HYDROGEOLOGIC INVESTIGATION WORK PLAN

FLEETWIDE TRITIUM ASSESSMENT
BYRON GENERATING STATION
BYRON, ILLINOIS

Prepared For:
Exelon Generation Company, LLC

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1.0 INTRODUCTION

This report is a Hydrogeologic Investigation Work Plan (Work Plan) for the Byron Generating Station (Station) in Byron, Illinois (Site). Conestoga-Rovers & Associates (CRA) has prepared this Work Plan on behalf of Exelon Generation Company, LLC (Exelon). The location of the Station is presented on Figure 1.

This Work Plan has been prepared to assess groundwater quality near the Station by recommending areas for further evaluation (AFEs) regarding potential tritium impacts. CRA's development of recommended AFEs is based on information provided by Exelon Station staff and reviewed by CRA as well as CRA's site visit. This Work Plan, including the recommended AFEs is subject to further review and revision in the event that additional relevant information is obtained while work is being performed or from any other source.

The Work Plan also considers any historical spills and disposal/storage areas to evaluate whether:

- Appropriate documentation exists to evaluate the AFEs;
- The media of concern were appropriately identified and evaluated;
- Specific AFEs require additional investigation;
- Any corrective actions implemented were effective; and
- Any additional corrective actions are warranted.

This Work Plan contains:

- A description of the AFEs identified at the Station;
- The specific investigation techniques to be used to investigate each AFE and the overall groundwater system at the Station; and
- Necessary supporting documentation, procedures, and appendices for field personnel to implement the scope of work.

1.1 OBJECTIVES

The purposes and objectives of this hydrogeologic investigation are to:

- Characterize the hydrogeologic conditions at the property including subsurface soil types, the presence or absence of confining layers, and the direction and rate of groundwater flow;

- Characterize the groundwater/surface water interaction at the Station, including a determination of the surface water flow regime;
- Evaluate groundwater quality at the Station including the vertical and horizontal extent of any tritium in the groundwater;
- Define the probable sources and estimated quantity of any tritium released at the Station;
- Evaluate potential human, ecological, or environmental receptors of tritium released to the groundwater;
- Evaluate whether interim response activities are warranted to address the groundwater; and
- Provide a technical basis to evaluate possible remedial alternatives for tritium impacts identified at the Station.

1.2 REPORT ORGANIZATION

The remainder of this Work Plan is organized as follows:

- Section 2.0 - Site Background and Reconnaissance: this section presents the Station background; summarizes the regional geology, hydrogeology, and groundwater flow; documents the results of CRA's inspection of the Station; summarizes previous environmental investigations; and identifies AFEs;
- Section 3.0 - Conceptual Model: this section presents a preliminary conceptual model for the Station based on existing information;
- Section 4.0 - Scope of Work: this section describes the scope of work to be implemented including a description of the proposed activities; and
- Section 5.0 - Schedule: this section presents the schedule for the investigation and reporting.

2.0 BACKGROUND AND RECONNAISSANCE

This section presents a summary of the Station background information, identifies AFEs and describes the physical setting and the Station. CRA inspected the Station on March 21 and 22, 2006. CRA was accompanied by Mr. Dave Starke of the Byron Station and reviewed documents at the Station. The documents were assembled by the Station and provided to CRA to identify potential AFEs for further evaluation in this Work Plan. A list of documents reviewed is presented in Appendix A. The following sections present a summary of the historical Station information and data provided as they relate to the tritium investigation.

2.1 STATION DESCRIPTION

This Section presents the Station-specific background information pertinent to the hydrogeologic investigation. Figure 2 presents a Station Property Map with the Station infrastructure and property boundary. Figure 3 presents the Station Base Map.

The Byron Generating Station is located at 4450 North German Church Road in Byron, Illinois, Rockvale Township, Ogle County. The Site consists of approximately 1,900 acres, of which approximately 1,200 acres consist of the generating facility. The other approximately 700 acres of property encompass a 'buffer zone' around the Station and property to the west of the Station. The buffer zone extends to the Rock River. The Byron Station is located approximately 2-miles east of the Rock River; the blowdown line from the Station discharges into the Rock River.

