known concentration of the target analyte prior to sample preparation and analysis. The recovery of the spike is calculated using the equation:

$$\frac{100\ (\text{Spiked Sample Result} - \text{Unspiked Sample Result})}{\text{Spike Amount Added}}$$

The recovery of the spike is used to measure the accuracy of the test performed. The spike is sometimes performed in duplicate in order to measure the precision of the test as well by comparing the resulting spike recoveries.

3.9.3.2 LABORATORY DUPLICATES

A laboratory duplicate consists of an intralaboratory split of an investigative sample prior to preparation and analysis. The split results in the sample being analyzed as two samples to measure the precision of the analysis. The relative percent difference of the duplicate analysis is measured as:

$$\frac{100\,|\text{Original Sample Result} - \text{Duplicate Sample Result}|}{1/2\,(\text{Original Sample Result} + \text{Duplicate Sample Result})}$$

3.9.3.3 SURROGATE SPIKES

Surrogate spikes are organic compounds similar to the target analytes of interest in both chemical composition and behavior, but which are not normally found in environmental samples. They are added to the samples to monitor the accuracy of the analytical procedure for organic testing.

3.9.3.4 LABORATORY CONTROL SAMPLES

Laboratory control samples are analyzed with the investigative samples in order to monitor analytical performance. They consist of a known matrix which is free of interferences (i.e., water, sand), which is subsequently spiked with the analytes of interest.

3.9.3.5 METHOD BLANKS

Method blanks are prepared and analyzed with the investigative samples to assess the potential level of contamination introduced to the analytical process by the laboratory. They consist of a matrix demonstrated to be analyte-free (i.e., sand, water) which is processed with each sample batch. Method blank results are used to evaluate the possible impact of laboratory contamination on the results reported for investigative samples.

3.9.4 LABORATORY ANALYSIS

Laboratories follow certain protocols to receive samples and perform laboratory analyses. A description of the procedures and instrumentation follows.

3.9.4.1 SAMPLE RECEIPT

Upon receipt of the cooler at the laboratory, the shipping cooler and the custody seal will be inspected by the sample custodian. The condition of the cooler and the custody seal will be noted on the chain-of-custody record sheet by the sample custodian. The sample custodian will record the temperature of one sample (or temperature blank) from each cooler and the temperature will be noted on the chain of custody. If the shipping cooler seal is intact, the sample containers will be accepted for analyses. The sample custodian will document the date and time of receipt of the container, and sign the form.

If damage or discrepancies are noticed (including sample temperature exceedances), they will be resolved by the laboratory with the appropriate CRA Chemist, and a project team member, if necessary, before samples are processed.

Each sample or group of samples shipped to the laboratory for analysis will be given a unique identification number. The sample custodian will record the client name, number of samples, and date of receipt of samples in the Sample Control Log Book. Samples removed from storage for analyses will be documented in the Sample Control Log Book.

3.9.4.2 ANALYTICAL PROCEDURES

Gas Chromatography (GC)

GC analysis is used to characterize the organic content of samples. It measures organic compounds such as VOC, semi-volatiles, organic compounds (SVOCs) pesticides, polychlorinated biphenyls (PCBs), and herbicides. The compounds which can be measured depend on several factors, including the GC column used, the GC oven temperature, and the type of detector in the instrument.

The sample or sample extract is injected into the GC and immediately vaporized. The concentrated vapor is swept into the GC column. The compounds are separated as the vapors are selectively adsorbed by the stationary phase of the column and then desorbed by a carrier gas. The compounds move through the column toward a detector, and will be eluted depending on the affinity of the compound toward the column.

The two types of columns generally used are packed and capillary. A variety of detectors are used, including thermal-conductivity, flame-ionization, electron-capture, photoionization, and hall-electrolytic-conductivity. The columns and detectors utilized in the GC will determine which class of organic compounds can be analyzed.

Sample analysis is performed by analyzing analytical standards of the compounds at varying concentrations, and constructing a calibration curve.

Gas Chromatography/Mass Spectrometry (GC/MS)

One special type of GC detector is the mass spectrometer. This detector fragments the vapor using an electron beam. These charged particles are then accelerated into a mass filter, where they can be ultimately identified by their characteristic fragmented patterns.

GC/MS instrumentation is commonly used to determine organic compounds such as volatiles and semi-volatiles. More sophisticated GC/MS instrumentation can also analyze PCB congeners and dioxin/furans.

Sample analysis is performed similar to GC except that the sample mass spectra is compared to a mass spectra library of organic compounds to ensure proper identification.

Inductively Coupled Plasma (ICP) Emission Spectroscan

Inductively Coupled Plasma (ICP) analysis is commonly used to determine element content in samples, specifically metals. The ICP is equipped with a torch which provides an excitation source by creating a plasma with a gas (usually argon). The sample is introduced in an aqueous state using a nebulizer. The sample is heated by the plasma, and each element present emits a characteristic color at a specific wavelength.

Sample analysis is performed by analyzing analytical standards of the elements at varying concentrations, and constructing calibration curves.

Atomic Absorption Spectroscopy

This instrumentation has largely been replaced by ICP for the analysis of metals. It is still frequently used for mercury analysis with cold vapor equipment. The mercury vapor is generated through chemical addition, and the resulting vapor is passed through a cell and analyzed at a specific wavelength by the instrument.

Classical Chemistry Procedures

In addition to the instruments detailed, there are a variety of laboratory procedures used to analyze classical chemistry parameters. These include titrimetric, gravimetric, spectroscopy, and dedicated instrumentation. Most classical chemistry procedures can be measured by a variety of methods.

CRA FIELD TRAINING MANUAL

SECTION 5.0:

SOIL SAMPLING STANDARD OPERATING PROCEDURES

PART 1: **SURFICIAL SOIL SAMPLING, BOREHOLE INSTALLATION AND SAMPLE COLLECTION, AND TEST PIT EXCAVATION AND SAMPLING**
(F102A)

PART 2: **CRA APPROACH FOR SOIL MATERIALS DESCRIPTION AND CLASSIFICATION**
(F102B)

OCTOBER 2009
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PLEASE ADHERE TO THE FOLLOWING QUALITY SYSTEM TRAINING REQUIREMENTS:

- **Employees who are required to conduct a specific field activity must be properly certified to do the work.**
- **This involves reviewing the SOP and completing the online training course and exam.**
- **Employees must also conduct this field work under supervised conditions on at least three occasions, and must be certified by a qualified mentor. Only then can an employee conduct a specific field activity on their own. This is documented on a Field Method Training Record (QSF-021).**
- **Complete the QSF-021 and forward it to trainingrecords@craworld.com.**
- **Please note that four topics are discussed in this SOP. A separate QSF-021 is required for each topic**:
  - **Surficial Soil Sampling**
  - **Borehole Installation and Sample Collection**
  - **Test Pit Excavation and Sampling**
  - **CRA Approach for Soil Materials Description and Classification**

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SP-03 TEST PIT STRATIGRAPHY LOG

SP-12 BOREHOLE INSTALLATION/SOIL SAMPLING EQUIPMENT AND SUPPLY CHECKLIST

SP-13 DRILLING/WELL CONSTRUCTION CHECKLIST

SP-14 STRATIGRAPHY LOG (OVERBURDEN)

LIST OF QUALITY SYSTEM FORMS

QSF-012 VENDOR EVALUATION FORM

QSF-014 FIELD EQUIPMENT REQUISITION FORM

QSF-019 PROPERTY ACCESS/UTILITY CLEARANCE DATA SHEET

QSF-021 FIELD METHOD TRAINING RECORD

QSF-030 SAFETY AND HEALTH SCHEDULE (CANADA)

QSF-031 SAFETY AND HEALTH SCHEDULE (U.S.)

5.0 SOIL SAMPLING STANDARD OPERATING PROCEDURES

5.1 INTRODUCTION

Soil sampling is conducted to characterize the physical and/or chemical conditions at a site. Standard Operating Procedures (SOPs) are presented herein for obtaining a variety of soil samples for physical and chemical analyses, including:

- Surficial soil samples (soil between ground surface and 6 to 12 inches (15 to 30 cm) below ground surface)
- Subsurface samples that require borehole installation
- Test pit excavations

This guideline is not intended to provide the basis for designing a soil sampling program, but instead assumes that a soil sampling program has been designed, a Work Plan has been established, and the sampling team is preparing to mobilize to the field.

Soil sampling procedures vary from project to project due to different parameters of concern, different guidance provided by the state/province where the site is located, or the specific objectives for the project. Therefore, it is essential that the sampling team members carefully review the Work Plan. The primary goal of surface soil sampling is to collect representative samples for examination and chemical analysis (if required).

The remainder of this section is organized as follows:

- Section 5.2 Sampling Methods
- Section 5.3 Planning and Preparation
- Section 5.4 Safety and Health
- Section 5.5 Quality Assurance/Quality Control
- Section 5.6 Equipment Decontamination
- Section 5.7 Procedures for Soil Classification
- Section 5.8 Procedures for Surficial Soil Sampling
- Section 5.9 Procedures for Borehole Installation and Sampling
- Section 5.10 Procedures for Test Pit Excavation and Sampling
- Section 5.11 Follow-up Activities
- Section 5.12 References

5.2 SAMPLING METHODS

5.2.1 SURFICIAL SOIL SAMPLING

Surficial soil sampling is less frequently used than subsurface soil sampling (which involves borehole installation). Typically, surficial soil sampling is used when a large site is being assessed and the extent of contamination is unknown. In this case, surficial sampling is helpful in identifying the location of surface releases (e.g., historical spills of hydrocarbons) that may have contributed to subsurface contamination. A surficial soil sampling program is also recommended for sites with suspected atmospheric deposition of contaminants (e.g., stacks), areas of surface spills, or recent spills.

Surficial soil sampling is used when contamination is known to be restricted to the surficial region of the soil stratum. Thus, surficial sampling can be useful at brownfield sites, where it is necessary to determine if soils are contaminated with specific contaminants of concern (e.g., metals) as part of a purchaser's due diligence. Surficial soil sampling can also be required when obtaining data in order to perform a site-specific risk assessment.

For the purposes of this section, the surficial soil is considered to be the 0- to 6-inch (0 to 15 cm) soil horizon.

Samples are collected from areas where surficial soil contamination is known or suspected. Samples from a particular depth increment must not be 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.

5.2.2 BOREHOLE INSTALLATION AND SAMPLING

A significant portion of CRA's field activities involve borehole installation.

Several manual methods are available for the collection of shallow subsurface soil samples (e.g., hand augers, post-hole augers). However, the most common methods used by CRA to advance boreholes are a drill rig equipped with continuous flight hollow-stem augers (HSAs) and split-spoon samplers, or a direct-push drilling unit equipped with solid tube soil samplers.

5.2.3 TEST PIT EXCAVATION AND SAMPLING

Test pits are typically excavated to explore and define geologic conditions (or buried waste/debris) and to allow the collection of subsurface soil samples for geotechnical or chemical analysis. Test pits give a more complete view of the subsurface soil conditions than soil borings. Test pits are excavated using either a rubber-tired backhoe or track-mounted excavator, and can extend 10 to 15 feet (3.0 to 4.6 m) below ground surface.

The use of test pits for investigation is determined on a site-specific basis. Experience from past projects has identified the following issues:

1. The nature and extent of contamination which may be encountered may be unknown. The Site-specific Health and Safety Plan (HASP) and Job Safety Analysis (JSA) must be specific to the level of Personal Protective Equipment (PPE); this may be Level A or B.
2. Waste materials, including drums, may be encountered. A plan must be in place specifying how this material will be handled.
3. Air emissions of some compounds may occur. A plan must be in place to ensure that employees and the public are adequately protected.
4. Community relations concerns may exist (e.g., workers in chemically protective "moon suits"). A notification plan may be required.
5. All underground utilities must be located utilizing documentation using the CRA Subsurface Clearance Protocol.

5.2.4 GRAB VERSUS COMPOSITE SAMPLES

A grab sample is collected to identify and quantify compounds at a specific location or interval. The sample is comprised of no more than the minimum amount of soil necessary to make up the volume of sample dictated by the required sample analyses. Composite samples are a mixture of a given number of sub-samples and are collected to characterize the average composition in a given surface area.

Samples to be analyzed for volatile organic compounds (VOCs) are always collected as grab samples. Mixing of soil samples to create a composite is not performed. Mixing of soil samples results in partial volatilization of VOCs from the soil, and thus compromises the integrity of the composite soil sample.

5.3 PLANNING AND PREPARATION

The following activities are required prior to undertaking a soil sampling program:

1. Review the Work Plan, project documents, and health and safety requirements with the Project Coordinator.
2. Complete a Field Equipment Requisition Form (QSF-014) and assemble all equipment, materials, log books, and forms. Form SP-02 (Project Planning, Completion, and Follow-Up Checklist) should be used for guidance throughout the project. Borehole Installation/Soil Sampling Equipment and Supply Checklist (Form SP-12) provides a summary of the typical equipment/materials required for soil sampling. Drilling/Well Construction Checklist (Form SP-13) provides a listing of pre-planning and site activities that is designed as an aid to preparing and completing the project.

3. Obtain a site plan and any previous stratigraphic logs. Determine the exact number, location, and depths of samples to be collected.
4. Complete a Vendor Evaluation Form (QSF-012) and file in the project file for any vendors that do not have full approval status or are not listed on the Approved Vendor List (QSL-004). Completion of a Safety and Health Schedule (QSF-030 for Canadian work; QSF-031 for U.S. work) is necessary for all vendors who complete field services. Prior to mobilization on site, the vendor must submit the form to the Regional Safety and Health Manager for review and approval (if not already posted on QSL-004).
5. Contact CRA's Chemistry Group to arrange/determine:
   - SSOW (simplified Scope of Work)
   - Glassware/sample jars
   - Cooler
   - Shipping details
   - Start date
   - Laboratory
   - Expected sampling duration
6. Initiate a Property Access/Utility Clearance Data Sheet (QSF-019), if necessary. In most instances, surface sampling activities do not require utility clearances.
7. Determine notification needs with the Project Coordinator. Have the regulatory groups, client, landowner, CRA personnel, and laboratory been informed of the sampling event?
8. Determine the methods for handling and disposal of wash waters and spent decontamination fluids.

In addition to the above, the following may be required when conducting a borehole or test pit program:

1. Establish a water source for drilling and decontamination activities. Pre-plan the methods for handling and disposal of drill cuttings, wash waters, and spent decontamination fluids.
2. Arrange with driller to provide paraffin wax, melting pot, and heat source (if required).

5.4 SAFETY AND HEALTH

CRA is committed to conducting field activities in accordance with sound safety and health practices. CRA adheres to high safety standards to protect the safety and health of all employees, subcontractors, customers, and communities in which they work. The safety and health of our employees takes precedence over cost and schedule implications.

Field personnel are required to implement the Safety Means Awareness Responsibility Teamwork (SMART) program as follows:

- Assure the HASP is specific to the job and approved by a Regional Safety and Health Manager.
- Confirm that all HASP elements have been implemented for the job.
- A JSA for each task has been reviewed, modified for the specific site conditions and communicated to all appropriate site personnel. The JSAs are a component of the HASP.
- Incorporate Stop Work Authority; Stop, Think, Act, Review (STAR) process; Safe Task Evaluation Process (STEP); Observations process; Near Loss and Incident Management process in the day-to-day operations of the job.
- Review and implement applicable sections of the CRA Safety and Health Policy Manual.
- Confirm that all site personnel have the required training and medical surveillance, as defined in the HASP.
- Be prepared for emergency situations, locating safety showers, fire protection equipment, evacuation route, rally point, and first aid equipment before you begin working, and make sure the equipment is in good working order.
- Maintain all required PPE, safety equipment, and instrumentation necessary to perform the work effectively, efficiently, and safely.
- Be prepared to call the CRA Incident Hotline at 1-866-529-4886 for all incidents involving injury/illness, property damage, and vehicle incident and/or significant Near Loss.

It is the responsibility of the Project Manager to:

- Ensure that all CRA field personnel have received the appropriate health and safety and field training and are qualified to complete the work.
- Provide subcontractors with a Job Hazard Analysis to enable them to develop their own HASP.
- Ensure that all subcontractors meet CRA's (and the client's) safety requirements.

5.5 QUALITY ASSURANCE/QUALITY CONTROL

A well-designed Quality Assurance/Quality Control (QA/QC) program will:

- Ensure that data of sufficient quality are obtained in order to facilitate good site management
- Allow for monitoring of staff and contractor performance
- Verify the quality of the data for the regulatory agency

The QA/QC program is developed on a site-specific basis. QA/QC requirements are discussed in detail in Section 3.9.

5.6 EQUIPMENT DECONTAMINATION

Borehole Installation and Sampling

Prior to use and between each borehole location at an environmental site, the drilling and sampling equipment must be decontaminated in accordance with the Work Plan or the methods presented in this section.

The minimum wash procedures for decontamination of drilling or excavating equipment are:

1. High pressure hot water detergent wash (brushing as necessary to remove particulate matter)
2. Potable, hot water, high pressure rinse

Cover the clean augers with clean plastic sheeting to prevent contact with foreign materials. For geotechnical, geologic, or hydrogeologic studies where contaminants are not present, it is sufficient to clean the drilling or excavating equipment simply by removing the excess soils.

On environmental sites, the soil sampler equipment (split spoons, trowel, spoons, shovels, bowls) are typically cleaned as follows:

1. Wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates
2. Rinse with tap water
3. Rinse with deionized water
4. Air dry for as long as possible

In addition, the following steps may be added when sampling for VOCs and metals:

1. Rinse with 10 percent nitric acid (only if samples are to be analyzed for metals)
2. Rinse with deionized water
3. Rinse with appropriate solvent (pesticide grade isopropanol, methanol, acetone, hexane, if required)
4. Rinse again with deionized water
5. Air dry for as long as possible
6. Wrap split-spoon samplers in aluminum foil to prevent contamination

***Caution**: Check the Quality Assurance Project Plan (QAPP) to confirm the cleaning protocol. Use of incorrect cleaning protocol could invalidate chemical data.*

5.7 PROCEDURES FOR SOIL CLASSIFICATION

This SOP for Soil Classification is not intended to provide complete training in soil classification. Soil Classification will require additional training and experience.

Criteria and procedures for soil classification and description include:

1. A standard method of describing the soil by name and group symbol
2. Standard field identification methods based on visual examination and manual tests on representative soil samples by a qualified CRA representative for interpretation of subsurface conditions at the site
3. Verifying field description descriptions through the inspection
4. Confirming descriptive information by laboratory determination of selected soil characteristics if required in the Work Plan
5. Factual overburden stratigraphic logs completed by CRA personnel responsible for interpreting the subsurface conditions at the site and review/confirmation of soil descriptions by the Project Coordinator

The overburden stratigraphic log is the factual description of the soil at each borehole location and will be relied on to interpret soil characteristics at the site. The overburden stratigraphic log will also be used to interpret the soil characteristics' influence and significance on the subsurface environment. CRA personnel responsible for interpreting the subsurface conditions at the site will also verify overburden stratigraphic log accuracy. If practical, the Project Coordinator, Geologist, or Geotechnical Engineer should confirm the soil descriptions and examine representative soil samples.