Operations at the Station began in 1984. Since February 2006, the Station and CRA have been conducting an investigation in response to water containing tritium observed within the vacuum breaker vaults associated with the Station's blowdown line. During the investigation, CRA and Station personnel collected multiple samples from the vacuum breaker vaults, from nearby residential wells, from the blowdown line itself, from on-Site holding ponds, and from existing and newly installed monitoring wells on the Site. To date, as part of the blowdown line investigation, CRA installed and sampled 15 temporary shallow overburden monitoring wells and 14 bedrock wells and sampled 23 existing monitoring wells. CRA has not yet compiled the information and analytical data gathered during the investigation into a summary report.

2.2 SURROUNDING LAND USE

The land surrounding the Site is mixed farmland/residential. Adjacent to the Site to the west is the Byron Salvage Superfund Site (Byron Salvage Site), which is administered by Region V of the U.S. EPA. The Byron Salvage Site consists of two separate properties: the Byron Salvage Yard property and the Dirk's Farm property. The Dirk's Farm property is owned by Exelon. Investigative and remedial actions were conducted at the Byron Salvage Site beginning in the 1980s. The Byron Salvage Site remediation is in the long-term groundwater monitoring phase. CRA conducts groundwater sampling at the Byron Salvage Site, and maintains a database of the soil and groundwater analytical data.

Two separate groundwater plumes historically emanated from the Byron Salvage Site: the first plume is characterized by elevated concentrations of trichloroethene and cyanide and it migrated to the north and west of the Byron Salvage Site; and the second plume is characterized by lower but still elevated concentrations of trichloroethene and 1,1,1-trichloroethane that migrated to the southwest of the Byron Salvage Site.

2.3 REGIONAL INFORMATION

The following section presents a general summary of the geology, hydrogeology, groundwater flow conditions, and surface water bodies in the vicinity of the Station.

2.3.1 GEOLOGY

The northern portion of the midwestern United States is located in the Central Lowlands Physiographic Province. This physiographic province has been divided into several physiographic sections. Parts of the northern Illinois are located in the Wisconsin Driftless Section, the Till Plains Section, and the Great Lake Section.

The Byron Station is located within the Till Plains Section. The Till Plains Section is characterized in general by the presence of glacial deposits overlying the bedrock surface. Local outcrops of bedrock are present. The Till Plains Section in Illinois is further subdivided into the following physiographic subsections: the Rock River Hill Country, the Green River Lowland, the Bloomington Ridged Plain, the Galesburg Plain, the Kankakee Plain, and the Springfield Plain.

The Byron Station is located in the Rock River Hill Country physiographic subsection. The Rock River Hill Country is characterized by gently rolling, dissected uplands covered by thin deposits of glacial drift overlain by a thin cap of loess. The southwest-trending Rock River valley passes through the eastern portion of the subsection. Bedrock is exposed locally along the Rock River and along small tributary streams and valleys of the Rock River.

The soil units in the region adjacent to the Station area are generally relatively thin and locally absent. They include alluvial deposits associated with the rivers and streams in the area, glacial deposits of till and outwash generally located in the upland areas, thin loess deposits which overlie the till, and locally some thin residual soils developed from the weathering of the bedrock.

The distribution of the rock units which form the bedrock surface within the region include a sedimentary sequence of Cambrian to Cretaceous- rocks and an igneous and metamorphic complex of Precambrian-aged rocks. The sedimentary sequence in northern Illinois in the proximity of the Station includes Ordovician-aged and Cambrian-aged strata. These strata consist of 2,000 to 3,000 feet of dolomites, sandstones, and shales. The Precambrian basement in northern Illinois consists of granites and granodiorites.

The Byron Station lies within the Central Stable Region tectonic province of the North American continent. This tectonic region is characterized by a sequence of southward-thickening sedimentary strata overlying the Precambrian basement and was subjected to a series of vertical crustal movements forming broad basins and arches during Paleozoic and early Mesozoic time. The arches and basins have been modified by local folding and faulting.