Describing and classifying soils is a skill that is learned through experience and by systematic training using laboratory results of soil composition in comparison to field descriptions.

Note: Attendance at a soil identification course provided by CRA is mandatory.

Descriptions for natural undisturbed soils are recorded on a Stratigraphy Log (Overburden) (Form SP-14). An example of a completed Stratigraphy Log (Overburden) is presented on Figure 5.1.

Soil descriptions are completed in the following order:

1. Unified Soil Classification System (USCS) group symbol(s) (e.g., SM) of primary soil components or dual or borderline symbols
2. Name and adjective description of primary, secondary, and minor grain size components
3. Relative density for non-cohesive soils or consistency for cohesive soils
4. Gradation and soil structure for non-cohesive soils or structure and plasticity for cohesive soils
5. Color

6. Moisture content
7. Other physical observations including presence of staining and or odors

Note:	*When describing observed odors, be as specific as possible to classify general odor category and strength of odor. Odors are generally chemical, petroleum, or septic related, varying from slight to moderate to strong. Identification of specific chemical compounds (i.e., benzene, gasoline) is not necessary and is often inaccurate as detailed chemistry commonly shows an array of chemicals present.*

When describing vegetative matter presence in soils, do not use the term organic. The use of the term organic often leads to confusion regarding the presence of organic chemicals [i.e., VOCs, semi-volatile organic compounds (SVOCs)]. Similarly, as noted above, use more specific terms for odors than organic.

The description of fill soils is similar to those used to describe native undisturbed soils. Fill soils will be identified as fill [i.e., SP/GP-Sand and Gravel (Fill)]. To determine if soils are fill, look for evidence that the soil has been artificially placed (e.g., brick fragments, slag, glass, wood fragments). Relative or inconsistent soil density can also assist in determining if soils are fill, along with irregular soil structure.

Soils are identified and grouped consistently to determine subsurface pattern or changes and non-conformities in the soil stratigraphy. The stratigraphy of each soil boring or test pit is compared to ensure that patterns or changes in soil stratigraphy are noted and that consistent terminology is used.

Visual examination, physical observation, and manual tests [based on ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)] are used to aid in classifying and grouping soil samples in the field. These procedures are described in the following subsection. ASTM D2488 should be reviewed for detailed explanations of the procedures. [Note that the related ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) uses slightly different percentages of soil components.) Visual-manual procedures used to aid in soil identification and classification include:

1. Visual determination of grain size, soil gradation, and percentage of various soil components to the nearest 5 percent (i.e., gravel, sand, silt, and clay)
2. Dry strength, dilatancy, toughness, and plasticity tests (i.e., thread or ribbon test) for identification of inorganic fine-grained soils (e.g., CL or CH [clays], and ML or MH [silts])
3. Soil compressive strength and consistency estimates based on thumb indent and or pocket penetrometer (preferred) methods

The three main soil divisions are:

1. Coarse-grained soils (e.g., sand and gravel)
2. Fine-grained soils (e.g., silts and clays)
3. Soils with high natural organic and vegetative matter content (e.g., peat, marl)

These soil divisions are presented in the table of USCS classifications below.

Major Divisions			Group Symbol	Typical Description
Coarse grained soils more than 50% retained on No. 200 sieve	Gravel more than 50% of coarse fraction retained on No. 4 sieve	clean gravel <5% fines	GW	well graded gravel, gravel-sand mixtures
			GP	poorly graded gravel, gravel-sand mixtures
		gravel with >15% fines	GM	silty gravel, gravel-sand-silt mixtures
			GC	clayey gravel, gravel-sand-clay mixtures
	Sand more than 50% of coarse fraction passes No. 4 sieve	clean sand <5% fines	SW	well graded sand, fine to coarse sand, gravelly sand
			SP	poorly graded sand
		sand with >15% fines	SM	silty sand, sand-silt mixtures
			SC	clayey sand, sand-clay mixtures
Fine grained soils more than 50% passes No. 200 sieve	Silt and Clay liquid limit <50, low plasticity	inorganic	ML	Inorganic silt
			CL	Inorganic clay
		organic	OL	organic silt, organic clay
	Silt and Clay liquid limit ≥50, high plasticity	inorganic	MH	silt of high plasticity, elastic silt
			CH	clay of high plasticity, fat clay
		organic	OL	organic clay, organic silt, low plasticity
			OH	organic clay, organic silt, high plasticity
Highly organic soils			Pt	peat

5.7.1 COARSE GRAINED SOILS

The USCS symbols for coarse-grained soil are primarily based on grain size, grain size distribution (gradation), and percent of fines (silt and clay content).

Grain size classification used for describing soils is in terms of particle size and sieve size (e.g., gravelly sand, trace silt). Coarse-grained soil is composed of more than 50 percent by weight, sand size, or larger (75 µm diameter, No. 200 sieve size). Note that there are other definitions for coarse-grained or coarse

textured soil and for sand and for sand size as soil having greater than 70 percent particles equal to or greater than 50 μm diameter (after "Guidelines for Contaminated Sites in Ontario") or 60 μm diameter ("Canadian Foundation Manual").

The percentage descriptors for soil components are different for coarse-grained versus fine-grained soils. The following are the percentage component descriptors for coarse-grained soils:

• Noun (e.g., sand, gravel)	Major Component
• Adjective (e.g., silty, clayey, sandy, gravelly)	Greater than 15%
• With (e.g., with silt, with clay, with sand, with gravel)	5% to 15%
• Trace (e.g., trace silt, trace clay, trace sand, trace gravel)	<5%

Grain size distribution of coarse-grained soils includes:

- Poorly graded (i.e., soil having a uniform or predominantly one grain size, SP and GP)
- Well graded (i.e., poorly sorted soils with a wide range of particle sizes with substantial percentage of intermediate sizes, SW and GW)
- Dirty (i.e., soil having greater than 15 percent fines, SM, SC, GM, and GC)

Coarse-grained soils are further classified based on the percentage of fine-grained soils (e.g., silts and clays) they contain. Coarse-grained soils containing greater than 15 percent fine-grained soils are described with an adjective (e.g., silty [SM, GM], clayey [SC, GC]). This description is attributed to soil particles that adhere when the soil sample is rubbed between the hands or adhere to the sides of sample jars after shaking, or rolling in the jar. The jar shake test will also result in the segregation of sand and gravel particles and can be used as a visual aid in determining sand and gravel content percentages.

Examples of the group symbol, name, and adjectives used to describe the primary, secondary, and minor components of soil are:

- GW - Sandy Gravel (e.g., 70 percent gravel and 30 percent sand, well graded)
- GW - Sandy Gravel-trace silt (less than 5 percent silt, well graded)
- SP - Sand (a uniform sand, predominantly one sand grain size)
- SM - Silty Sand, with clay (sand with greater than 15 percent silt, and 5 to 15 percent clay)

Relative density is important in establishing the engineering properties and behavior of coarse-grained soils. Relative density of non-cohesive (coarse-grained) soils is determined using the standard penetration test (SPT) blow counts (N-values) in accordance with ASTM D1586. A detailed discussion of the SPT and N values can be found in Section 5.9.2.1.

The SPT provides reliable indications of the relative density of sand and fine gravel. N-values in coarse-grained soil are influenced by a number of factors that result in overestimated relative densities.

For example, in coarse-grained gravel, dilatent silty fine sands, sand below the water table and uniform coarse sand, N-values tend to be conservative and under estimate the relative density. The Project Geotechnical Engineer will assess these effects, if required.

Other methods, such as modified SPT and cone penetration tests, are used on occasion to supplement or replace the SPT method for certain site-specific conditions. All modifications to the SPT or substitute methods must be recorded as required to interpret test results and correlate relative density.

5.7.2 FINE-GRAINED SOIL

A fine-grained soil is made up of more than 50 percent silt and clay (i.e., fines greater than 50 percent by weight passing the 75 μm (No. 200) sieve size). Description of visual-manual field methods and criteria to further characterize and group fine-grained soil (e.g., CL, CH, ML, and MH) are discussed in ASTM D2488.

The percentage descriptors for components is different for fine-grained versus coarse-grained soils. The following are the percentage component descriptors for fine-grained soils:

- Noun (e.g., silt, clay) — Major Component
- Adjective (e.g., sandy, gravelly, silty, clayey) — Greater than 30%
- With (e.g., with sand, with gravel, with silt, with clay) — 15% to 30%
- Few (e.g., few sand, few gravel, few silt, few clay) — 5% to 15%
- Trace (e.g., trace silt, trace clay, trace sand, trace gravel) — <5%

Further soil characterization tests include dry strength, dilatency, toughness, and plasticity (thread or ribbon test).

Criteria for Describing Dry Strength

Description	*Criteria*
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen crumbles into powder with finger pressure; specimen will break into pieces between thumb and a hard surface
Very High	The dry specimen cannot be broken between the thumb and a hard surface

Criteria for Describing Dilatancy

Description	*Criteria*
None	No visible change in small wetted specimen when rapidly shaken in palm of hand
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing or stretching

Criteria for Describing Toughness

Description	*Criteria*
Low	Only slight pressure is required to roll the thread near the plastic limit; the thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit; the thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit; the thread and the lump have very high stiffness

Criteria for Describing Plasticity

Description	*Criteria*
Nonplastic	1/8-inch (3 mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit; the thread cannot be re-rolled after reaching the plastic limit; the lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit; the thread can be re-rolled several times after reaching the plastic limit; the lump can be formed without crumbling when drier than the plastic limit

Examples of group symbol identification based on visual-manual procedures and criteria for describing fine grained soil are:

Group Symbol	*Dry Strength*	*Dilatancy*	*Toughness*	*Plasticity*
ML	None to low	Slow to rapid	Low or thread cannot be formed	Slight
CL	Medium to high	None to slow	Medium	Low
MH	Low to medium	None to slow	Low to medium	Low
CH	High to very high	None	High	High

Positive classification by USCS group symbols as described in ASTM D2487, is through laboratory determination of particle size characteristics, liquid limit, and plasticity index. The need for laboratory testing will be determined by the Project Hydrogeologist, Geologist, or Geotechnical Engineer and will be detailed in the Work Plan. If no laboratory testing is performed to confirm soil classification, a statement of qualification (method used) is required for group symbols.

Examples of terminology that accompany the group symbols are:

- ML - Sandy Silt (e.g., 30 percent sand)
- CL - Clay (lean) with sand (e.g., 15 to 29 percent sand)

The USCS group symbols require the use of lean clay (CL) and fat clay (CH). The use of these symbols is dependent on the plasticity of the soil. Classification such as silty clay can only be used for a very narrow set of conditions, and will only be used if Atterberg Limit results are available. The lean and fat clay designations are not universally used, but adherence to the USCS requires that these symbols be used.

Correlation of N-values and consistency for clays is unreliable. Consistency determinations will be performed using more appropriate static test methods, especially for very soft to stiff clays. N-values are more reliable in hard clays.

Estimates of unconfined compressive strength (Su) can be obtained by a pocket penetrometer test. To estimate consistency and compressive strength with a pocket penetrometer, cut a minimum 4-inch (10 cm) soil core perpendicular to the soil core length. Hold the core with moderate confining pressure so as not to deform the soil core. Slowly insert the pocket penetrometer tip into the perpendicular face of the soil core until the pocket penetrometer indents the soil core to the mark indicated on the piston of the penetrometer. The pocket penetrometer estimate of the soil compressive strength (Su) is the direct reading of the value mark on the graduated shaft indicated by the shaft ring marker, or by the graduated piston reading at the shaft body. For average estimates, complete this procedure several times on the ends and middle of the soil core. For Shelby tube samples (or thin wall samplers), perform the pocket penetrometer test at several locations on the exposed ends of the sample.

In situ shear vane tests or other test methods provide better compressive strength estimates for very soft to stiff consistency clay soil.

Describing soil consistency is an important component in evaluating the engineering properties and strength characteristics of fine-grained cohesive soil. Consistency terms like soft and hard are based on the unconfined compressive strength (Su) and shear strength or cohesion (cu) of the soil.

Patterns of soil gas and groundwater movement in fine-grained soil are influenced by natural soil structure. Soil structure is dependent on the depositional method and to a lesser extent climate. The identification of fill soil is equally important in determining soil characteristics in fine-grained soils.

5.8 PROCEDURES FOR SURFICIAL SOIL SAMPLING

This section provides a limited discussion on considerations for the design of a soil sampling program in order to provide the sampling team members with a basic understanding of those considerations.

5.8.1 BACKGROUND

Soil sampling locations are selected in order to obtain representative soils with the minimum number of samples. Prior to conducting an investigation, a site inspection may eliminate many uncertainties with respect to site characteristics and result in a more complete soil sampling study. The site inspection should identify pertinent features (e.g., rock outcrops, drainage patterns, surface runoff, surface cover characteristics (e.g., grass, gravel, concrete), wet areas, and fill areas) and evaluate the relationship between those features and potential sources of contaminants. An understanding of these relationships and conditions is important in developing a sampling plan.

5.8.2 RANDOM, BIASED, AND GRID-BASED SAMPLING

Unless there is a strong indication of contaminant presence, such as staining, soil sample locations may be randomly selected from several areas within the site, such as near obvious potential sources of current or historic contamination. Potential sources include large transformers, aboveground storage tanks (ASTs), mandoors, outdoor storage racks, and drainage swales.

If an area shows evidence of contamination, such as staining or vegetative stress, biased samples are collected from the area to characterize the contamination. Background and control samples are also biased, since they are collected in locations typical of non-site-impacted conditions.

When a soil sampling investigation involves a large area, grid-based soil sampling is performed. There is no single grid size that is appropriate for all sites. Common grid sizes are developed on 50- and 100-foot (15 to 30 m) centers. It is acceptable to integrate several different grid sizes in a single investigation.

For a surficial soil sampling program, it is also important to consider the presence of structures and drainage pathways that might affect contaminant migration. It is sometimes desirable to select sampling locations in low-lying areas which are capable of retaining some surface water flow since these areas could provide samples which are representative of historic site conditions (worst-case scenario if surface water flow is a concern).

5.8.3 SAMPLE INTERVAL

Surficial soil is generally considered to be soil between ground surface and 6 to 12 inches (15 to 30 cm) below ground surface. However, for risk assessment purposes, regulatory authorities often consider soil from ground surface to 2 feet (0.6 m) below ground surface to be surficial soil.

Note: Ontario regulations state that surficial soils are 0 to 6 inches (0 to 15 cm) below ground surface.

The exact interval to be considered as surficial soil is often a matter of discussion with the regulatory authorities that review the Work Plan. The sample interval is important to the sample collection method and to the manner in which the data are ultimately interpreted. Another important factor is the type of soil. If there are different types of soil present at the site, this may have a bearing on the sample interval. For example, it may be important to separately sample a layer of material with high organic carbon content which overlies a layer of fine-grained soil.

5.8.4 PROCEDURES FOR SURFICIAL SAMPLING

Soil sampling methods are dependent upon the sample interval of interest, the type of soil material to be sampled, and the requirements for handling the sample after retrieval. The most common method for collection of surficial soil samples is the use of a stainless steel trowel. Soil samples may also be collected with spoons and push tubes. Often a shovel is required to open a trench such that sampling can be conducted. Soil that has come in contact with the shovel cannot be used as sample material.

In all cases, the sampling device must be constructed of an inert material with smooth surfaces which can be easily decontaminated. The decontamination protocol employs a sequence of cleaning agents and water designed to remove surface contaminants (refer to Section 5.6). All sampling equipment is cleaned between sample locations. A typical surficial soil sampling protocol is outlined below:

1. Collect surficial soil samples using a precleaned stainless steel trowel or other appropriate tool. Each sample consists of soil from the surface (or other starting depth) to the depth specified in the Work Plan. Sample in ditches only when there is no water present.
2. Use a new pair of disposable gloves at each sample location.
3. Prior to use, at each sample location, decontaminate all sampling tools as specified in the Work Plan or as described in Section 5.5.
4. Use a precleaned sampling tool to remove the sample from the layer of exposed soil. Place the collected soil directly into a clean, prelabeled sample jar and seal with a Teflon-lined cap. If a sample is to be split for duplicate analyses, first homogenize the soil in a precleaned stainless steel bowl.
5. After collection, place the samples on ice or cooler packs in a laboratory-supplied cooler.

Surficial debris (e.g., grass cover) should be removed from the area where the sample is to be collected using a separate precleaned device.

In the event that soil conditions are not as described in the Work Plan, or if there are unexpected distinct layers of soil present (e.g., a layer of high organic carbon content overlying a layer of fine-grained soil), sampling personnel should immediately report the conditions to the Project Coordinator for direction. Similarly, if a sampling location is in a gravel or paved area, sampling personnel should confirm with the Project Coordinator whether the surface samples are to be collected from the gravel/pavement subbase material or from the first layer of soil beneath these layers.

Also, sampling team members should immediately report any conditions to the Project Coordinator that they believe may have a negative effect on the quality of the results.

It is generally inadvisable to collect samples containing excessive amounts of large particles such as gravel. Gravel presents difficulties for the laboratory in terms of sample preparation and the results may not be truly representative of contaminant concentrations in nearby soil.

All conditions at the time of sample collection are properly documented in a field log book. This includes a thorough description of the sample characteristics including grain size, color, and general appearance; date/time of sampling; and labeling information. The location of the sampling point is described in words, and three measurements are taken from adjacent permanent structures so that, if necessary, the sample location can be readily identified in the field at a future date. It is often advisable to have a licensed land surveyor accurately survey the locations.

Soil samples are homogenized in a stainless steel bowl prior to filling sample containers. This step can be bypassed if only one sample container is required to be filled, as long as the laboratory will homogenize the sample upon receipt. It is important that soil samples be mixed thoroughly to ensure that the sample is as representative as possible of the sample interval. When using a round bowl, mixing is achieved by stirring the material in a circular motion and occasionally turning the material over. Fill the sample container completely, leaving no headspace.

Do not mix soil for samples for VOC analyses as this promotes the partial volatilization of compounds from the soil.

In 1997, EPA adopted new methods for sampling soils for VOC analysis. Method 5035 calls for collecting soil using a coring device (EnCore). For analysis of low level VOCs (typically 1 to 200 μg/kg), soil is sealed in a specially prepared vial with a solution of sodium bisulfate. For higher levels of VOCs, the soil is placed in a vial with a volume of methanol. This method increases the complexity of collecting soils and makes it imperative that the sampler and laboratory work closely together. For some soil sampling programs, multiple EnCores are required for each sample interval. The number of EnCores required per sample interval should be ascertained during the prior planning and preparation stage.

Discrete Grab Sampling Methodology for Surficial Soils

Discrete grab sampling is employed when the sampling location is considered to be a small area (approximately 1 square foot [0.1 square meter]) that has both a consistent soil type and a consistent level of contaminant impact.