2.3.2 HYDROGEOLOGY

The area is underlain by the Ordovician-age Galena-Platteville dolomites and the older Ordovician-age Glenwood Formation and St. Peter Sandstone. The most important aquifer in the region is the Cambrian-Ordovician Aquifer, made up of all bedrock between the top of the Galena-Platteville dolomites and the top of the Eau Claire Formation. These strata are in descending order, the Ordovician-age Galena, Platteville, Ancell, and Prairie du Chien Formation, and Ironton and Galesville Sandstones. At the Bryon Station, the Galena-Platteville dolomites are separated from the missing Cambrian-Ordovician Aquifer by the Harmony Hill Shale Member of the Glenwood Formation. The Cambrian-Ordovician Aquifer is separated from the deeper Mt. Simon

Aquifer by the shale beds of the Eau Claire Formation. Available data indicate that, on a regional basis, the entire sequence of strata above the Eau Claire Formation behaves hydraulically as one aquifer. In places, pressure heads between the waterbearing units differ, and the hydraulic connection is imperfect. The Maquoketa Shale Group is absent in the Site area. The St. Peter, Ironton, and Galesville Sandstones are recharged from overlying glacial deposits in the central and western parts of northern Illinois where the Maquoketa Shale Group has been removed by erosion. These units are also recharged by vertical leakage through the Maquoketa Shale Group in northeastern Illinois and by through-flow from the outcrop area in southern Wisconsin.

The Galena and Platteville Groups dolomites are extensively fractured near the top, with solutionally enlarged openings in places but become dense at depth. Water from the Galena-Platteville dolomites in the area is generally hard. Relatively low yields, water hardness, and susceptibility of the aquifer to contamination because of thin drift, fractures, and solution channels do not favor development of the Galena-Platteville dolomites.

Below the Galena-Platteville dolomites are the thin shales, sandstones, and limestones of the Glenwood Formation. This unit grades down into the thick sandstones of the St. Peter Sandstone. The Ordovician-age St. Peter Sandstone is permeable and has a relatively uniform lithology throughout the area. In the regional area, the St. Peter Sandstone is discharged primarily through wells for small municipalities, subdivisions, parks, and several industries that have water requirements generally less than 200 gpm. If the overlying Galena-Platteville dolomites were cased off and the casing extended through the Glenwood Formation into the sandstone, softer water than in any of the overlying units should be obtained.

Deep-well logs in the area suggest that the Prairie du Chien Group is locally missing and that Cambrian-aged dolomites of the Eminence Formation, Potosi Dolomite, and Franconia Formation underlie the St. Peter Sandstone.

Below the Franconia Formation are the Ironton and Galesville sandstones. The sandstones are discharged primarily through wells to industries and municipalities. Regionally, the Ironton and Galesville sandstones are considered the best bedrock aquifer in northern Illinois because of their consistent permeability and thickness.

Below the Ironton and Galesville sandstones is the Eau Claire Formation. The basal part of the Eau Claire Formation and the underlying Mt. Simon Sandstone form the basal Cambrian-age Mt. Simon Aquifer. Wells yielding many hundreds of gallons per minute have been finished in the Mt. Simon Sandstone, which contains fresh water to depths of about 2,000 feet. It is recharged in outcrop areas in Wisconsin and from vertical leakage from overlying aquifers.

2.3.3 GROUNDWATER FLOW

Groundwater flow in the Galena-Platteville dolomites occurs along joints and bedding planes. Solutioning along these pathways continues at an imperceptible rate due to the low solubility of the dolomite, the hardness of the groundwater, and the relatively low hydraulic gradient within the aquifer.

The general regional groundwater flow direction in the Galena-Platteville dolomites and the underlying Glenwood Formation and St. Peter Sandstone is to the west toward the Rock River. Local variations in the flow directions are common due to topographic changes in the thickness of the aquifer units.

2.3.4 SURFACE WATER BODIES

Woodland Creek is located to the north of the Station and flows to the northwest toward the Rock River and an unnamed creek is located to the west of the Station and flows to the west toward the Rock River. Both of these creeks are ephemeral, flowing only during times of heavy rainfall. The Rock River is approximately two miles west of the Station.

A total of seven ponds exist in the northeast section of the Station (see Figure 3). Six of these ponds are in an east-west trending series and are referred to as the Treated Runoff (TR) ponds. The four western TR ponds collect water from the plant; the water from these four ponds is pumped to the waste treatment building for processing. The two eastern TR ponds collect rainwater from the stormwater sewers; the water from these ponds is pumped to the Construction Runoff Pond (CROP) located north of the TR ponds. Water from the CROP pond is eventually pumped back into the Station's cooling towers.