When collecting a discrete grab surficial soil sample, use the following procedure:

1. Using the sampling device (e.g., trowel, spoon, Oakfield sampler) scoop soil from the top 2 inches (5 cm) into the sample container. If the sample is being collected for VOC analyses, perform this step as quickly as possible in order to minimize the loss of volatile compounds from the soil.
2. Collect a field screening sample from the same sampling location as the discrete grab sample and at the same time. Scoop soil into a zip-loc bag until it is no more than one quarter full.
3. Do not mix the soil for samples collected for VOC analyses (for sample homogenization purposes) as this will promote the loss of volatile compounds from the soil. The laboratory will obtain a representative sample from the container by using coring techniques before the laboratory analysis is performed.

Composite Sampling Methodology for Surficial Soils

A composite sample can be obtained directly from the soil surface by combining a number of discrete grab samples from a number of sampling locations on the soil surface. For preparation of a meaningful composite sample, the soils from the sub-samples taken from the different sampling locations should have (by visual observation) similar contaminant concentrations.

When collecting a composite surface soil sample, use the following procedure:

1. Choose a number of discrete sampling locations that will give a representative sample of the defined composite area at each sampling location.
2. Using the sampling device (e.g., trowel, spoon), scoop the soil from the top 2 inches (5 cm) into the sample container. As much as practical, try to put approximately the same volume of soil from each sampling location into the container.
3. Move to the next sampling location and repeat steps 1 and 2.
4. Collect a maximum of five surface samples (to avoid the complete dilution of any hot spots).
5. When the last location has been sampled, ensure the sample container is filled with soil, leaving no headspace.
6. Since composite samples are used for semi-volatile organic compounds (SVOCs) and inorganic parameters, minimizing the sample collection time is not as important as when discrete samples for VOC analyses are being collected. However, the preferred practice is that the sampler take no longer than necessary to obtain the sample.

7. Collect a field screening sample from the same sampling location as the composite sample and at the same time. As much as practical, try to put approximately the same volume of soil from each discrete grab sampling location into a zip-loc bag. The zip-loc bag should be no more than one quarter full after all the sub-samples have been added.

Since composite samples are not analyzed for VOCs, there is no reason to avoid mixing the sub-samples from the various sampling locations in the sample container (homogenization). However, since the laboratory will use coring techniques to ensure that a sample is representative of the entire container, there is no need to perform field homogenization of the soil within the sample container.

During the sampling program, the sampling team leader will stay in contact with the CRA chemist assigned to the project such that the CRA chemist can properly inform the contract laboratory of the progress of the work. This includes submitting sample summaries and/or copies of completed chain-of-custody forms to the CRA chemist.

Finally, some CRA QAPPs require a designation of a QA/QC officer for field activities. The sampling team leader may be required to conduct certain field audit activities and, at minimum, should be familiar with and responsible for completion of all QA/QC sample activities.

5.9 PROCEDURES FOR BOREHOLE INSTALLATION AND SAMPLING

Once the prior planning and preparation activities are completed, the drilling program can proceed. The typical series of events that takes place is:

1. Locating and marking boring locations.
2. Initiation of a Property Access/Utility Clearance Data Sheet (QSF-019), including obtaining appropriate signoffs by the client representative and drilling subcontractor representative.
3. Contractor mobilization; equipment and material check.
4. Site selection of decontamination pad and drum staging area (if applicable); final visual examination of proposed drilling area for utility conflicts.
5. Decontamination of sampling and drilling equipment prior to use in accordance with the Work Plan or as described in Section 5.6.
6. Borehole advancement utilizing the approved method as outlined in the Work Plan.
7. Soil sample collection; descriptions of the soil samples in accordance with CRA protocol.
8. Monitoring well installation (if applicable).
9. Sample preparation and packaging.
10. Abandonment of boreholes or installation of monitoring wells.
11. Collection of groundwater samples (if monitoring wells are installed).
12. Surveying of borehole location and elevations.
13. Field note completion and review.

5.9.1 LOCATION AND MARKING OF DRILL SITES/FINAL VISUAL CHECK

The proposed borehole locations marked on the site plan are located in the field and staked. On most sites, this will likely be done several days in advance of the drill rig arriving on site. Unless boreholes are to be installed on a fixed grid, the proposed locations are usually strategically placed to assess site conditions.

Note:	*Any borehole (and all the records thereof) which is completed with casing as a temporary or permanent monitoring well, will be designated by the monitoring well number only (i.e., MW1-yy). Boreholes drilled strictly as soil test borings in which no casing is set (even if an open-hole groundwater sample is collected) will be designated by the boring number only (i.e., BH1-yy).*

Once the final location for the proposed boring has been selected and utility clearances are complete, one last visual check of the immediate area should be performed before drilling proceeds. This should confirm the locations of any adjacent utilities (subsurface or overhead) and verification of adequate clearance. If gravity sewers or conduits exist in the area, any access manholes or chambers should be opened and the conduit/sewer alignments confirmed. Do not enter manholes unless confined space procedures are followed.

If possible, it is prudent to use a hand auger or post-hole digging equipment to a sufficient depth to confirm that there are no buried utilities or pipelines. Alternatively, a Hydrovac truck can vacuum a large diameter hole to check for utilities, although soils collected this way may require containment on site. This procedure generally clears the area to the full diameter of the drilling equipment which will follow.

Caution:	*Do not assume site plan details regarding pipe alignments/position are correct. Visually check pipe position when drilling near sewers. Personnel should also be alert to additional piping presence if the plans are outdated.*

If it is necessary to relocate a proposed borehole due to terrain, utilities, access, etc., the Project Coordinator must be notified and an alternate location will be selected.

5.9.2 SAMPLE COLLECTION

A boring is advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the Project Coordinator or Work Plan. Typically, the depth interval for sampling is 2.5 to 5 feet (0.75 to 1.5 m), or less in homogeneous strata, with at least one test and sampling location at every change of stratum. In some cases samples are taken continuously (i.e., 2-foot (0.6 m) long samples at 2-foot (0.6 m) intervals).

Collected soil samples are described in the field using the USCS (visual-manual procedure). The soil description is recorded on a Stratigraphic Log (Overburden) (Form SP-14) or field book in the following order:

1. USCS Soil Symbol of major component
2. Native or fill
3. Secondary and minor soil components
4. Relative densities/consistency
5. Grain-size/plasticity
6. Gradation/structure
7. Color
8. Moisture content
9. Observations of odor or visual chemical presence (i.e., non-aqueous phase liquid [NAPL])
10. Additional descriptions

For environmental sampling, always change gloves between collecting subsequent soil samples to prevent cross-contamination. Decontaminate all tools (e.g., samplers, spatulas) prior to use on each sample to prevent cross-contamination in accordance with the Work Plan or as described in Section 5.6.

Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler, and assures that the standard penetration test (SPT) or other sampling technique is performed on essentially undisturbed soil, is acceptable. The drilling method is selected based on the subsurface conditions. Each of the following methods has proven to be acceptable for specific subsurface conditions:

- HSA with inside diameter between 2.5 and 6.25 inches (5.7 to 15.9 cm)
- Solid stem auger (SSA) with auger diameter between 2.5 and 6.25 inches (5.7 to 15.9 cm)
- Direct-push (dual tube systems, discrete soil sample systems)
- Open-hole rotary drilling
- Wash boring

Several drilling methods are not acceptable. These include:

- Jetting through an open tube sampler and then sampling when the desired depth is reached
- SSA use below the groundwater table in non-cohesive soils
- Casing driven below the sampling depth prior to sampling
- Advancing a borehole with bottom discharge bits
- Advancing a boring for subsequent insertion of the sampler solely by means of previous sampling when performing SPT (the open hole must be larger in diameter than the split-spoon sampler)

Discrete Grab Sampling Methodology for Boreholes

When borehole drilling, the split-spoon sample retrieved from the borehole is considered a discrete grab sample that has been taken from one sampling location, as long as both the stratigraphy of the entire sample and the level of contamination are consistent over the length of the split-spoon sample. If a single split-spoon sample contains soils from two different stratigraphic units, the soils from each of these stratigraphic units are considered separate discrete grab samples.

If a single split-spoon sample contains soils from a single stratigraphic unit, but visual observation indicated that some of the soil was heavily impacted with contaminants, while the rest of the soil was only lightly impacted, then the soils representing each of the two levels of contamination are considered two separate discrete grab samples.

Composite Sampling Methodology for Boreholes

A composite sample is obtained by combining a number of discrete grab samples from the same borehole. For preparation of a meaningful composite sample, the soils from the sub-samples taken from the different split-spoon samples should be from a single stratigraphic unit and have (by visual observation) similar contaminant concentrations (or be physically similar for geotechnical testing purposes).

Use the following methodology for preparing a composite sample from these discrete grab split-spoon samples:

1. Prior to collecting a sample of the soil for field vapor screening or chemical analysis, if smearing of soil is apparent on the outside of the soil core, scrape away the outer layer of the soil using a decontaminated putty knife, stainless steel spoon, or similar implement. This should only be performed if the soil core sample is consolidated. Do not use this procedure for unconsolidated soil samples.
2. Split the sample longitudinally along the length of the split-spoon sampler. Use one half of the core sample to prepare a composite sample to be used in soil headspace vapor screening measurements, and the other half to prepare a composite sample to be submitted to the laboratory for chemical analysis or geotechnical testing.
3. Place sub-samples from various sampling locations (i.e., split-spoon samples) into a zip-loc bag for field screening. As much as practical, attempt to place approximately the same volume of soil from each sampling location into the zip-loc bag.
4. For samples where laboratory analysis is also desired, place sub-samples from various sampling locations into the appropriate soil sample containers. As much as practical, attempt to place approximately the same volume of soil from each sampling location into the sample container.

The following subsections describe specific protocols for split-spoon sampling, Shelby tube sampling, and methods for collecting soil samples using a direct-push rig.

5.9.2.1 SPLIT-SPOON SAMPLERS

This method is used to obtain representative samples of subsurface soil materials and to determine a measure of the in situ relative density of the subsurface soils. The test methods described below must be followed to obtain representative samples.

SPT involves the use of split-barrel samplers (also known as split spoons). Split-spoon sampling is performed in accordance with ASTM D1586. The split-spoon sampler consists of an 18- or 24-inch (45 or 60 cm) long, 2-inch (5 cm) outside diameter tube, which comes apart lengthwise into two halves. An example of a split-spoon sampler is presented on Figure 5.2.

Note:	*A typical 2-inch (5 cm) outside diameter split-spoon is 1 3/8-inch (3.5 cm) diameter at the drive shoe and 1 1/2-inch (3.8 cm)diameter within the barrel of the split spoon. The volume of the soil in a completely filled 24-inch (61 cm) long split-spoon is approximately 19.8 oz (586 mL), thus the sample volume requirements are important if multiple types of parameters requiring differing analytical techniques are required (i.e., VOCs, SVOCs, metals, petroleum hydrocarbon compounds [PHC]). Soil recovery in a split spoon is often less than 24 inches (61 cm), resulting in less available volume.*

Once the borehole is advanced to the target depth and cleared of cuttings, representative soil samples are collected in the following manner:

1. The split-spoon sampler is inspected to ensure it is properly cleaned and decontaminated. The driving shoe (tip) should be relatively sharp and free of severe dents and distortions.
2. The cleaned split-spoon sampler is attached to the drill rods and lowered into the borehole. Do not allow the sampler to drop onto the soil in the bottom of the borehole.
3. After the sampler has been lowered to the bottom of the hole, it is given a single blow to seat it and make sure that it is in undisturbed soil. If there still appears to be excessive cuttings in the bottom of the borehole, remove the sampler from the borehole and remove the cuttings.
4. Mark the drill rods in three or four successive 6-inch (15 cm) increments, depending on sampler length, so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-inch (15 cm) increment.

The sampler is then driven continuously for either 18 or 24 inches (45 or 60 cm) by use of a 140-pound (63.5 kg) hammer. The hammer may be lifted and dropped by either the cathead and rope method, or by using a trip, automatic, or semi-automatic drop system. The hammer should free-fall a distance of 30 inches (±1 inch) (75 cm, ±25 mm) per blow. Measure the drop at least daily to ensure that the drop is correct. To ensure a free-falling hammer, no more than 2 1/4 turns of the rope may be wound around the cathead (see ASTM D1586). The number of blows applied in each 6-inch (15 cm) increment is counted until one of the following occurs:

1. A total of 50 blows have been applied during any one of the 6-inch (15 cm) increments described above
2. A total of 100 blows have been applied
3. There is no advancement of the sampler during the application of ten successive blows of the hammer (i.e., the spoon is 'bouncing' on a stone or bedrock)
4. The sampler has advanced the complete 18 or 24 inches (45 or 60 cm) without the limiting blow counts occurring as described above

In some cases where the limiting number of blow counts has been exceeded, CRA may direct the driller to attempt to drive the sampler more if collection of a greater sample length is essential, as long as the sampler is still being advanced.

On the field form, record the number of blows required to drive each 6-inch (15 cm) increment of penetration. The first 6 inches (15 cm) is considered to be a seating drive. The sum of the number of blows required for the second and third 6 inches (15 cm) of penetration is termed the "standard penetration resistance" or the "N-value".

Note: If the borehole has sloughed and there is caved material in the bottom, the split spoon may push through this under its own weight, but now the spoon is partially 'pre-filled'. When the spoon is driven the 18 or 24 inches (45 or 60 cm) representing its supposedly empty length, the spoon fills completely before the end of the drive interval. Three problems arise:

1. *The top part of the sample is not representative of the in-place soil at that depth.*
2. *The SPT value will be artificially higher toward the bottom of the drive interval since the spoon was packed full. These conditions should be noted on the field log.*
3. *The available sample volume is significantly reduced.*

The sampler is then removed from the borehole and unthreaded from the drill rods. The open shoe (cutting end) and head of the sampler are partially unthreaded by the drill crew and the sampler is transferred to the geologist/engineer work surface.

Note: A table made out of two sawhorses and a piece of plywood is appropriate, or a drum, both covered with plastic sheeting.

The open shoe and head are removed by hand by the drill crew or CRA representative, and the sampler is tapped so that the tube separates.

Note: Handle each split spoon with clean disposable gloves if environmental samples are being collected from that split-spoon sample.

Measure and record the length of sample recovered making sure to discount any sloughed material that is present on top of the sample core.

Caution must be used when conducting split-spoon sampling below the groundwater table, particularly in sand or silt. These soils tend to heave or "blow back" into the HSA due to the difference in hydraulic pressures between the inside of the HSA and the undisturbed soil. To equalize the hydraulic pressure, it may be necessary to fill the inside of the HSA with potable water from a reliable and pre-tested source. Drilling mud is uncommonly used and presents problems for sample collection and well development. The water level within the boring or HSA needs to be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling. Since heave or blow back is not always obvious to the driller, it is essential that the water level in the borehole always be maintained at or above the groundwater level. Split-spoon sampling below the water table in sands and silt occasionally results in non-representative samples being collected due to the heaving effect disturbing the soil. This is particularly important if the water level in the hole has not been maintained at the in situ water level.

Heaving conditions and the volume of potable water used should be noted on a Stratigraphic Log (Overburden) (Form SP-14). The volume of water added must be removed during well development prior to groundwater sampling. This practice may not be acceptable if environmental samples are to be collected.

Suspected low N-values should be noted on the field logs. If it is critical to have accurate N-values below the water table, other methods can be employed, such as conducting a dynamic cone penetration test. This quick and easy test involves attaching a cone shaped tip to the end of the drill rods, and driving the tip into the ground similar to the split-spoon method, except that the borehole is not pre-augered. Cones may be driven 20 to 40 feet (6.1 to 12.2 m) through a formation without augering. Blow counts are recorded for each 1 foot (0.3 m) of advancement. Consult the Project Manager if such conditions are unexpectedly encountered.

Note:	*A 3-inch (7.5 cm) outside diameter split spoon is available in order to obtain larger sample volumes. However, the SPT values from driving this sampler are typically much higher than those for the 2-inch (5 cm) split spoon.*

Larger-Diameter Barrels

A variation of split-barrel sampling involves the use of a longer, larger diameter barrel in conjunction with a HSA. The sampling barrel is installed inside the auger with a swivel attachment to limit rotation of the barrel. After completion of a 5-foot (1.5 m) auger penetration, the auger is left in place and the barrel retrieved from the borehole. This method provides a larger diameter core, which may be desirable for bench-scale testing or where a large volume of soil is required for sample analyses. The sampler should be handled and the sample retrieved in the same way as described above for split-spoon sampling.

5.9.2.2 SHELBY TUBE SAMPLERS

Thin-walled samplers such as Shelby tubes are used to collect relatively undisturbed samples (as compared to split-spoon samples) of soft to stiff clayey soils. The Shelby tube has an outside diameter of 2 or 3 inches (5 to 7.5 cm) and is 3 feet (0.9 m) long. These undisturbed samples are used for certain laboratory tests of structural properties (consolidation, hydraulic conductivity, shear strength) or other tests that might be influenced by sample disturbance. Procedures for conducting thin-walled tube sampling are provided in ASTM D1587, and are briefly described below:

1. The soil deposit being sampled must be cohesive in nature, and relatively free of gravel and cobble materials, as contact with these materials will damage or collapse the sampler.
2. Clean out the borehole to the sampling elevation using whatever method that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above groundwater level during the sampling operation.
3. Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted.
4. Remove loose material from the center of the casing or HSA as carefully as possible to avoid disturbance of the material to be sampled.
5. Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler into the formation without rotation by a continuous and relatively rapid motion. Usually hydraulic pressure is applied to the top of the drill rods.
6. Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.
7. In no case should the length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 inches (7.5 cm) for cuttings.
8. The tube may be rotated to shear the bottom of the sample 2 to 3 minutes after pressing in, and prior to retrieval to ensure the sample does not slide out of the tube. Lift the weight of the rods off of the tube prior to rotating.
9. Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.
10. Package and transport the sample in accordance with project-specific requirements.

Occasionally, the Project Manager/Coordinator may require extraction of the sample from the tube in the field. Use the following procedure:

1. A sample extruder, which consists of a clamp arrangement to hold the tube and a hydraulic ram to push the sample through the tube, is usually provided by the driller. To prevent cross-contamination, ensure the extruder is field cleaned between each sample.
2. The sample is then extruded into a carrying tray; these are often made from a piece of 4-inch (10 cm) or 6-inch (12.5 cm) diameter polyvinyl chloride (PVC) pipe cut lengthwise. Ensure the

carrying tray is field cleaned between each sample. The sample is carried to the work station for geologic description. Trim the potentially cross-contaminated exterior and place it in the appropriate container.

3. The Shelby tube sampler is then thoroughly field cleaned and decontaminated for reuse. Since they are thin-walled, the tubes are easily damaged, crimped, or otherwise distorted during handling or pushing. The Shelby tube should be inspected before use and, if significantly damaged, rejected.

5.9.2.3 DIRECT-PUSH SAMPLING SYSTEMS

Direct-push refers to the sampler being 'pushed' into the soil material without the use of rotation to remove the soil. This method relies on the drill unit static weight combined with rapid hammer percussion for advancement of the tool string. Soil samples are continuously obtained. Groundwater and vapor samples can also be collected utilizing this method and appropriate tooling. Subsurface investigations typically sample to depths of 30 feet (9.1 m) or more; however, depth will vary based on the site-specific geology.

Direct-push methods are widely used for underground storage tank (UST) investigations and property investigations. This method is used extensively for initial site screening activities to establish site geology and to delineate vertical and horizontal plume presence. Small diameter wells (3/4 or 1 inch [2 or 2.5 cm]) diameter can be installed using direct-push methods, often using a pre-packed screen. SPT values cannot be obtained when sampling with a direct–push discrete soil sampler.

This method is also popular due to the limited cuttings produced during the drilling and sampling process and the increased sampling process speed, which can be much quicker than the sample description and sample preparation process. (It is often helpful to have two people, depending on the nature of the work program.)

Continuous soil samples are collected in tube samplers (various lengths), affixed with a cutting shoe and internal liner (PVC, Teflon, or acetate are available). The soil sampler may be operated in open-mode (when borehole collapse is not a concern), or closed-mode (when minimization of sample slough is desired). Closed-mode operation involves the placement of a temporary drill-point in the cutting shoe and driving the assembled sampler to depth. Once at the required depth, the temporary drill–point is released (via internal threading) and the sampler is driven to the desired soil interval. The drill-point slides inside the sample liner, riding above the collected soil column. Once driven to depth, the sampler is retrieved to the ground surface and the sample liner with soil, is removed for examination.

Caution: *Be careful when opening interval liners with knives, as severe cuts may result from the knife slipping. A special two-blade hooked knife is available for opening the liners. Generally the driller/helper will open the liner for you.*

5.9.3 FIELD SAMPLE SCREENING

When soil sampling at sites with known or suspected VOC impact, it is often required to measure the soil for the presence of undifferentiated organic vapors. This field screening can be performed using a photoionization detector (PID). Immediately upon the opening of the split-spoon or discrete soil sampler, the soil is screened with a PID (HNu, Microtip, or equivalent) for the presence of undifferentiated organic vapors. This is accomplished by running the PID along the length of the soil sample. Record the highest reading.

Note:	*The PID measurement must be taken upwind of the drill rig or any running motors so that exhaust fumes will not affect the measurements.*

Another method of field screening is head space measurement. This consists of placing a portion of the soil sample in a sealable glass jar, placing aluminum foil over the jar top, and tightening the lid. The jar is only partially filled. The jar is shaken and set aside for at least 30 minutes. After the sample has equilibrated, the lid of the jar is opened, the foil is punctured with the PID probe, and the air (headspace) above the soil sample is monitored. Record this headspace reading on the field form or in the field book. As an alternative, the soil can be placed in a sealable zip-loc bag.

Note:	*Perform headspace readings in an area that is not subject to wind. Also, in the winter, it is necessary to allow the samples to equilibrate in a warm area to ±70°F (20°C (e.g., site trailer or van, but not direct heat or sunshine). The portion of the sample used for headspace analysis cannot be used for VOCs analysis.*

Representative portions of the soil sample must be retained for geologic record following description. Place the soil portions into labeled, sealable sample containers (usually mason jars or zip-loc bags) without destroying any apparent stratification. If a stratigraphic change is observed within the split-spoon sampler, a separate geologic record sample is kept.

All geologic record samples are to be retained by the client. Geologic record samples must not return to or be placed in storage at a CRA office. An example of a properly completed Stratigraphy Log (Overburden) is presented on Figure 5.2.

5.9.4 CHEMICAL DESCRIPTION

During soil examination and logging, carefully check for the presence of light or dense NAPL. NAPL may be present in gross amounts or present in small/minute quantities. The adjectives and corresponding quantities used when describing NAPL within a soil matrix are as follows:

Visual Description	*Fraction of Soil Pore Volume Containing NAPL*
Saturated	>0.5
Some	0.5 - 0.25
Trace	<0.25

A complete description of NAPL must describe the following:

- Color
- Quantity
- Density (compared to water) (i.e., light/floats or heavy/sinks)
- Odor (if observed)
- Viscosity (i.e., mobile/flowable, non-mobile/highly viscous-tar like)

The presence of an "iridescent sheen" by itself does not constitute "NAPL presence", but may be an indicator that NAPL is close to the area.

NAPL presence within a soil matrix may be confirmed by placing a small soil sample within water, shaking, and observing for NAPL separation (i.e., light or dense) from the soil matrix.

Trace amounts of NAPL are identified/confirmed by a close visual examination of the soil matrix, (i.e., separate soil by hand, wearing disposable gloves) and performing a careful inspection of the soil separation planes/soil grains for NAPL presence.

Often during sample examination with a knife, an iridescent sheen will be noted on the soil surface (i.e., clay/silts) if the knife has passed through an area of NAPL.

There are a number of more complicated tests available to confirm/identify NAPL presence, these are:

- Ultraviolet (UV) fluorescent analysis
- Hydrophobic dyes (use with care, consult the health and safety SOPs as some hydrophobic dyes are potential human carcinogens)
- Centrifugation
- Chemical analysis

CRA typically utilizes organic vapor detection results, visual examination, soil/water shake testing, and chemical analysis, to confirm NAPL presence. The more complex techniques described may be incorporated on sites where clear colorless NAPL is present and its field identification is critical to the program.

5.9.5 CHEMICAL SAMPLE PREPARATION AND PACKAGING

Subsurface soil samples are usually grab samples, used to characterize the soil at a specific depth or depth interval (e.g., 2 to 4 feet [0.6 to 1.2 m]). On occasion, composite samples are collected from a borehole over a greater depth interval (e.g., 5 to 15 feet [1.5 to 4.1 m]).

The following describes the collection of grab samples for chemical analysis (all soil from one split spoon). Figure 5.2 shows the split-spoon sample selection details.

Clayey Soils

1. Discard upper and lower ends of sample core (3 inches [7.5 cm])
2. Use a precleaned stainless steel knife
3. Cut the remaining core longitudinally
4. With a sample spoon, remove soil from the center portion of the core and place in a precleaned stainless steel bowl
5. Remove large stones and natural vegetative debris
6. Homogenize the soil and place directly into sample jars

Note:	*Samples for VOC analysis* ***must not be homogenized****. Collect soil from the length of the center portion of the core and place in the sample container. Completely fill the container. No air space (headspace) should remain in the sample container.*

Sandy Soils

As sandy soils have less cohesion than clayey soils, it is not easy to cut the core longitudinally to remove the center of the sample. Therefore, with a stainless steel spoon, scrape away surface soils which have likely contacted the sampler and then sample the center portion of the soil core.

Note:	*Place all soil samples collected for chemical analysis immediately into a cooler with ice.*

Record all soil samples in the sample log book. Label samples as specified in Section 3.9.1.2.

In 1997, EPA adopted new methods for sampling soils for VOC analysis. Method 5035 calls for collecting soil using a coring device (EnCore). For analysis of low-level VOCs (typically 1 to 200 µg/kg) soil is commonly sealed in a specially prepared vial with a solution of sodium bisulfate. For higher levels of VOCs, the soil is placed in a vial with a volume of methanol. This method increases the complexity of collecting soils and makes it imperative that the sampler and laboratory work closely together. For some soil sampling programs, multiple EnCores are required for each sample interval. Holding times for samples in EnCores may be 24 to 48 hours if not field preserved; therefore, the CRA sampler, laboratory, and CRA chemist should discuss sampling and shipping procedures prior to beginning the work program.

5.9.6 PHYSICAL SAMPLE PREPARATION AND PACKAGING

When a sample is collected for geotechnical or hydrogeologic properties, the sample needs to be prepared and packaged in a manner to maintain its physical properties. Soil samples are usually grab samples, collected from a specific depth or depth interval (e.g., 2 to 4 feet [0.6 to 1.2 m]). On occasion, composite samples are collected from the borehole over a greater depth interval (e.g., 5 to 15 feet [1.5 to 4.6 m]).

The following describes the collection of grab samples for geotechnical or hydrogeologic purposes for common samplers, the split-spoon, thin-wall, and direct-push discrete soil sampler. For soil samples collected for geotechnical purposes, the samples must not be allowed to freeze.

5.9.6.1 SPLIT-SPOON SAMPLES

1. Following completion of PID screening of the split spoon, remove and dispose of soil at the top of the sample that is obviously sloughed material not representative of the soil at the sampled depth.
2. Measure the length of the sample and record as the recovered length.
3. If cohesive, perform a pocket penetrometer reading and describe the soil.
4. Carefully transfer the sample onto a sheet of aluminum or tin foil, taking care to maintain structure and bedding of the soil sample as much as possible. This may not be possible with non-cohesive soils with low silt or clay contents. The sample may need to be packaged in three 6- to 8-inch (15 to 20 cm) segments.
5. Roll the sample in the tin foil and fold over the ends to seal. Wrap in a second layer of tin foil.
6. Identify the top, middle, and bottom segments with a T, M, and B using an indelible marker.
7. For each segment record the "up" direction with an arrow.
8. Place the foil wrapped sample in a plastic bag and write the sample identification on the bag using an indelible marker. Storing the sample in foil, as opposed to a jar, has the advantage of retaining the soil's in-place structure and preventing loss of moisture.
9. If the soils are sandy and it is not possible to retain the soils structure by rolling it in tin foil, packaging the sample in a jar or zip-loc bag is also acceptable, provided the jar or zip-loc bag is filled to eliminate air space which could result in the soil sample drying out.

A split-barrel sample is approximately 4 inches (10 cm) in diameter and requires different handling than a split-spoon or Shelby tube sample. For a cohesive core sample, the section of drill core is wrapped in several layers of cheesecloth, coated with paraffin wax, and the process repeated until the entire sample is sealed adequately. These samples are usually utilized for specific bench-scale tests.

5.9.6.2 SHELBY TUBE SAMPLES

1. Remove any sloughed material from the top of the sample using a knife or similar long bladed instrument. If it is not possible to distinguish sloughed soil from intact soil, do not remove.
2. Following removal of sloughed material, measure the tube length and the air space in the tube above the sample and record the difference as the sample recovery. In the unusual circumstance that there is also air space at the bottom of the sample, subtract this as well and record this latter measurement as a separate entry.
3. Seal the top and bottom of the sample with wax (wax is normally provided and prepared by the driller) and first pour the liquefied wax into the top of the sample to a thickness of about 1 inch (2.5 cm). Once this is cooled, remove approximately 1/2 inch (1.3 cm) of soil from bottom of sample (unless there is already a cavity at bottom of sample) and seal similarly.
4. Fill the remaining air space above the sample with loose soil to prevent the sample from shifting in the tube, and then cap both ends of the sample with plastic caps. Tape the caps on using duct tape.
5. Write the sample identification number on the cap using an indelible marker.

Shelby tubes containing soft clays and wet silts need to be handled with care to avoid damage to the sample. Keep samples in an upright position at all times and transport either in a specifically designed cushioned box or position in your vehicle with cushioning under and around the individual tubes. Do not allow geotechnical soil samples to freeze.

5.9.6.3 DIRECT–PUSH SOIL SAMPLES

1. Once removed to the ground surface, open the discrete soil sampler by removing the cutting shoe, and extract the soil liner (with recovered soil) from the sampler body.
2. Place the soil liner into a holder and cut lengthwise (using a liner knife) to expose the collected soil core.
3. Perform PID screening for organic vapors and record readings.
4. Measure length of sample and record as the recovered length.
5. If cohesive, perform pocket penetrometer reading and describe soil.
6. Carefully transfer the sample onto a sheet of aluminum or tin foil taking care to maintain structure and bedding of the soil sample as much as possible. This may not be possible with non-cohesive soils with low silt or clay contents. The sample may need to be packaged in multiple 6- to 8-inch (15 to 20 cm) segments.
7. Roll the sample in the tin foil and fold over the ends to seal. Wrap in a second layer of tin foil.
8. Identify the depth interval of each segment using an indelible marker.
9. For each segment record the "up" direction with an arrow.

10. Place the foil-wrapped sample in a plastic bag and write the sample identification on the bag using an indelible marker. Storing the sample in foil, as opposed to a jar, has the advantage of retaining the soil's in-place structure and preventing loss of moisture. If the soils are sandy and it is not possible to retain the soils structure by rolling it in tin foil, packaging the sample in one or more jars or zip-loc bags is also acceptable, provided each jar or bag is filled to eliminate air space which could result in the soil sample drying out.

The soil core is split lengthwise to allow inspection. Chemical samples can be removed from the soil core (if required), or soil record samples can be retained (if a component of the project scope). Soil record samples are often retained to allow sample collection for analysis later (depending upon analyte sensitivity/holding times), or for later inspection/geotechnical testing if required.

5.9.7 COMMUNICATION OF FIELD FINDINGS

Field findings should be communicated frequently with the office technical staff responsible for the program. This communication allows the office staff to: confirm that the investigation meets the intent of the Work Plan; alter procedures and sampling protocol if soil conditions are markedly different from those assumed; and assist in determining screening intervals for piezometers or monitoring wells.

Call office staff no later than the completion of the first borehole, and sooner if possible. Be prepared to discuss the results by faxing the field logs beforehand (wherever possible) and by having a copy of the field log in hand when on the telephone. Call after each borehole and call before leaving the site.

5.9.8 BOREHOLE ABANDONMENT

Following completion of the borehole it must be properly abandoned in accordance with the project documents. Some jurisdictions have requirements or standards of practice that require filling the borehole with bentonite or cement grout.

Note:	*The integrity of any underlying confining layer must be restored to prevent chemical cross-contamination or hydraulic cross-connection. This is true for all sites, regardless of the known presence or absence of contaminants. This normally requires grouting of the borehole within the zone of the confining layer.*

Whenever possible, the cuttings are returned to the borehole to within 1 foot (0.3 m) of the ground surface. The remainder of the borehole is topped off with material consistent with the surrounding ground surface. Excess cuttings are usually collected in drums or a lugger box or spread on the surrounding ground surface consistent with the protocols specified in the Work Plan and as required by federal, state, provincial, and local regulations.

Check with the Project Coordinator to determine the method for handling drill cuttings.

Note:	*Always include the method of abandonment in the field log book or on a Stratigraphic Log (Overburden) (Form SP-14)*

5.9.9 BOREHOLE TIE-IN/SURVEYING

Recording the locations of boreholes on the site plan is extremely important, and may be accomplished by manual measurement (i.e., swing ties) and surveying. Manual measurements for each borehole must be tied into three permanent features (e.g., buildings, utility poles, hydrants). Include diagrams with measurements in the field book.

In addition to manual measurements, surveying with respect to a geodetic benchmark and a site coordinate system is often completed at larger sites for horizontal and vertical control.

Note:	*Manual field measurements are always necessary regardless of whether a survey is completed.* *Manual measurements in field notes allow future identification of the sample/drill site without the need for a survey crew to locate positions using a grid system. This becomes important when trying to locate flushmount wells buried by snow or soils.*

5.9.10 FIELD NOTES

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

Field notes documenting events, equipment used, and related items are typically recorded in a standard CRA field book, while soil descriptions and PID readings are recorded on a Stratigraphic Log (Overburden) (Form SP-14). Standard CRA field books are available from all CRA equipment administrators. Form SP-14 is available as a printable linked document in this file or as a bound pad from each office.

Note:	*Use a Stratigraphic Log (Overburden) for recording all soil descriptions and related notes unless otherwise approved by the Project Coordinator/Manager.*

Field book/form entries are made in black ink and any changes/corrections are stroked out with a single line, initialed, and dated to indicate when and by whom the correction was made.

The field notes should document the following for each borehole completed:

1. Identification of borehole
2. Depth

3. Static water level depth and measurement technique
4. Time started and completed
5. Measured field parameters
6. Sample appearance
7. Sample odors (if respiratory protection is not required)
8. Types of sample containers and sample identification numbers
9. Parameters requested for analysis
10. Field analysis data and method(s)
11. Sample distribution and transporter
12. Laboratory shipped to
13. Chain-of-custody number for shipment to laboratory
14. Field observations on sampling event
15. Name of collector(s)
16. Climatic conditions including air temperature
17. Problems encountered and any deviations made from the established sampling protocol

5.10 PROCEDURES FOR TEST PIT EXCAVATION AND SAMPLING

Once the prior planning and preparation activities are completed, the test pit excavation and subsurface soil sampling program can proceed. The typical series of events which takes place is:

1. Location and marking of test pit locations
2. Final visual examination of proposed excavation area for utility conflicts
3. Excavation of test pits and collection of the soil samples
4. Field screening of soil sample with specific air monitoring equipment (e.g., PID, LEL meter)
5. Description of soil sample and test pit
6. Completion of Test Pit Stratigraphy Log (Form SP-03)
7. Documentation, including photographs and/or videotape, as required
8. Chemical sample preparation and packaging
9. Backfilling of test pit excavation
10. Surveying of test pit locations
11. Field note completion and review.

5.10.1 LOCATION AND MARKING OF TEST PITS/FINAL VISUAL CHECK

Proposed test pit locations marked on the site plan are located in the field and staked. The proposed test pit locations are usually strategically placed to assess site conditions, former facilities, waste areas, etc.

Once the final location for the proposed test pit has been selected and utility clearances are complete, one last check of the immediate area is performed before excavation proceeds to confirm the locations of any adjacent utilities (subsurface or overhead) and verify adequate clearance. If gravity sewers or conduits exist in the area, any access manholes or chambers are opened and the conduit/sewer alignments confirmed.

***Caution**: Do not assume site plan details regarding pipe alignments/position are correct. Visually check pipe position when excavating near sewers. Personnel should also be alert to the presence of additional piping, especially if the plans are outdated.*

If it is necessary to relocate a proposed test pit due to terrain, utilities, access etc., the Project Coordinator must be notified and an alternate location will be selected.

5.10.2 TEST PIT LOCATION SETUP

The test pit location is set up as follows:

1. The excavator is positioned such that the excavation spoils are deposited by the excavator downwind of all staff
2. A sheet of polyethylene is placed downwind of the test pit location to accept spoils, if required by the Work Plan
3. To the extent practicable, the investigation area is set up such that water or liquids that may be excavated, freely drain back into the excavation
4. The excavation begins at one location with the excavator backing up (as required) to extend the pit

5.10.3 SAMPLE COLLECTION

Soil samples can be collected from the backhoe/excavator bucket or from the test pit excavation face. Samples which require a discrete depth interval are collected from the excavator bucket following excavation of all or a portion of the test pit. Samples are collected using a cleaned steel trowel, shovel, or stainless steel spoon. Samples are placed in a stainless steel bowl and mixed (except VOCs). **Do not enter the test pit**. (Confined Space Entry requirements apply and proper shoring of the excavation walls may be necessary.)