2.3.5 SURROUNDING AREA GROUNDWATER USE

Potable water for the residences south, east, and west of the Station is provided by private water wells at each property. As a result of the Byron Salvage Site remediation, a water main from Byron was installed to service many of the residents located north of the Station. The St. Peter Sandstone is the primary aquifer for residential potable water in the area. Retec completed a water well search and survey for the Station in 2005. CRA is updating the water well search.

2.4 STATION-SPECIFIC GEOLOGY AND HYDROGEOLOGY

2.4.1 EXISTING ONSITE WELLS

Figure 4 presents a map of the Station with the existing on-site well network. A total of 79 wells exist on Exelon property. Of these, Exelon owns 33 wells and the rest are owned by the Byron Salvage Site PRP Group. A summary of the existing well information is provided in Table 1.

There are two former farmhouse water supply wells on the Exelon property (Figure 4). The wells are designated GW-9 and Well 7. During the course of the Byron Salvage project, a large number of monitoring wells were installed, and many of the wells were installed on the Station Site. The monitoring wells are set at different depths to screen all three hydrogeologic units located under the Site. CRA monitors the levels and water quality of the wells at the Station as part of the long-term monitoring program for the Byron Salvage Site.

There are two deep wells in the Station's Protected Area (PA). The wells are designated Deep Well 1 and Deep Well 2 and are used for the Station's water supply. Both wells were installed during the construction of the Station and draw water from depths greater than 500-feet below grade (Figure 4).

As described in Section 2.1, 15 temporary shallow overburden monitoring wells and 14 bedrock wells have been installed along the blowdown line and within the Station's PA as part of the blowdown line investigation.

2.4.2 STATION GEOLOGY

The Station is underlain by a thin veneer of overburden deposits, followed by flat-lying bedrock formations. The overburden deposits vary from less than 1 foot to approximately 12 feet in thickness and consist mainly of silty loam and loess, with alluvial deposits near the Rock River. The bedrock is comprised of Ordovician-aged dolomitic and sandstone layers progressing downward as follows:

- Galena Group Dolomites (upper aquifer);
- Platteville Group Dolomites (upper aquifer); and
- Ancell Group, consisting of:
  - Glenwood Formation (shale with sandy dolomite, semi-confining layer),
  - St. Peter Sandstone Formation (lower aquifer), and
  - older Cambrian formations.

The Station was constructed on an area of a 'bedrock high'. The Station's foundation was installed into the bedrock. Figures 5 and 6 present generalized cross-sections of the geology prepared from geologic information gathered from boreholes advanced prior to construction of the Station. The locations of the cross-sections are shown on Figure 4.

2.4.3 STATION HYDROGEOLOGY

Groundwater flow patterns vary at the Site. Figure 7 presents the groundwater flow contours within the upper aquifer (Galena-Platteville dolomites). In July 1974, the Station assessed groundwater flow using a system of wells and piezometers installed prior to Station construction. Since the facility sits upon a bedrock high, groundwater flow directly beneath the facility is radially outward in all directions.

To the west of the Station near the blowdown line, which follows a northwest and then westerly path from the Station to the Rock River, groundwater flow was assessed as part of the Byron Salvage Site. There is a northwest/southeast trending groundwater divide near Razorville Road, west of the Station, and perpendicular to the blowdown line. The direction of groundwater flow at points along the blowdown line is to the northwest, then to the southwest, and eventually to the west, depending upon the location. Groundwater flowing to the southwest could ultimately discharge to the quarry pond.

2.5 DETERMINATION OF AREAS FOR FURTHER EVALUATION

This section provides a review of the factors used by CRA to identify AFEs for the Station. A summary of the AFEs identified by CRA is presented in Table 2.

CRA evaluated information concerning potential historical releases at the Station and the structures, components, and areas of the Station which have the potential for the release of tritium to the environment, combined with the understanding of groundwater flow at the Station, to determine the AFEs for the Station.

2.5.1 TRITIUM RELEASES

CRA has reviewed information concerning confirmed or potential historical releases at the Station, including reports and documentation previously prepared by Exelon and compiled for CRA's review. This information was considered by CRA in developing this Work Plan, which will address all confirmed and potential releases described therein.