Caution:	*Personnel observing or sampling test pit operations must never stand within the "turning radius" or "reach-zone" of the excavation equipment. Operator error or equipment failure could result in severe injury or death if struck by the backhoe bucket or the backhoe itself. Stand opposite the backhoe well beyond the far end of the trench for communication.* *Personnel should also be alert to test pit side wall conditions which typically undermine the ground surface and create unstable soils surrounding the test pit area.*

Discrete Grab Sampling From Test Pits

When taking discrete grab samples from a test pit using an excavator bucket, the sampling location is considered a volume of soil in the bucket that has both a consistent soil type and a consistent level of contaminant impact. When sampling using an excavator bucket, the operator will dig to the desired depth and then provide a small volume of soil from a discrete position and depth in the test pit.

When collecting a discrete grab sample from the excavator bucket, use the following procedure:

1. Scrape off the top 2 inches (5 cm) of soil at the sampling location in the excavator bucket.
2. Using the sampling device (e.g., trowel, spoon) scoop the freshly exposed soil into the sample container. Ensure that the samples taken were not in contact with the excavator bucket to avoid the potential for cross-contamination.
3. Pushing the sample container into the soil in order to fill the container is not recommended. This could result in breaking the sample container and potential injury to field personnel (e.g., cutting hands on broken glass).
4. If the sample is being collected for VOC analyses, perform this step as quickly as possible in order to minimize the loss of volatile compounds from the soil.
5. Collect a field screening sample from the same sampling location as the discrete grab sample and at the same time. Scoop soil into a zip-loc bag until it is no more than one quarter full.
6. Do not mix the soil for samples collected for VOC analyses (for sample homogenization purposes) as this will promote the loss of volatile compounds from the soil. The laboratory will obtain a representative sample from the container by using coring techniques before the laboratory analysis is performed.

Composite Sampling

A composite sample can be obtained by combining a number of discrete grab samples from a test pit sampling location (i.e., excavator bucket). For preparation of a meaningful composite sample, the soils from the sub-samples taken from the different sampling locations should be from a single stratigraphic unit and have (by visual observation) similar contaminant concentrations.

When taking composite samples from multiple excavator buckets, consider each excavator bucket of soil to be a sampling location. When taking a composite sample using the excavator, use the following procedure:

1. Pick a number of discrete sampling locations that will give a representative sample of the horizon of interest in the test pit.
2. From each of these sampling locations, obtain a soil sample from the excavator bucket using the same methodology described in the previous subsection for a discrete grab sample.
3. The sample container should be partially filled with soil from each discrete grab sampling location. As much as practical, try to put approximately the same volume of soil from each sampling location into the container.
4. Move to the next sampling location and obtain another discrete grab soil sample.
5. Collect a maximum of five surface samples (to avoid the complete dilution of any hot spots).
6. When the last location has been sampled, ensure the sample container is filled with soil, leaving no headspace.
7. Since composite samples are used for SVOCs and inorganic parameters, minimizing the sample collection time is not as important as when discrete samples for VOC analyses are being collected. However, the preferred practice is that the sampler take no longer than necessary to obtain the sample.
8. Collect a field screening sample from the same sampling location as the composite sample and at the same time. As much as practical, try to put approximately the same volume of soil from each discrete grab sampling location into a zip-loc bag. The zip-loc bag should be no more than one quarter full after all the sub-samples have been added.

5.10.4 FIELD SAMPLE SCREENING

Upon collection of a soil sample, the soil is screened with a PID (HNu, Microtip, or equivalent) for the presence of undifferentiated organic vapors. This is accomplished by running the PID across the soil sample. Record the highest reading and sustained readings.

Note:	*The PID measurement must be taken upwind of the excavating equipment or running motors so that exhaust fumes will not affect the measurements.*

Another method of field screening is head space measurement. This consists of placing a portion of the soil sample in a sealable glass jar, placing aluminum foil over the jar top, and tightening the lid. The jar should only be partially filled. Shake the jar and set aside for at least 30 minutes. After the sample has equilibrated, open the lid of the jar, puncture the foil with the PID probe, and monitor the air (headspace) above the soil sample. Record this headspace reading on a Test Pit Stratigraphy Log (Form SP-03) or in the field book.

Note:	*Perform all headspace readings in an area that is not subject to wind.* *Also, in winter it is necessary to allow the samples to equilibrate in a warm area (e.g., site trailer or van). This requirement is usually dictated by the Work Plan.*

5.10.5 SAMPLE DESCRIPTION AND LOGGING OF TEST PITS

During the excavation of a test pit, samples may be collected to provide a geologic record, to assist the geologist/engineer in completing or characterizing the stratigraphic units, and to allow for physical or chemical testing.

Soil samples collected are described in the field using the USCS. The soil descriptions are recorded on the field form or field book in the following order:

1. USCS Soil Symbol of major component
2. Native or fill
3. Secondary and minor soil components
4. Relative densities/consistency
5. Grain size/plasticity
6. Gradation/structure
7. Color
8. Moisture content
9. Observations of odor or visual chemical presence (i.e., NAPL)

In addition to describing the soil properties, enter the following information into a Test Pit Stratigraphy Log (Form SP-03):

1. Presence of groundwater and the rate of seepage (if groundwater is encountered)
2. Thickness of each stratigraphic unit
3. Description of bedding plane features (e.g., continuous, discontinuous, graded, wavy bedding)
4. Description of joints, fractures and faults, if bedrock is encountered (number and orientation)
5. Any appearance of weathering
6. Description of fill and waste materials

Note: When describing observed odors, be specific in terms of general odor category and strength of odor noted. Odors may typically be chemical, petroleum, or septic related, varying from slight, to moderate, to strong. Identification of specific chemical compounds (i.e., TCE or C-56 odor) is usually unnecessary and often inaccurate as a detailed analysis commonly shows an array of chemistry present.

When describing the presence of vegetative matter in the soil sample, do not use the term "organic" as this often leads to confusion with regards to the presence of organic chemicals (i.e., NAPL).

When describing the soil samples and the stratigraphy observed in the test pit, it is imperative that the sampler use consistent terms from one test pit to the next. As test pits are installed, compare the stratigraphy of completed test pits to the stratigraphy of the test pit you are currently excavating. Be aware of patterns and confirm all inconsistencies at the time the test pit is being excavated. Since soil stratigraphy is so important to understanding site conditions, soil samples are collected from each stratigraphic unit, and described in full.

5.10.6 CHEMICAL DESCRIPTION

Representative portions of the soil sample should be retained as a geologic record along with a description. Place the soil portions into labeled, sealable, sample containers (usually mason jars) without destroying any apparent stratification.

All geologic record samples are to be retained by the client. Geologic record samples must not return to or be placed in storage at a CRA office.

An example of a properly completed Test Pit Stratigraphy Log is presented on Figure 3.12 and described in Section 3.4.1.5.

During soil examination and logging, carefully check for the presence of light or dense NAPL. NAPL may be present in gross amounts or present in small/minute quantities. The adjectives and corresponding quantities used when describing NAPL within a soil matrix are as follows:

Visual Description	*Fraction of Soil Pore Volume Containing NAPL*
Saturated	>0.5
Some	0.5 - 0.25
Trace	<0.25

A complete description of NAPL includes the following:

- Color
- Quantity
- Density (compared to water) (i.e., light/floats or heavy/sinks)
- Odor (if observed)
- Viscosity (i.e., mobile/flowable, non-mobile/highly viscous-tar like)

The presence of an iridescent sheen by itself does not constitute NAPL presence, but may be an indicator that NAPL is close to the area.

NAPL presence within a soil matrix may be confirmed by placing a small soil sample within water, shaking, and observing for NAPL separation (i.e., light or dense) from the soil matrix.

Trace amounts of NAPL are identified/confirmed by a close visual examination of the soil matrix, (i.e., separate soil by hand [wearing disposable gloves]) and perform a careful inspection of the soil separation planes/soil grains for NAPL presence.

Often during the sample examination with a knife, an iridescent sheen will be noted on the soil surface (i.e., clay/silts) if the knife has passed through an area of NAPL.

There are a number of more complicated tests available to confirm/identify NAPL presence, these are:

- UV fluorescent analysis
- Hydrophobic dyes
- Centrifugation
- Chemical analysis

CRA typically utilizes organic vapor detection results, visual examination, soil/water shake testing, and chemical analysis, to confirm NAPL presence. The more complex techniques described may be incorporated on sites where clear colorless NAPL is present and its field identification is critical to the program.

5.10.7 CHEMICAL SAMPLE PREPARATION AND PACKAGING

Subsurface soil samples are usually grab samples, used to characterize the soil at a specific depth or depth interval (e.g., 2 to 4 feet [0.6 to 1.2 m]). On occasion, composite samples are collected from a test pit over a greater depth interval (e.g., 5 to 15 feet [1.5 to 4.6 m]).

The following describes the collection of grab samples for chemical analysis.

Clayey Soils

Scrape away the surface soils and collect the sample. Remove large stones and natural vegetative debris and homogenize the soil and place it directly into the sample jars.

Note:	*Samples for VOC analysis must not be homogenized. Remove the outer layer of soil from the excavation face then collect the sample and place it in the sample container. Completely fill the container. No air space (headspace) should remain.*

Sandy Soils

As sandy soils have less cohesion than clayey soils, with a stainless steel spoon or other device scrape away surface soils which have likely contacted the backhoe/excavator bucket, then collect the sample.

Note: All soil samples collected for chemical analysis must be placed immediately into a cooler with ice.

Record all soil samples recorded in the sample log book as described in Section 3.4.1. Labeling of samples shall be consistent with Section 3.9.1.2.

5.10.8 DOCUMENTATION

In addition to completing all field logs and books, it will generally be necessary for test pits to be documented with photographs and/or video tape. This requirement should be fully ascertained and coordinated in advance of field activities.

5.10.9 TEST PIT ABANDONMENT

Following completion of the test pit, backfill the excavation using the soil excavated from the pit. To the extent practicable, replace materials in the test pit in the same intervals from which they were extracted.

It should be noted that the material will tend to "bulk" after excavation. As a result, the excavator operator must be informed to compact the materials as they are replaced within the excavation.

5.10.10 RESTORATION

The test pit location must be fully restored. Ensure that restoration activities are properly designed and incorporated within the scope of services for the test pit contractor.

Restoration could include:

- Landscaping
- Paving
- Concrete

5.11 FOLLOW-UP ACTIVITIES

Complete the following activities at the conclusion of the field work:

1. Double check the Work Plan to ensure all samples have been collected and confirm this with the Project Coordinator.
2. Ensure that all sample locations are surveyed such that the sample location could be readily re-established.

3. Clean equipment and return to the equipment administrator with the appropriate form dated and signed. Complete water disposal (if required), and cleaning fluid disposal requirements as specified in the Work Plan.
4. Notify the contract laboratory as to when to expect the samples. Enclose the chain-of-custody and covering letter, indicating the parameters and number of samples, in the sample cooler. Ensure that the CRA chemist has all relevant information required to track the progress of the sample analysis.
5. Submit a memo to the Project Coordinator indicating sampling procedures and observations (such as surface staining), grid layout, and all QA/QC documentation.
6. Prepare and distribute a Project Planning, Completion, and Follow-Up Checklist (Form SP-02).

5.12 REFERENCES

For additional information pertaining to this topic, the user of this manual may reference the following:

Surficial Soil Sampling

ASTM D4547	Practice for Sampling Waste and Soils for Volatile Organics
ASTM D6044	Guide for Representative Sampling for Management of Waste and Contaminated Media
ASTM D6051	Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities

Subsurface Soil Sampling

ASTM D420	Guide for Site Characterization for Engineering, Design, and Construction Purposes
ASTM PS 89	Guide for Expedited Site Characterization of Hazardous Waste Contaminated Sites
ASTM D5434	Guide for Field Logging of Subsurface Explorations of Soil and Rock
ASTM D2487	Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D2488	Practice for Description and Identification of Soils (Visual-Manual Procedure)
ASTM D5781	Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
ASTM D5782	Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
ASTM D5783	Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
ASTM D5784	Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

ASTM D5872	Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
ASTM D5875	Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
ASTM D5876	Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
ASTM D4700	Guide for Soil Sampling from the Vadose Zone
ASTM D1586	Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils
ASTM D1587	Practice for Thin-Walled Tube Geotechnical Sampling of Soils
ASTM D4220	Practices for Preserving and Transporting Soil Samples
ASTM D6001	Guide for Direct-Push Water Sampling for Geoenvironmental Investigations

CRA FIELD TRAINING MANUAL

SECTION 7.0:

WATER SAMPLING STANDARD OPERATING PROCEDURES

A. GROUNDWATER
B. RESIDENTIAL
C. SURFACE WATER

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PLEASE ADHERE TO THE FOLLOWING QUALITY SYSTEM TRAINING REQUIREMENTS:

- **Employees who are required to conduct a specific field activity must be properly certified to do the work.**
- **This involves reviewing the SOP and completing the online training course and exam.**
- **Employees must also conduct this field work under supervised conditions on at least three occasions, and must be certified by a qualified mentor. Only then can an employee conduct a specific field activity on their own. This is documented on a Field Method Training Record (QSF-021).**
- **Complete the QSF-021 and forward it to trainingrecords@craworld.com.**
- **Please note that three topics are discussed in this SOP. A separate QSF-021 is required for each topic**:
  - **Groundwater Sampling**
  - **Residential Water Sampling**
  - **Surface Water Sampling**

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SP-05 GROUNDWATER SAMPLING EQUIPMENT AND SUPPLY CHECKLIST

SP-06 WELL DEVELOPMENT AND STABILIZATION FORM

SP-07 WELL PURGING FIELD INFORMATION FORM

SP-08 SAMPLE COLLECTION DATA SHEET - GROUNDWATER SAMPLING PROGRAM

SP-09 MONITORING WELL RECORD FOR LOW-FLOW PURGING

SP-17 EQUIPMENT AND SUPPLY CHECKLIST - SURFACE WATER SAMPLING, SEDIMENT SAMPLING, AND FLOW MEASUREMENT

LIST OF QUALITY SYSTEM FORMS

QSF-012 VENDOR EVALUATION FORM

QSF-014 FIELD EQUIPMENT REQUISITION FORM

QSF-019 PROPERTY ACCESS/UTILITY CLEARANCE DATA SHEET

QSF-021 FIELD METHOD TRAINING RECORD

QSF-030 SAFETY AND HEALTH SCHEDULE (CANADA)

QSF-031 SAFETY AND HEALTH SCHEDULE (U.S.)

7.0 WATER SAMPLING (GROUNDWATER, RESIDENTIAL, AND SURFACE WATER) STANDARD OPERATING PROCEDURES

7.1 INTRODUCTION

Groundwater, residential, and surface water sampling are conducted in order to characterize the groundwater and surface water quality at a site. Standard Operating Procedures (SOPs) are presented herein for the collection of groundwater and surface water samples from:

- Monitoring wells
- Residential wells
- Surface water bodies

This guideline is not intended to provide the basis for designing a groundwater or surface water monitoring program, but instead assumes that a groundwater and/or surface water monitoring program has already been designed. It is also assumed that a site-specific Work Plan has been established and that a CRA representative is preparing to mobilize to the site.

Groundwater and surface water sampling procedures vary from project to project due to:

- Different chemicals of concern
- Different guidance provided by local, provincial/state, and/or federal regulatory agencies with jurisdiction at the site
- The specific objectives of the project

It is essential that all groundwater, residential, and surface water sampling activities conform to local, state/provincial, and federal regulations. Therefore, it is essential that the CRA representative carefully reviews the Work Plan requirements. The primary goal of groundwater, residential, and surface water sampling is the collection of samples representative of the hydrostratigraphic unit and/or surface water body. It is necessary to use appropriate sampling techniques to collect representative samples that provide reliable and reproducible results in accordance with the Work Plan and all relevant regulations.

The remainder of this section is organized as follows:

- Section 7.2 Background
- Section 7.3 Planning and Preparation
- Section 7.4 Safety and Health
- Section 7.5 Quality Assurance/Quality Control
- Section 7.6 Equipment Decontamination
- Section 7.7 Field Procedures for Groundwater Sampling
- Section 7.8 Field Procedures for Residential Sampling

- Section 7.9 Field Procedures for Surface Water Sampling
- Section 7.10 Follow-Up Activities
- Section 7.11 References

7.2 BACKGROUND

The objective of a groundwater and residential monitoring program is to obtain samples that are representative of existing groundwater conditions, or samples that retain the physical and chemical properties of groundwater in the hydrostratigraphic unit. Surface water sampling is performed to collect samples that are representative of physical and chemical properties of surface water bodies. Improper sampling and transport practices will cause compounds of interest to be removed or added to a sample prior to analysis. The importance of proper and consistent field sampling methods cannot be over emphasized. It is equally important that proper documentation occurs throughout the sampling program.

The most important aspect of groundwater sampling is the collection of groundwater samples that are free of suspended silt, sediment, or other fine-grained material. Fine-grained material has a variety of chemical compounds sorbed to the particles or has the ability to sorb chemicals from the aqueous phase. This causes a bias in the subsequent analytical results. Reproducible and reliable analytical data are invaluable to a groundwater monitoring program. CRA frequently criticizes the sampling activities completed by others due to the collection and analyses of turbid samples. This SOP discusses sampling protocols that typically achieve sediment-free samples.

When sampling for monitored natural attenuation (MNA) parameters, more stringent protocols are followed to ensure sediment-free samples that are representative of the total mobile load (i.e., dissolved and naturally suspended particles). Low-flow purging (LFP) techniques are strongly recommended, if not mandated, when collecting groundwater samples for MNA parameters. The LFP techniques detailed in Section 7.7.5.3 are in accordance with United States Environmental Protection Agency (USEPA) LFP procedures (Puls and Barcelona, 1996).

Groundwater sampling is required for various reasons, including:

- Investigating potable or industrial water supplies
- Tracking contaminant plumes
- Investigating a site with suspected groundwater contamination

Groundwater is usually sampled from in-place wells, installed either temporarily or permanently. Municipal, industrial, or residential wells may also be sampled during an investigation. When completing residential well sampling it is important that representative samples are collected. Poor or incorrect sampling techniques will result in erroneous results. Incorrect results disclosed to the public

will create a false impression, making it difficult to change the perception when correct results are reported.

Groundwater and residential sample collection are performed from non-impacted to most impacted locations. This eliminates the potential for cross-contamination. A review of all historical analytical data is performed to ensure the exact sampling sequence.

Surface water sampling locations are selected based on many factors including:

- The study objectives
- The location of point source discharges
- The location of no-point source discharges and tributaries
- The presence of structures (e.g., bridges, dams)
- Accessibility

Surface water sampling should be performed from downstream to upstream locations. This ensures that surface water sampling activities do not cause suspended sediments to bias samples collected downstream.

7.3 PLANNING AND PREPARATION

Prior to groundwater, residential, and surface water sampling:

1. Review the Work Plan, project documents, and Site-Specific Health and Safety Plan (HASP) with the Project Manager/Coordinator.
2. Review the Quality Assurance Project Plan (QAPP) with the Project Coordinator and Project Chemist to determine Quality Assurance/Quality Control (QA/QC) and decontamination requirements.
3. Complete a Field Equipment Requisition Form (QSF-014). Assemble all sampling equipment and supplies required per the Groundwater Sampling Equipment and Supply Checklist (Form SP-05). The Project Planning, Completion, and Follow-Up Checklist (Form SP-02) should be used for guidance throughout the project.
4. Assemble the site plan, well logs, and previous sampling/purging data required for the sampling event. Determine the exact number and locations of wells to be sampled.
5. Obtain all forms to record purging and sampling activities (Forms SP-06, SP-07, SP-08, and SP-09).
6. Confirm with the Project Manager/Coordinator that a Property Access/Utility Clearance Data Sheet (QSF-019) has been completed. For residential sampling, ensure that homeowners have been notified of the intended sampling event. Confirm the presence of any dogs on site, modify the site-specific Job Safety Analysis, if there is a dog.

7. Arrange access to the site. Obtain all well and site keys. Consider site access conditions (e.g., snow).

8. For surface water sampling consider if hazards exist due to deep/fast moving water, difficult access, and if additional CRA personnel are required for safety and health reasons.

9. For residential sampling contact homeowners to make arrangements for a site visit, arrange for site dog to be removed from all areas where a CRA employee will be working. The client of another party may be responsible for making arrangements.

10. Complete a Vendor Evaluation Form (QSF-012) and file in the Project file for any Vendors that do not have full approval status or are not listed on the Approved Vendor List (QSL-004). Completion of a Safety and Health Schedule (QSF-030 for Canadian work; QSF-031 for U.S. work) is necessary for all Vendors who complete field services. Prior to mobilization on site, the Vendor must submit the form to the Regional Safety and Health Manager for review and approval (if not already posted on QSL-004).

11. Contact the CRA Chemistry group to arrange:
    - SSOW (Simplified Scope of Work)
    - Laboratory
    - Sample containers delivery
    - Preservatives if required
    - Filtration information if required
    - Coolers
    - Shipping details
    - Sample starting date
    - Expected duration of sampling program

12. If several sampling events are planned, evaluate with the client the benefit of purchasing and installing dedicated sampling equipment. Dedicated purging and sampling equipment reduces potential cross-contamination and reduces decontamination requirements. At a minimum, sample tubing is dedicated to each well and is left secured in the well for future use. For LFP it is recommended that each well is dedicated with a bladder pump and tubing to eliminate well disturbance.

13. Evaluate sample notification needs with the Project Coordinator. Have the regulatory groups, client, landowner, CRA personnel, and laboratory been notified of the sampling activities?

14. Evaluate containment and disposal requirements for purge waters.

15. Plan sampling activities to ensure that wells that historically go dry or have poor recharge fit into the sampling program. This will reduce the time required for sample collection.

16. Plan the sequence of sampling activities to reduce the potential for cross-contamination. For groundwater sampling, start with clean wells and progress to impacted wells. For surface water sampling, start downstream and progress upstream.

7.4 SAFETY AND HEALTH

CRA is committed to conducting field activities in accordance with sound safety and health practices. CRA adheres to high safety standards to protect the safety and health of all employees, subcontractors, customers, and communities in which they work. The safety and health of our employees takes precedence over cost and schedule implications.

Field personnel are required to implement the Safety Means Responsibility Awareness Teamwork (SMART) program as follows:

- Assure the HASP is specific to the job and approved by a Regional Safety & Health Manager.
- Confirm that all HASP elements have been implemented for the job.
- A Job Safety Analysis (JSA) for each task has been reviewed, modified for the specific site conditions, and communicated to all appropriate site personnel. The JSAs are a component of the HASP.
- Incorporate Stop Work Authority; Stop, Think, Act, Review (STAR) process; Safe Task Evaluation Process (STEP); Observations process; Near Loss and Incident Management process in the day-to-day operations of the job.
- Review and implement applicable sections of the CRA Safety & Health Policy Manual.
- Confirm that all site personnel have the required training and medical surveillance as defined in the HASP.
- Be prepared for emergency situations, locating safety showers, fire protection equipment, evacuation route, rally point, and first aid equipment before you begin working, and make sure that the equipment is in good working order.
- Maintain all required Personal Protective Equipment (PPE), safety equipment, and instrumentation necessary to perform the work effectively, efficiently, and safely.
- Be prepared to call the CRA Incident Hotline at 1-866-529-4886 for all involving injury/illness, property damage, vehicle incident, and/or significant Near Loss.

It is the responsibility of the Project Manager to:

- Ensure that all CRA field personnel have received the appropriate health and safety and field training and are qualified to complete the work
- Provide subcontractors with a Job Hazard Analysis to enable them to develop their own HASP
- Ensure that all subcontractors meet CRA's (and the Client's) safety requirements

7.5 QUALITY ASSURANCE/QUALITY CONTROL

A well-designed QA/QC program will:

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

It is important to note that a QA/QC program should be developed on a site-specific basis. QA/QC requirements are discussed in Section 3.9.

7.6 EQUIPMENT DECONTAMINATION

Equipment decontamination procedures for a groundwater, residential, or surface water monitoring program will be described in detail in the site-specific Work Plan or in the QAPP.

Equipment is decontaminated between sampling locations and prior to leaving the site. Upon completion of the sampling program, all equipment is decontaminated at the site and then returned clean to the appropriate field equipment manager.

For most groundwater, residential, and surface water sampling programs, sampling equipment (e.g., pumps, bailers, water level indicators) is typically cleaned as follows:

1. Wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates.
2. Rinse with tap water.
3. Rinse with deionized water.
4. Air dry for as long as possible.

If required, the following steps may be added when sampling for Volatile Organic Compounds (VOCs) and metals:

1. Rinse with 10 percent nitric acid (only if samples are to be analyzed for metals).
2. Rinse with deionized water.
3. Rinse with appropriate solvent (pesticide grade isopropanol, methanol, acetone, hexane, if required).
4. Rinse again with deionized water.
5. Air dry for as long as possible.

6. Wrap samplers in aluminum foil to prevent contamination.

***Caution**: Check the QAPP to confirm the cleaning protocol. Use of incorrect cleaning protocol could invalidate chemical data.*

7.6.1 PURGE WATER AND DECONTAMINATION FLUID DISPOSAL

Project-specific disposal methods for purged groundwater and decontamination fluids are determined by the Project Manager during the sampling program's planning and preparation stage (see Section 7.3), but may include:

1. Off-site treatment at private treatment/disposal facility or publicly owned treatment facilities (sanitary sewer)
2. On-site treatment at a client-operated facility
3. Direct discharge to the surrounding ground surface, allowing infiltration to the underlying subsurface
4. Direct discharge to an impervious pavement surface allowing for evaporation

Options 3 and 4 are permitted only after careful review of these practices and the anticipated site conditions. Under no circumstances shall CRA personnel aggravate an existing condition or spread contamination into clean areas.

Decontamination fluids (specifically cleaning solvents/acids) are segregated and collected separately from wash water and purge water. Often small volumes of solvents used during the course of a groundwater, residential, or surface water sampling program will evaporate if left in an open pail. If evaporation is not possible, off-site disposal need to be arranged.

7.7 FIELD PROCEDURES FOR GROUNDWATER SAMPLING

The typical series of events that takes place for a groundwater sampling program is:

1. Well identification and inspection
2. Air monitoring
3. Water level monitoring
4. Well depth sounding
5. Well volume calculation
6. Purging and sampling equipment installation
7. Well purging and stabilization monitoring
8. Sample collection, sample preparation, completion of chain-of-custody, (COC) sample packaging

9. Final water level monitoring (if required), purging, sampling equipment removal, secure the well
10. Equipment decontamination
11. Field note completion and review
12. Sample shipment and COC distribution
13. Purged groundwater and decontamination fluid disposal
14. Sample record documentation, equipment return
15. Completion and distribution of appropriate forms

It is recommended that new plastic sheeting be placed on the ground around the well to prevent contamination of purging and sampling equipment and accessories (e.g., pumps, hoses, rope.).

7.7.1 WELL IDENTIFICATION AND INSPECTION

At sites with numerous wells or wells nests, misidentification of wells has occurred. The CRA representative must be alert to the possibility of potential cap switching, mislabeled wells, or unlabeled well locations.

Determine proper well location and identification by comparing the well log details to the measured well depths (i.e., total well depth, casing diameter, casing stick-up, or stick-down distances), field tie-ins, and site plan.

Once well identification has been established, complete a thorough well inspection:

1. Determine if the well cap and lock are secure, and check for vandalism
2. If no lock is present, dedicate a new lock to the well location
3. Examine the integrity of the surface seal
4. Check for cracks, evidence of frost heave, or subsidence in the vicinity of the well
5. Examine the integrity of the protective casing. Ensure that the casing can be closed and locked
6. If required, re-label the well to assist in future identification
7. If the well is installed with dedicated sampling equipment, check for cracks or leaks in tubing, and worn or frayed rope
8. Record all the well inspection details in the field book to document well conditions and suitability for groundwater sampling activities
9. Forward the well inspection results to the Project Coordinator, especially if repairs are required

7.7.2 AIR MONITORING

Prior to removing a well cap, measure the breathing space above the well with a photoionization detector (PID) to establish background of undifferentiated organic vapor levels. Repeat this process once the well cap has been removed. If either of the PID levels exceed the air quality criteria established in the HASP, air-purifying respiratory (APR) protection or a supplied air system is required. Also take a PID reading inside the riser pipe. This PID reading is a good indication of elevated chemical or non-aqueous phase liquids (NAPL) presence. Report all elevated PID levels to the Project Coordinator immediately to determine if additional health and safety and personnel protective equipment is required. The HASP will provide the required action levels and PPE.

7.7.3 WATER LEVEL MONITORING/WELL DEPTH SOUNDING

Prior to commencing well purging and groundwater sampling, the water level is measured for hydraulic monitoring and to determine the well volume. Typically, a complete round of water level measurements is taken at a site to establish groundwater conditions prior to initiating well purging or groundwater sampling activities.

A watertight cap provides an airtight seal on the casing and the water level positioned in the casing area. The cap creates a vacuum or pressurized condition in the casing section which can support or depress the water column in the well casing. This can produce an artificially high or low water level in the well casing. This effect can cause a few inches or feet of error in the static water level. Once the cap is removed, allow the pressure to stabilize for about a half hour. Measure the water level frequently to ensure that stabilization of the water level has occurred. Once the water level has stabilized (i.e., is static) the correct water level may be measured.

A number of instruments are available to measure groundwater levels. CRA typically uses:

- Battery-operated water level indicators (i.e., audible and/or visual identification of water level)
- Battery-operated oil/water interface probes (i.e., audible and/or visual identification of water levels and presence of NAPL)
- Electronic transducers (numerous manufacturers) and recording devices for long-term hydraulic monitoring
- Stevens™ recorders (both float and electronic instrumentation) for long-term hydraulic monitoring

Section 8.0 describes in detail the equipment and monitoring techniques for water level measurements.

Well depth sounding is often required to confirm well identification, evaluate the accumulation of sediment in the well bottom, or assist in determining the standing well volume. Sounding is performed using a water level indicator or a measuring tape with a weighted end. The water level indicator or weighted tape is lowered to the bottom of the well and a comparison is made of the installed well depth

versus the measured well depth. The presence of excessive sediment or drill cuttings may warrant redevelopment of the well prior to well purging and groundwater sampling activities.

The total well depth is compared to the original installed total well depth. If the well screen is more than 50 percent blocked by accumulated sediment, the well is redeveloped prior to the next groundwater sampling event. Report all wells requiring redevelopment to the Project Coordinator. Well depth sounding is performed on an annual or biannual basis if the well is equipped with a dedicated pump.

For LFP, well depth measurement is performed to ensure proper pump intake placement. The used of a wide-based probe, such as a weighted tape, is necessary to minimize penetration and disturbance of accumulated sediment. The measuring device is lowered slowly through the water column to the well bottom to minimize mixing of the stagnant well casing water and disturbance of sediment.

Note:	*Don't forget that decontamination procedures apply to the water level monitoring equipment as well as the groundwater sampling equipment. If well sounding is performed, the entire measuring device must be thoroughly decontaminated prior to re-use. Measuring the well depth with certain water level indicators may damage the probe seal. Therefore, a tape with a weighted end should be used to measure well depth.*

7.7.4 WELL VOLUME CALCULATION

Prior to commencing well purging, the volume of water in the well must be known to determine the volume of groundwater to be removed. A well volume is defined as the volume of water contained in the well screen and casing (and in the case of an open bedrock hole, the volume of water in the open corehole and possibly in the well casing). To determine the standing water volume in a well:

1. Calculate the distance from the bottom of the well to the static water level.
2. Measure the inside diameter of the well or casing. Obtain the volume of standing water in the well using the following formula:

$$V = \pi r^2 h \text{ (7.48 U.S gallons/cubic feet) (1 liter/1,000 cubic centimeters)}$$

where:

V = volume of water in gallons or liters
π = 3.142
r = radius of well casing (feet or meters)
h = depth of water column in the well (feet or meters)

Typical 1-Foot Casing Volumes	
Diameter (inches)	*Gallons (U.S.) of Water Per Foot of Casing*
1.5	0.09
2	0.16
3	0.37
4	0.65
6	1.47

Typical 1 Meter Casing Volumes		
Diameter		*Litres per Meter of Casing*
(inches)	*(cm)*	
1.5	3	1.14
2	5	2.02
3	8	4.56
4	10	8.11
6	15	18.24

7.7.5 WELL PURGING AND STABILIZATION MONITORING

7.7.5.1 TYPICAL METHOD

Prior to initiating groundwater sample collection, the wells is purged of the standing stagnant groundwater volume. This volume is not representative of the groundwater in the hydrostratigraphic unit. Purging is performed until the water in the well is representative of the actual conditions in the hydrostratigraphic unit. Stabilization is usually achieved by the removal of three to five times the volume of standing water in the well (USEPA convention). Purging is considered complete once purged groundwater is free of sediment and field parameters including specific conductance, temperature, and turbidity are stable. Stabilization is achieved when field measurements for specific conductance and temperature are within a range of plus or minus 10 percent of the average for the last three readings. Field measurement for pH should be within a range of plus or minus 0.1 pH unit of the average for the last three readings, and groundwater turbidity values should be less than 5 nephelometric turbidity units (NTU) (guidance value only). Once the number of well volumes required to achieve stabilization is established, the volume required to reach stabilization for future sampling events is reduced or eliminated. Extended purging of a well will generally result in achieving sediment-free groundwater conditions.

During purging, if stabilization has not occurred after removal of five well volumes, purging is continued until ten well volumes have been removed. If stabilization still has not been achieved, stabilization may be dropped as a pre-condition to groundwater sampling. The Project Coordinator should be notified that stabilization has not occurred after the removal of ten well volumes.

At high yielding wells, removing three to five well volumes is usually sufficient prior to initiating groundwater sampling. For low yield wells (i.e., wells that pump dry after one well volume) it is necessary to purge the well dry on three successive days, unless the well recovers to full static conditions in a shorter time. If the recharge is relatively high, groundwater sampling will be initiated once the well has fully recovered to static groundwater conditions, or to a level that is sufficient to collect the necessary groundwater sample volume.

Note: Purging of dry wells should be scheduled to begin on Monday or Tuesday, to reduce weekend requirements.

Turbidity of purged groundwater is evaluated by a visual examination for sediment/silt presence or by using a nephelometer which physically measures groundwater turbidity in NTUs. Generally, a turbidity value of 50 NTU or less is acceptable, although some regulatory agencies have established lower criteria (i.e., less than 5 NTU). If 50 NTU is not achieved, filtration of samples may be required. LFP can generally result in turbidity values less than 5 NTU.

Note: Agitation of the water column within the well will increase turbidity. Therefore, bailers and inertia pumps (Waterra™) are of limited use for collecting sediment-free samples. The tubing of peristaltic pumps must be secured to prevent movement of the tubing within the water column which would disturb sediment. The best method to reduce sediment disturbance is low-volume non-agitation pumping (i.e., bladder pump).

Well purging is accomplished using dedicated equipment or by using either peristaltic, bladder, or other approved purging methods. Purging and sampling equipment are dependent on the total well depth. Bailing can be used for well purging but this method stirs up sediment and increases the purging effort required before stabilization is achieved. Equipment available for well purging is discussed in Section 7.7.7. Monitoring equipment used during well purging includes a water level indicator, pH meter, thermometer, conductivity meter, and turbidity meter.

7.7.5.2 PURGING ENTIRE WATER COLUMN

The purging equipment is lowered into the top of the standing water column. Well purging is completed from as close to the top of the water column as possible, not from the well bottom, unless poor well recovery occurs. Purging from the top of the water column moves water from the formation through the well screen of the well and into the well casing. This allows for the entire static volume to be removed. Purging at depth in the water column does not remove water above the pump intake and results in the collection of unrepresentative samples.

If required, the pump intake can be adjusted. If the recovery rate is greater than the pumping rate, the pump should remain suspended until the required purged volume has been removed. If the recovery rate is less than the pumping rate, the pump should be lowered to ensure the removal of the required well volume.

7.7.5.3 LOW-FLOW PURGING (LFP) TECHNIQUE

LFP purging results in minimal drawdown during well purging, so less purging is required before formation water is removed. The volume required for purging using LFP is significantly reduced. LFP results in less agitation and mobilization of sediments compared to traditional sampling techniques.

A pre-cleaned stainless steel bladder pump equipped with a Teflon™ bladder is strongly recommended for LFP. The discharge line should be polyethylene or Teflon™ lined tubing with an inside diameter of 1/4 or 3/8 inch (6 or 10 mm). Check the Work Plan or QAPP to ascertain the proper bladder and discharge tubing. Smaller discharge tubing ensures that the tubing remains filled with water and reduces air bubbles at low purging rates. The airline to the pump is generally 1/4-inch (6 mm) inside diameter polyethylene tubing. The pump is secured to nylon rope and positioned in the well so that the pump intake is set at the mid-point of the well screen, or a minimum of 2 feet (0.6 m) above the bottom of the well or accumulated sediment level. It is important that the rope, airline, and discharge tubing are measured prior to installation in the well. The bladder pump and tubing are lowered very slowly through the water column to minimize mixing of the stagnant well casing water and to minimize the agitation of sediment into suspension, which would increase the purging time. It is recommended, and in some instances regulated, that pump installation occurs at least 24 hours prior to initiating LFP. It is recommend that a bladder pump be dedicated to the well for regular monitoring events.

During LFP, the pumping rate should be between 100 and 500 milliliters per minute (mL/min). It is recommended that initial pumping be conducted at a lower rate to limit drawdown in the well. During purging, groundwater levels are measured to maintain a maximum 0.4 foot (0.1 m) of drawdown. The pumping rate can be gradually increased during LFP. Pumping rate increases will be dependent on the drawdown and the stabilization of field parameters discussed below. Pumping rate adjustments should occur in the first 15 minutes of purging. After this time the pumping rate should remain constant and flow rate adjustments should be avoided. During purging, the pumping rate and groundwater level should be measured at least every 10 minutes. It is recommended that water level measurements occur at 5-minute intervals.