2.5.2 EXELON SYSTEMS EVALUATIONS

Exelon has reviewed the systems at this Station that manage tritium-containing materials. CRA has received mark-ups of Station drawings showing the locations of these systems. Figures 8 and 9 present the locations of the systems that manage tritium-containing materials at the Station.

Exelon has evaluated the significance of each of these systems with respect to potential tritium releases to soils and groundwater. Based on CRA's review of information provided by the Station, the following is a listing of systems that contain or potentially contain tritium and are in direct contact with soils and/or groundwater.

System Identification Number	Description
AB	Boric Acid Proc
AS	Aux Stream
BR	Boron Thermal Regeneration
CD	Condensate
CP	Condensate Cleanup
CW	Circ Water
DM	Misc. Bldg. Dr
DV	FW Heater Drain/Vents
FC	Fuel Pool Cooling
FP	Fire Protection
GS	Turbine Gland Seals
HD	Feedwater Drains
MS	Main Steam
OD	Equipment/Floor Oil Drain
PS	Process Sampling
PW	Primary Water
RF	Reactor Bldg. Floor Drains
SH	Station Heat

[illegible]	[illegible]
SI	Safety Injection
ST	Sewage Treatment
SX	Essential Service Water
TE	Turbine Bldg. Equipment Drains
TF	Turbine Bldg. Floor Drains
TR	Treated Runoff
VF	Filter Vents
VR	Volume Reduction
WE	Aux. Bldg. Equipment Drain
WF	Aux. Bldg. Floor Drain
WS	Non-Essential Service Water
WX	Radwaste Disposal

CRA has reviewed the Exelon Risk Evaluation Template to determine whether any of the systems require further evaluation outside of the activities already completed as part of the blowdown line investigation. All of the Systems identified by Exelon as being worthy of assessing are in the PA.

CRA has recently installed five monitoring wells in the Station's PA. The five monitoring wells were installed downgradient from the systems that manage(d) tritiated water.

If a tritium release occurs inside the PA, it would be expected to migrate downward through the bedrock to the water table approximately 60-feet below grade, and then would move radially outward with the groundwater. Therefore, these monitoring wells will provide a 'first response' should a future failure of one of the systems occur.

2.5.3 UTILITIES THAT MAY BE POTENTIAL MIGRATION PATHWAYS

Based on documents provided by Station personnel, CRA has completed a review of the Station's subsurface utilities, depths, sizes, locations, and paths, including abandoned utilities and/or existing utility corridors. CRA has completed this review to identify potential preferential groundwater migration pathways to other on-Station or off-Station receptors.

Based on information gathered by CRA during the blowdown line investigation and from existing geologic reports, the first groundwater unit under the Station is approximately 60-feet below grade. This is well below the depth of the utilities. Therefore, none of the utilities are considered to be preferential pathways for groundwater migration.

2.5.4 PREVIOUS INVESTIGATIONS AND REMEDIATIONS

2.5.4.1 TRITIUM DATA

As described in Sections 2.1, water was observed in the concrete vault for VB-6 of the blowdown line in July 2005 during an annual inspection. Samples of the water contained less than 2,000 pCi/L of tritium. Samples of water observed in several other vacuum breaker vaults in December 2005/January 2006 contained concentrations of tritium ranging from non-detect to 80,123 pCi/L.

During the blowdown line investigation, CRA and Station personnel collected multiple samples from the vacuum breaker vaults, nearby residential wells, the blowdown line, on-Site holding ponds, and existing and newly installed monitoring wells on Site. Tritium concentrations detected in water samples collected from the vaults, especially vaults 2 and 3, have fluctuations below and above the lower level of detection (LLD). Groundwater samples from three monitoring wells contained detectable concentrations of tritium. CRA collected the following groundwater samples on April 4, 2006:

- monitoring well AR-2, downgradient and adjacent to VB-2 - contained 442 pCi/L tritium;
- monitoring well AR-3, downgradient and adjacent to VB-3 - contained 489 pCi/L tritium; and
- monitoring well AR-4, located downgradient and adjacent to VB-4 - contained 3,741 pCi/L tritium.

Monitoring well AR-11 has recently been installed near AR-4 to further investigate the tritium concentration detected in the groundwater sample collected near VB-4.