During LFP, stabilization of the purged groundwater is required to ensure the collection of representative groundwater samples from the formation and not from the stagnant water in the well casing. Field parameters including pH, temperature, specific conductance, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity should monitored during LFP. The measurement of these field parameters is used to evaluate if stabilization of the purged groundwater has occurred prior to the collection of groundwater samples. The field measurements should be measured and recorded at 5-minute intervals. Groundwater stabilization is considered achieved when three consecutive readings for each of the field parameters, taken at 5-minute intervals, are within the following limits:

- pH ±0.1 pH units of the average value of the three readings
- temperature ±3 percent of the average value of the three readings

- conductivity ±0.005 milliSiemen per centimeter (mS/cm) of the average value of the three readings for conductivity <1 mS/cm and ±0.01 mS/cm of the average value of the three readings for conductivity >1 mS/cm
- ORP ±10 millivolts (mV) of the average value of the three readings
- DO ±10 percent of the average value of the three readings
- turbidity ±10 percent of the average value of the three readings, or a final value of less than 5 NTU

During LFP, field parameters are measured using a flow-through cell apparatus. At the start of LFP the purge water is visually inspected for clarity prior to connecting to the flow-through cell. If the purge water is turbid, LFP continues until the purge water is visually less turbid prior to connecting to the flow-through cell. Field parameters may be obtained using individual meters or a multiple meter unit; however, the use of a flow-through cell is highly recommended. All meters must be calibrated daily in accordance with the manufacturer's and CRA's calibration instructions, and a calibration record maintained in a standard CRA field book.

During LFP the meter readings are monitored for evidence of meter malfunction. The following are common indicators of meter malfunctions:

- DO above solubility (e.g., oxygen solubility is approximately 11 milligrams per liter (mg/L) at 10°C) may indicate a DO meter malfunction
- negative ORP and DO less than 1 to 2 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have positive ORP and DO less than 1 to 2 mg/L under oxidizing conditions)
- positive ORP and DO less than 1 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have a negative ORP and DO less than 1 mg/L under reducing conditions)

Meter calibration fluids should be available for meter recalibration in the field. Spare meters should also be available for meter replacement if necessary.

Note:	*DO levels exceeding the solubility of oxygen in water are erroneous and are indicative of meter malfunction or poor sampling techniques causing turbulence and aeration. DO concentrations cannot exceed:*			
	9 mg/L at 20°C	*10 mg/L at 15°C*	*11 mg/L at 10°C*	*14 mg/L at 1°C*

Stabilization will be considered complete when the field parameters have stabilized as indicated in the above table. Purging will continue if stabilization does not occur, until a maximum of 20 screen volumes has been removed. LFP causes groundwater to be drawn from a significant distance above or below the pump intake. Therefore, the screen volume is based on a 5-foot (1.5 m) screen length. After the removal of 20 screen volumes, purging will continue if the purged water remains visually turbid and appears to be clearing. Also purging will continue if the field parameters vary only slightly outside of the stabilization criteria and appear to be approaching stabilization.

If the recharge to the well is insufficient to conduct LFP, the well should be pumped dry and allowed to recharge sufficiently for the collection of the groundwater sample volume. Wells purged dry are required to meet the stabilization criteria detailed above.

7.7.5.4 SAMPLING TECHNIQUES

Upon completion of purging, with groundwater stabilization and clarity meeting the applicable protocol described above, groundwater sample collection can proceed. Generally the field parameters of pH, temperature, and specific conductance are monitored first, then any other required field measurements.

Samples are collected directly from the purging pump, when possible, or an alternate device (i.e., pump or bailer) may be installed or used. If new sampling equipment is installed, the first few bails or discharge volumes should be discarded to allow acclimation of the sampling equipment with the groundwater.

Samples are typically collected from the pump or bailer with the discharged groundwater collected directly in the appropriate sample containers. The interior of the bottle or cap must not be touched or handled in anyway. New gloves (i.e., disposable nitrile gloves or equivalent) should be worn for the collection of each sample. Caps from sample bottles must not be placed on the ground or in pockets to eliminate the possibility of cross-contamination.

Descriptions of the various equipment and sampling methods for the collection of groundwater samples are contained in Section 7.7.7.

The following describes the main activities involved in the collection of groundwater samples.

7.7.5.5 ORDER OF SAMPLE COLLECTION

Groundwater samples are collected and containerized in the order following volatilization sensitivity:

1. VOCs
2. Semi-volatile organic compounds (SVOCs)
3. Total organic carbon
4. Total organic halides
5. Extractable organics
6. Total metals
7. Dissolved metals
8. Phenols
9. Cyanide

10. Sulfate and chloride
11. Nitrate and ammonia
12. Microbiological parameters
13. Radionuclides

QA/QC requirements for groundwater sampling are described in detail in Section 3.9.

7.7.6 SAMPLE ACQUISITION AND TRANSFER

If groundwater sample collection is performed using a pump, the flow rate must not exceed 100 mL/min during the collection of groundwater samples for VOCs. The low flow rate will reduce the possibility of degassing samples. During the collection of groundwater into the sample container or filtration device, minimize agitation and aeration of the sample. Groundwater samples are transferred directly into the sample container for submittal to the laboratory. Groundwater samples should not be collected in larger containers and subsequently transferred to smaller sample containers; however, on occasion this will be required for filtration or sample composting. During VOC sample collection, samples must not be collected, handled, or containerized near or in the vicinity of a running motor or exhaust which may contaminate the samples.

Groundwater samples for VOCs are collected in laboratory supplied 40 mL glass vials. The vials are filled to the top until a meniscus is formed, then topped with a Teflon™-lined cap. To prevent the loss of volatiles, it is important that no air bubbles or headspace are present in the sample container. Inverting and tapping the vial will check for the presence of air bubbles. If air bubbles are present, the sample should be topped off again and resealed. This process may only be performed a maximum of twice, at which time the sample must be discarded and the sample retaken. If preservatives were present in the bottle from the laboratory, a new sample vial must be used.

Note:	*Gas bubbles that appear in VOC containers after sample collection may be a result of degassing or reaction with preservative. If this occurs, note this occurrence on the chain-of-custody. Re-sampling is not required in most cases.*

During sample collection ensure groundwater samples are preserved according to laboratory requirements. If required and supplied by the laboratory, preserve the samples in accordance with the QAPP. Some laboratories pre-preserve bottles so that once the groundwater sample is added the preservation is completed. In either case, it is advisable to check sample preservation using litmus paper. Using litmus paper ensures that groundwater sample preservation has been completed to the proper pH as required by the QAPP. If preservation of a sample does not meet the requirements of the QAPP, it may be necessary to add additional preservative, or note on the chain-of-custody that incomplete sample preservation has occurred.

Once sample collection is complete, samples are placed in a cooler on ice to maintain a sample temperature no more than 4°C.

7.7.6.1 SAMPLE LABELS/SAMPLE IDENTIFICATION

Label all groundwater samples with the following, written in indelible ink

1. A unique sample number (see Section 3.9 for guidance)
2. Date and time
3. Parameters to be analyzed
4. Job number
5. Sampler's initial

Secure the label to the bottle. It is recommended that bottle labels be covered with wide clear tape to protect the label during sample packing and shipment. Pack glassware in appropriate packing material to deter breakage during sample packing and shipment. Sample labels can be prepared in advance in CRA offices that have label-generating programs.

An example of a groundwater sample log entry is provided on Figure 3.8.

Section 3.9 details sample labeling requirements for environmental sampling programs. Section 3.9 also details COC requirements and sample shipment requirements.

7.7.7 PURGING/SAMPLING EQUIPMENT

CRA maintains a wide variety of purging and sampling equipment for well purging and groundwater sample collection. The groundwater sampler should be familiar with purging and sampling equipment and understand equipment limitations and proper use. Some equipment is very useful for well purging (i.e., high flow rates) but is not permissible for LFP or for sampling sensitive parameters (e.g., VOCs cannot be collected with a submersible (turbine) or suction pump). If the groundwater sampler understands the various equipment operation and limitations, the proper selection of purging and sampling equipment is made, which will minimize the purging and sampling duration and maximize productivity.

***Caution**: Gas powered equipment requires special attention to ensure that staff hauling these units do not cause equipment or sample contamination. Frequent changes of disposable glove as well strict separation of sampling crew tasks (i.e., those handling pumps and hoses do not contact generator or are involved in any refueling activities) are required.*

The following subsections describe the equipment available for groundwater sampling, the equipment use, approximate flow rates, and advantages and disadvantages of the equipment.

7.7.7.1 PERISTALTIC PUMPS

A peristaltic pump is acceptable for purging wells and for most groundwater sample analytes. The groundwater sampler must ensure that a peristaltic pump is acceptable to regulatory agencies with local jurisdiction for VOC and SVOC sample collection. The QAPP will provide sampling requirements.

A peristaltic pump is capable of lifting water from a maximum depth of 25 feet (7.6 m) below ground surface or the pump, whichever is greater. A peristaltic pump is a self-priming, low volume, suction pump which consists of a rotor with ball bearing rollers. Flexible silicon tubing is inserted around or in the pump rotor and squeezed in place by the heads as they revolve in a circular pattern. The section of silicon tubing must not exceed 3 feet (0.9 m) in length. Additional rigid polyethylene or Teflon™ tubing is attached to the flexible tubing and placed in the well. Another piece of rigid tubing is attached to the discharge end of the flexible silicon tubing to facilitate sample collection. The entire length of rigid and flexible silicon tubing is dedicated to the well for future use. The tubing is typically tied and suspended in the well. The flexible or rigid tubing is not reused in other wells because cross-contamination will occur.

Note:	*Often a length of tubing is accidentally dropped into a well and can be difficult to retrieve. Retrieval can be accomplished by sending another piece of tubing down the well overlapping the lost section of tubing. Once in place, rotate the tubing, essentially wrapping or corkscrewing the lost tubing and new tubing together. After a number of turns are completed pull the tubing, hopefully with the lost section wound around the new piece. Repeat the procedure until successful.*

Liquid is pulled into the tubing by the peristaltic pump through the creation of a vacuum as the rotor head turns. An advantage of using a peristaltic pump is that no pump parts come in direct contact with the sample. A peristaltic pump is capable of providing low flow sampling rates (i.e., typically less than 500 mL/min) with less agitation than other suction pumps. However, it is important that the tubing is secured during pumping to prevent the tubing from moving and causing agitation. A peristaltic pump also allows for regulation of the flow rate by increasing or decreasing the rotor head speed.

Peristaltic pumps are small and easily mobilized to remote sample locations. They require minimal setup, and do not require decontamination between sample locations. The disadvantages of a peristaltic pump are its limited lift and flow capabilities and the limited ability to collect VOC and SVOC samples. If VOC or SVOC sampling, check the QAPP to see if sampling with a peristaltic pump is allowed. Also check with regulatory agencies with local jurisdiction to see if the use of a peristaltic pump for collection of VOC and SVOC samples is acceptable. If using a peristaltic pump for purging, and the collection of VOCs and SVOC samples with the peristaltic pump is not acceptable, it is common to collect the initial VOC and SVOC analytes with a stainless steel bottom loading bailer. The peristaltic pump can then be used to collect the remaining sample analytes.

Peristaltic pumps are becoming more popular for LFP. However, it should be noted that a peristaltic pump may cause degassing, pH modification, and possible VOC loss.

7.7.7.2 SUCTION PUMPS

A number of suction pumps (e.g., centrifugal) exist that can be used for purging applications only. A suction pump draws water through a suction line by creating a vacuum in the suction line or hose. Once drawn into the pump, the groundwater comes into direct contact with the pump rotor/pumping chamber area and it is therefore undesirable for groundwater sampling due to high groundwater agitation. Decontamination of suction pumps is extremely difficult. As with peristaltic pumps, most suction pumps have a limited lift capability of about 25 feet (7.6 m). Larger suction pumps, like 2-inch (5 cm) trash pumps, can achieve high flow rates under low hydraulic head. Flow rates of 15 to 20 U.S. gallons per minute (USgpm) [57 to 76 liters per minute (L/min)] can be achieved. This high flow rate minimizes purging time. New or dedicated suction line should be used at each well if a suction pump is used for purging.

Large suction pumps are also useful for well development, in conjunction with agitation and surging.

Large suction pumps are not suited for LFP due to degassing, pH modifications, VOC loss, and lack of flow adjustment.

***Caution**: The groundwater sampler must prevent the siphoning of purged water from a bulk container back into the well. For example, the following scenario is possible: Joe Sampler has completed purging well 'xyz' and has turned off the 2-inch trash pump. The trash pump discharge line is inserted into a wastewater tank and is submerged below the tank water level. As Joe prepares his glassware and sample pump, the wastewater tank contents are siphoned back into the well. This can result in cross contamination with water from other sites/wells which have been purged either:*

- *into the tank,*
- *through the pump, or*
- *through the discharge line.*

All discharge lines/groundwater purge pumps must be provided with a check valve to prevent this situation.

Drilling rig pumps including Moyno, progressive cavity, bean, and mud pumps can be used for well purging and well development.

Suction pumps are a useful tool for high rate purging and well development. They require no additional equipment other than a suction line and discharge line for each well. They are mobile and easily transported around and between sites. Suction pumps are limited to use in wells with less then 25 feet (7.6 m) of lift, are difficult to decontaminate, and are unsuitable for sample collection. Large suction pumps are not suitable for LFP.

7.7.7.3 SUBMERSIBLE PUMPS

A submersible pump generally provides high discharge rates for purging at depths beyond the capabilities of a suction pump. Based on its size, a submersible pump can pump water from substantial depths at very high pumping rates and can provide higher groundwater extraction rates than other methods. At high pumping rates, a submersible pump can cause agitation and aeration. This results in some submersible pumps not being suitable for the collection of groundwater samples for VOC and SVOC analysis.

Adjustable rate submersible pumps, constructed of stainless steel or Teflon™, are suitable and approved for LFP provided low flow rates are maintained.

The submersible pump, including the electrical cable and lowering cable, must be decontaminated between wells in accordance with the Work Plan or QAPP.

A submersible pump installed in bedrock or in a deep well should be attached to rigid piping (i.e., 3/4-inch (1.9 cm) steel) to allow for pulling or pushing of the pump. The pump may need to be pushed or pulled to the appropriate installation depth, past tight spots in the well, and when affixing the electrical cable and lowering the cable/safety line. Even when rigid piping is used, a safety line must be attached to the pump in case the piping becomes unthreaded or the pump connection is lost.

Submersible pumps can provide high flow rates that are useful for deep well or large diameter well purging activities. They tend to be labor intensive because of decontamination problems, power supply, and discharge piping size. Some submersible pumps are not suitable for some sample analytes. Small submersible pumps (i.e., 2-inch (5 cm) Grundfos™) have the proper construction and have adjustable flow rates, making them suitable for LFP.

7.7.7.4 AIR LIFT PUMPS

An air lift pump operates using compressed air or nitrogen. The compressed air or nitrogen comes into direct contact with the groundwater and forces groundwater from the pump chamber through a series of check balls into the discharge line. An air lift pump operates on alternate pump discharge and pump recharge cycles. The pump and recharge cycles are controlled using a control box at ground surface. Air lifting is possible from deep depths with moderate to low flow rates [2 to 3 USgpm (7.6 to 11.5 L/min)] depending on the pump installation depth, static head, discharge tubing diameter, and air supply pressure.

Since the air or nitrogen comes in direct contact with the groundwater, an air lift pump should not be used for the collection of groundwater samples for VOC and SVOC analysis.

An air lift pump is a good tool for deep well purging and development. If an air lift pump is used for purging, an alternate sampling method will be required (e.g., bailers or bladder pump) for the collection of VOC and SVOC groundwater samples.

7.7.7.5 BLADDER PUMPS

Bladder pumps, as with air lift pumps, are driven by compressed air or nitrogen but the air or nitrogen does not come in contact with the groundwater. The contact between the air or nitrogen and the groundwater is eliminated by the presence of a Teflon™, polyethylene, or natural rubber bladder. The pump operation, as with the air lift pump, is cyclic and is controlled using a control box at ground surface. The control box controls the pump filling and discharge time. Because the air or nitrogen does not come in direct contact with the groundwater, and there is limited groundwater agitation and degassing, a bladder pump is the best sampling equipment for the collection of groundwater samples for VOC and SVOC analysis.

Bladder pump operation is very quiescent, causing little formation and well disturbance. By using a bladder pump, collecting a sediment-free groundwater sample is easily achieved. An adjustable rate bladder pump should be used for LFP. Bladder pumps generally are only able to achieve a maximum pumping rate of 1.5 USgpm (5.7 L/min). It is important to note that flow rates should be reduced in deep well applications.

Well purging and sampling can be performed using a bladder pump. Once sampling is completed, the pump should be disassembled and decontaminated in accordance with the Work Plan or QAPP prior to use in other wells. The sample tubing is generally 1/4- or 3/8-inch (6 or 10 mm) diameter polyethylene or Teflon™ lined polyethylene tubing. The air line is generally 1/4-inch (6 mm) polyethylene tubing. The sample and air line tubing are typically suspended in the well for future use (dedicated). At some sites a complete sampling system (bladder pump, discharge tubing, and air line) is dedicated to each well.

Bladder pumps provide excellent sample quality and are useful in deeper sampling applications. There are no analyte restrictions. Bladder pumps are strongly recommended for LFP applications.

Bladder pumps require additional equipment including control box, compressed air or nitrogen, and tubing. The setup of a bladder pump is quite labor intensive unless a dedicated system is in place. Decontamination of a bladder pump requires pump disassembly and re-assembly. Finally, bladder pumps are not capable of high flow rates, thus purging times tend to be increased slightly.

7.7.7.6 INERTIA PUMPS

An Inertia pump or Waterra™ pump is a manually operated or mechanically driven pump which uses only a foot valve on the sample/purge tubing. "Jerking" the sample/purge tubing with the attached foot valve removes groundwater from the well. The rapid lifting and lowering action of the tubing imparts an inertia to the water column within the sample/purge tubing. This causes the water column to rise to ground surface and discharge from the end of the sample/purge tubing. The foot valve holds the water column in the tubing during the lifting process and allows groundwater to enter the sample/purge tubing during the lowering, or down stroke.

CRA owns both manual and mechanical gas-powered inertia systems. Flow rates with inertia pumps are variable and are dependant on cycle speed, tubing size, foot valve size, well depth, and depth to groundwater. The inertia pump is a useful method for purging and for collection of most groundwater sample analytes. Acceptability of VOC and SVOC sampling with inertia pumps is gaining approval in selected areas. Prior to using an inertia pump as a sampling device, check the sampling requirements in the QAPP, or obtain approval from the Project Coordinator.

Inertia pumps are useful for the extraction of dense non-aqueous phase liquids (DNAPL). The only equipment that is exposed to the gross contamination is the foot valve and a small section of the sample/purge tubing. On most projects, the foot valve and sample/purge tubing are dedicated to the well.

Inertia pumps tend to cause extensive disturbance to the water column. The vigorous lifting and lowering of the inertia pump tends to make it difficult to collect sediment-free groundwater samples. Therefore, inertia pumps are not suitable for LFP.

7.7.7.7 BAILERS

A bailer is a manual sampling device consisting generally of a hollow tube (e.g., Teflon™, PVC, or stainless steel) with a lower check ball that permits water entry and prevents water loss. The bailer is lowered slowly into the well. This allows water to enter the bailer through the bottom, and the weight of the water inside the bailer closes the check ball when the bailer is retrieved from the well. A rope or cable is affixed to the bailer to allow the lowering and retrieval of the bailer from the well. Bailing tends to be disruptive to the water column and formation. Obtaining sediment-free groundwater samples using a bailer tends to be difficult, if not impossible. VOCs and SVOCs, as well as other analytes can be collected using a bailer, but it is important that these analytes be as sediment-free as possible. The compatibility of the bailer material and groundwater analytes should be reviewed and approved prior to using a bailer for the collection of groundwater samples. Generally, Teflon™ bailers are acceptable for the collection of most analytes.

Power winches with overhead tripods are available to assist in purging and sampling deep or large volume wells.

Flow rates attained using a bailer is a function of the bailer size and retrieval frequency. Retrieval frequency is dependent on well depth, water depth, and well recharge rate. Bailing is not practical for deep wells or for the removal of large well volumes.

A bailer is a useful tool for well development as the surging action from the bailer insertion and removal from the well promotes sediment suspension and subsequent removal. However, obtaining completely sediment-free samples, or samples below 50 NTU, is difficult if not impossible using a bailer.

A bailer provides representative samples once the well has been adequately developed and purged. A bailer is not suitable for LFP. Rope used for bailing must be kept off the ground and free of other contaminating material that could be introduced to the well. Rope can either be dedicated to the well for future use or discarded.

7.7.7.8 PASSIVE DIFFUSION BAGS

When sampling with diffusion bags the well must be fully developed using an alternate method.

A diffusion bag is a polyethylene bag that contain deionized water. The bag is attached to an appropriate length of rope or cable in order to be submerged to the appropriate depth (indicated in the Work Plan, QAPP, or as instructed by the Project Coordinator). Cable or rope used to suspend diffusion bags can be dedicated to the well for future use or discarded.

Once submerged to the appropriate depth, the diffusion bag is left in the well for an extended period of time, usually 14 days, to allow the bag to equilibrate with the water in the well. The use of diffusion bags eliminates well purging prior to sampling. Placement of multiple diffusion bags in a well allows for vertical groundwater profiling.

Diffusion bags are a low cost method for the collection of groundwater samples. Advantages include:

- No purge water to dispose of
- No equipment decontamination between wells
- Simple logistics and operation
- Reduction in personnel and exposure times
- Samples collected are representative of formation water adjacent to well
- Allow for vertical profiling of water column
- Appropriate for long-term monitoring programs

The disadvantage of diffusion bags is the length of equilibrium time, generally 14 days. Currently, there are membranes available for diffusion bags suitable for the collection of groundwater samples for select SVOC, and metals analyses. However, there are no membranes currently available for polychlorinated biphenyls (PCBs).

Note: Handle diffusion bags only when wearing clean nitrile or surgical gloves.

7.7.8 FILTERING OF GROUNDWATER SAMPLES

Filtering is an important process to remove suspended particulate that affect sample results. Filtration of groundwater samples is generally limited to metals analysis.

Filtering can be completed in the field using in-line filters or a vacuum filter kit. Filtering of samples can also be completed by the laboratory, in which case the samples must not be preserved and must be at the laboratory in at least 24 hours of sample collection.

7.8 FIELD PROCEDURES FOR RESIDENTIAL SAMPLING

7.8.1 GENERAL

When sampling potable water supply wells it is important to ensure that the samples collected are representative of the aquifer being sampled. Poor or incorrect sampling techniques will result in erroneous sample results that can be disclosed to the public. Incorrect sample results may make any changes in the public perception hard to accomplish when correct results are reported.

7.8.2 FIELD PROCEDURES

The requirements of a residential well sampling program should be reviewed with the Project Coordinator prior to initiating sampling activities. While similar field procedures used in groundwater sampling (including documentation, sample identification, date, time, etc.) are required in residential well sampling, additional procedures are also required.

Prior to collection of groundwater samples from a residential well, the well must be purged to ensure that samples collected are representative of the formation. Purging removes standing water from the well casing, pipes, and pressure or holding tank. Purging of a residential well requires the removal of one well volume. If access to the well is not available to determine the well volume, purging for a period of 15 to 30 minutes is generally sufficient. Field measurements for pH, conductivity, and temperature are recorded during purging activities until the readings indicate that stabilization has occurred.

Sampling of residential wells is generally performed using the existing pumping system. However, CRA purging and sampling equipment can be used. It is important that only designated **clean** purging and sampling equipment be used for residential well sampling. The use of the existing pumping system is preferred, as this is more representative of the water quality provided to the residence. Using the existing pumping system also minimizes the possibility of damaging the well and existing pumping system when installing additional purging and sampling equipment.

If CRA equipment is used for residential well sampling, it must be cleaned prior to and between use with a bleach and deionized water solution wash followed by a thorough deionized water rinse.

Note:	*In addition to the special technical procedures noted, CRA personnel must be aware of this unique situation of conducting sampling at private residences. Special care must be taken to be polite and courteous at all times. Offer only necessary information and maintain a clean work area that is returned to pre-sampling conditions. Personnel should have proper identification available, and only remain in areas long enough to*

complete the required tasks.

Taps selected for residential well sampling should be located as close to the well as possible. Locate the taps before any treatment systems and, if possible, the pressure tank. It is important to note, if possible, all water treatment devices in operation at the residence including:

- Water softeners
- Filtration units
- Ultraviolet light
- Reverse osmosis
- Distillers
- Chlorinators

Leaking taps that allow water to flow from the stem of the valve handle and around the tap should not be used as sampling locations. Aerators, strainers, and hose attachments should be removed prior to sampling. Maintain a steady flow of water during sampling activities to avoid pressure fluctuations that may cause sheets of microbial growth lodged in the pipes to break loose. Open the cold water tap for a period of 15 to 30 minutes to allow for the complete purging of the pumping system. Maintain a smooth-flaring water stream at a low to moderate pressure without splashing. Do not change the flow rate. Changes in the flow could dislodge particles in the pipes or faucet.

When sampling for microbiological parameters, the end of the faucet must be flame sterilized. During residential well sample, never place caps from sample containers on the ground or in a pocket. Instead, hold the sample container in one hand and the sample container cap in the other. Be very careful not to touch the inside of the sample container cap. Wear new disposable gloves at each sampling location and following contact with a potential contaminant source. The inside of the sample bottle must not be touched with bare hands or allowed to contact the surface of the faucet.

7.8.3 FIELD NOTES FOR RESIDENTIAL SAMPLING

Full documentation of each residential well is required and includes:

1. Well depth
2. Casing construction and diameter
3. Well installation date if known
4. Pumping system configuration
5. Piping system construction (e.g., copper, lead-joint, ABS)
6. Presence of treatment devices

Obtain the name and exact mailing address for all residence or well owners, as well as home and work telephone numbers. This information is required to inform the residence or well owner of the results of the sampling activities.

Document residential well sampling activities in a standard CRA field book. Figure 3.8 provides typical residential well sampling field note requirements. Note that additional documentation of well details, treatment devices, piping system, and special circumstances are required in the field book in addition to the sample log entry.

7.9 FIELD PROCEDURES FOR SURFACE WATER SAMPLING

7.9.1 GENERAL

Surface water sampling is performed to obtain samples for surface water bodies that are representative of existing surface water conditions.

Surface water sampling locations for surface water quality and groundwater interaction studies are selected based on the following:

1. Study objectives
2. Location of point surface discharges
3. Non-point source discharges and tributaries
4. Presence of structures (e.g., bridge, dam)
5. Accessibility

During surface water sampling it is important to obtain samples that are not impacted by the re-suspension of sediment produced because of improper or poor surface water sampling techniques.

7.9.2 SURFACE WATER SAMPLE LOCATION SELECTION

Prior to conducting surface water sampling activities, the first requirement is the consideration and development of surface water sampling locations. It is important that all surface water sampling locations be selected in accordance with the Work Plan and described to and discussed with the Project Coordinator.

Bridges and piers are good locations for surface water sampling locations since they provide easy access and permit water sampling across the entire width of the surface water body. The JSA for sampling from bridges must include a traffic management plan to assure the employee has considered using a spotter, signage, cones, and flags to warn car traffic of the work adjacent to the roadway. Wading for surface water samples increases the chances of disturbance of sediments from the floor of the surface water body.

When wading for surface water samples in lakes, ponds, streams, and slow moving rivers be aware of potential safety and health risks. A life vest and safety line must be worn at all times where footing is unstable or when sampling in fast moving or more than 3 feet (0.9 m) deep. A two-person team is required for most surface water sampling activities, a Project Manager must approve a one person sampling team. If the site conditions require the use of the life vest and safety line, the two people involved in the sampling must be competent swimmers.

Surface water samples must be collected with no suspended sediments. Surface water samples are collected commencing with the furthest downstream location to avoid sediment interference with upstream locations.

7.9.2.1 RIVERS, STREAMS, AND CREEKS

Surface water samples are generally collected in areas of surface water bodies that are representative of the surface water body conditions. Representative surface water samples will usually be collected in sections of surface water bodies that have a uniform cross section and flow rate. Mixing is influenced by turbulence and water velocity, therefore the selection of surface water sampling locations immediately downstream of a riffle area (i.e., fast flow zone) will ensure good vertical mixing. These locations are also likely areas for deposition of sediment since this occurs in areas of decreased flow velocity.

Surface water sampling locations should not be established in areas near point source discharges including tributaries, industrial effluents, and municipal effluents. Surface water sampling of these source discharge points can be performed to assess the impact of these source areas on overall surface water quality.

Sample tributaries as close to the mouth as possible. It is important to select surface water sample locations considering the impact downstream, including tributary flow and sediment.

In all instances, properly document all surface water sampling locations in a standard CRA field book. Documentation may include photographs and tie-ins to known structures.

7.9.2.2 LAKES, PONDS, AND IMPOUNDMENTS

The surface water in lakes, ponds, and impoundments has a greater tendency to be stratified than water in rivers and streams. Lack of mixing in these surface water bodies may require additional surface water sample collection. Extreme turbidity variances may occur where highly turbid surface water courses enter a lake or pond. Therefore, each layer of the stratified surface water column may need to be considered separately. Stratification is generally a result of water temperature differences, with cooler heavier water being trapped below warmer water.

Surface water sample locations for lakes, ponds, and impoundments should adequately represent the conditions of the surface water body. All intakes and outflows that may provide biased surface water

representation should be identified and documented. Surface water sample locations with adjacent structures (e.g., banks, piers) may also provide biased samples, as the potential for boundary flow and eddies exists.

The number of surface water sample locations on lakes, ponds, or impoundments will vary depending on the purpose of the investigation, as well as the size and shape of the surface water body. In ponds and small impoundments a single surface water sample should be collected at the deepest point. In naturally formed ponds, the deepest point is usually near the center of the surface water body. In impoundments the point is usually near the dam.

In lakes and larger impoundments, several sub-samples should be taken to form a single composite sample. These vertical surface water sampling locations are collected along a pre-determined grid.

In irregular shaped lakes with several bays and covers that are protected from the wind, additional surface water samples are required to properly represent surface water quality at various locations in the lake. Additional surface water samples should be taken at discharges, tributaries, and other factors or sources that are suspected of affecting the surface water quality.

In all instances, properly document all surface water sampling locations in a standard CRA field book. Documentation may include photographs and tie-ins to known structures.

7.9.3 SAMPLING EQUIPMENT AND TECHNIQUES

When collecting surface water samples, direct dipping of the sample container into the stream or water is acceptable unless the sample container contains preservatives. If preserved, a pre-cleaned unpreserved sample container should be used to collect the surface water sample. The surface water sample is then transferred to the appropriate preserved sample container. When collecting surface water samples, submerse the inverted bottle to the desired sample depth and tilt the opening of the sample container upstream to fill. During surface water sample collection, wading or movement may cause sediment deposits to be re-suspended and can result in biased samples. Wading is acceptable if the stream has a noticeable current and the samples are collected directly in the sample container when faced upstream. If the stream is too deep to wade in or if addition samples must be collected at various depths, additional sampling equipment will be required. Surface water samples should be collected about 6 inches (15 cm) below the surface, with the sample bottles being completely submerged. Taking the surface water sample at this depth eliminates the collection of floating debris in the sample container.

Surface water sample collection where the flow depth is less than 1 inch (<2.5 cm) requires the use of special equipment to eliminate sediment disturbance. Surface water sampling may be conducted with a container then transferred to the appropriate sample container, or collection may be performed using a peristaltic pump. A small excavation in the stream bed to create a sump for sample collection can also be considered but should be prepared in advance to allow all the sediment to settle prior to surface water sampling activities.

Teflon™ bailers can be used for surface water sampling if it is not necessary to collect surface water samples at specific depths. A bottom loading bailer with a check ball is sufficient. When the bailer is lowered through the water, the water is continually displaced through the bailer until the desired depth is reached. The bailer is retrieved and the check ball prohibits the release of the collected surface water sample. Bailers are not suitable in surface water bodies with strong currents, or where depth-specific sampling is required.

For discrete and specified depth surface water sampling, and the parameters to be monitored do not require a Teflon™ coated sampling device, a standard Kemmerer or Van Dorn sampler can be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the sampler ends open while the sampler is being lowered. The sampler is lowered in a vertical position to allow water to pass through. The Van Dorn sampler is plastic and is lowered in a horizontal position. For both samplers, a messenger is sent down a rope when the sampler has reached the required depth. The messenger causes the stopper on the sampler to close. The sampler is then retrieved and the surface water sample can be collected through a valve. DO sample bottles can be filled by allowing overflow using a rubber tube attached to the valve. During depth-specific surface water sampling, take care not to disturb bottom sediments.

Glass beakers or stainless steel cups may also be used to collect surface water samples if parameter interference does not occur. The beaker or cup must be rinsed at least three times with the surface water sample prior to sample collection.

All equipment must be thoroughly decontaminated as outlined in Section 7.6.

7.9.4 FIELD NOTES FOR SURFACE WATER SAMPLING

Use a standard CRA field book to record daily surface sampling activities, describe surface water sampling locations, sampling techniques, and, if applicable, provide a description of photographs taken. Visual observations are important and provide valuable information when interpreting surface water quality results. Observations include:

1. Weather conditions
2. Stream flow directions
3. Stream physical conditions (width, depth, etc.)
4. Tributaries
5. Effluent discharges
6. Impoundments
7. Bridges
8. Railway trestles
9. Oil sheens
10. Odors

11. Buried debris
12. Vegetation
13. Algae
14. Fish and other aquatic life
15. Surrounding industrial areas

The following factors should be considered for surface water sampling:

1. Predominant Surrounding Land Use: Observe the prevalent land use type in the vicinity and note any other land uses in the area which, although not dominant, may potentially affect surface water quality.
2. Local Watershed Erosion: Note the existing or potential erosion of soil in the local watershed and its movement into the stream. Erosion can be rated through visual observation of watershed stream characteristics including increases or decreases in turbidity.
3. Local Watershed Non-Point Source Pollution: This refers to problems or potential problems other than erosion and sedimentation. Nonpoint source pollution can be diffuse agricultural and urban runoff. Other factors may include feed lots, wetlands, septic systems, dams, impoundments, and mine seepage.
4. Estimated Stream Width: The estimated distance from shore at a transect representative of the stream width in the area.
5. Estimated Stream Depth: Riffle (rocky area), run (steady flow area), and pool (still area). Estimate the vertical distance from the water surface to the bottom of the surface water body at a representative depth at three locations.
6. High Water Mark: Estimate the vertical distance from the bank of the surface water body to the peak overflow level, as indicated by debris hanging in bank or flood plain vegetation, and deposition of silt. In instances where bank flow is rare, high water marks may not be evident.
7. Velocity: Record or measure the stream velocity in a representative run area.
8. Dam Present: Indicate the presence or absence of a dam upstream or downstream of the surface water sampling location. If a dam is present, include specific information detailing the alteration of the surface water flow.
9. Channelized: Indicate if the area surrounding the surface water sampling location is channelized.
10. Canopy Cover: Note the general proportion of open to shaded areas which best describes the amount of cover at the surface water sampling location.

7.10 FOLLOW-UP ACTIVITIES

The following should be performed once groundwater, residential, and surface water sampling is completed:

1. Double check the Work Plan and QAPP to ensure all samples and QA/QC samples have been collected and confirm with the Project Coordinator.
2. Decontaminate all equipment at the site then return clean to the appropriate office equipment manager.
3. Dispose of purge water and cleaning fluid as specified in the Work Plan.
4. Notify the contract laboratory when the samples should arrive. Enclose a completed chain-of-custody in each cooler.
5. Complete and file the appropriate forms and data sheets. Also file the field notes. For groundwater, residential, and surface water sampling these forms include:
   - Project Planning, Completion, and Follow-Up Checklist (Form SP-02);
   - Well Development and Stabilization Form (Form SP-06);
   - Well Purging Field Information Form (Form SP-07);
   - Sample Collection Data Sheet - Groundwater Sampling Program (Form SP-08); and
   - Monitoring Well Record for Low-Flow Purging (if performed) (Form SP-09).
6. Return site and well keys.

7.11 REFERENCES

For additional information pertaining to groundwater sampling activities the user of this manual may reference the following:

ASTM D5474 Guide for Selection of Data Elements for Groundwater Investigations

ASTM D4696 Guide for Pore-Liquid Sampling from the Vadose Zone

ASTM D5979 Guide for Conceptualization and Characterization of Groundwater Systems

ASTM D5903 Guide for Planning and Preparing for a Groundwater Sampling Event

ASTM D4448 Standard Guide for Sampling Groundwater Wells

ASTM D6001 Standard Guide for Direct-Push Water Sampling for Geoenvironmental Investigations.

For additional information pertaining to surface water sampling, the user of this manual may reference the following:

ASTM D5358 Practice for Sampling with a Dipper or Pond Sampler

ASTM D4489 Practices for Sampling of Waterborne Oils

ASTM D3325	Practice for the Preservation of Waterborne Oil Samples
ASTM D4841	Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents
ASTM D4411	Guide for Sampling Fluvial Sediment in Motion
ASTM D4823	Guide for Core-Sampling Submerged, Unconsolidated Sediments
ASTM D3213	Practice for Handling, Storing, and Preparing Soft Undisturbed Marine Soil
ASTM D3976	Practice for Preparation of Sediment Samples for Chemical Analysis
ASTM E1391	Guide for Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing
ASTM D4581	Guide for Measurement of Morphologic Characteristics of Surface Water Bodies
ASTM D5906	Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths
ASTM D5073	Practice for Depth Measurement of Surface Water
ASTM D5413	Test Methods for Measurement of Water Levels in Open-Water Bodies