2.5.4.2 GROUNDWATER REMEDIATION

No groundwater remediation has been required or completed at the Station.

2.5.4.3 OTHER REMEDIATION

No other remediation for tritium has been completed at the Station.

2.6 AREAS FOR FURTHER EVALUATION

Exelon launched an initiative to systematically assess the structures, systems and components that potentially store, use, or convey potentially radioactive contaminated liquids. Each structure or identified component was subsequently evaluated against the following seven primary criteria:

- Location of the component (i.e., basement or second floor of building);
- Component construction material (i.e., stainless steel or steel tanks);
- Construction methodologies (i.e., welded or mechanical pipe joints);
- Concentration of material stored or conveyed;
- Amount of material stored or conveyed;
- Existing controls (i.e., containment and detection); and
- Maintenance history.

The evaluation process resulted in the identification of structures, components, and areas that require further evaluation. The structures, components, and areas, hereinafter referred to as AFEs, may include:

- Aboveground storage tanks;
- Condensate vents;
- Areas where confirmed or potential historical releases, spills or accidental discharges may have occurred;
- Pipes;
- Pools;
- Sumps;
- Surface water bodies (i.e., basins, pits, ponds, or lagoons);
- Trenches;
- Underground storage tanks; and
- Vaults.

CRA determined the AFEs based on information provided by the Stations including a list of the systems that contain tritium and information to create maps of those systems.

Table 2 presents a summary of the AFEs and the monitoring wells which have been installed to investigate the AFEs. A summary of the AFEs is presented below:

- AFE Byron Station 1 - Former Fiberglass Blowdown Line; and
- AFE Byron Station 2 - Vacuum Breaker Vaults.

No other AFEs have been identified for the Station. There are, however, several locations within the Station PA that are considered higher priority primary systems areas in which tritium water could be released to the environment if a failure or set of events were to occur. To investigate these higher priority areas, the Byron Station and CRA have installed five monitoring wells in locations downgradient of these areas. The rationale for the locations of these five wells is shown in Table 2.

3.0 CONCEPTUAL MODEL

As part of the preparation of this Work Plan, a preliminary conceptual model for the Station was developed using historical Site data. The following presents the preliminary conceptual model, which serves as the basis for evaluating the fate and transport of tritium in the groundwater at the Station.

Because the groundwater under the property is relatively deep (60 feet below grade), any water containing tritium released to the environment would migrate vertically down to the water table, and then would travel with the groundwater in the direction of flow. Due to a bedrock high on Site, the groundwater directly under the Station flows radially away from the Station. To the west, in the area of the blowdown line, the groundwater flow varies, and is regulated by a groundwater divide located in the area of Razorville Road (Figure 7).

Both of the AFEs identified for the Station, as well as other areas, are already being evaluated as part of the blowdown line investigation. The locations of monitoring wells installed as part of the blowdown line investigation were selected based on the topography of the area and the hydrogeologic properties of the bedrock aquifers.

The AFEs are potential sources of tritium to the subsurface. If a tritium release impacts groundwater, it would migrate down to the water table and move primarily with groundwater flow. Potential off-property discharge points include domestic wells, a quarry pond, and potentially the Rock River. Water samples collected recently from the residences near the blowdown line have all been non-detect for tritium.

Potential human receptors of tritium released to groundwater are off-property residential users, off-property recreational users of the Rock River, and on-property employees. Potential ecological receptors of tritium released to groundwater are aquatic and wildlife associated with the Rock River and the quarry pond.

4.0 SCOPE OF WORK

This section presents the scope of work for the tritium groundwater investigation. Appendix B provides a description of the detailed field investigation methodologies to be used during the investigation. Appendix C provides a Site-Specific Health and Safety Plan. Appendix D provides a property access/utility clearance data sheet for the Station. Appendix E presents CRA's standard operating procedures that are relevant to this project. Appendix F describes reporting and data validation.

CRA is completing a hydrogeologic investigation for Exelon that addresses all AFEs identified. As a result, CRA does not recommend the installation of any additional monitoring wells at the Site. The scope of work proposed for the tritium groundwater investigation involves one complete round of groundwater sampling along with the preparation of a comprehensive report documenting the blowdown line investigation and the additional groundwater sampling.

4.1 TASK 1 - GROUNDWATER SAMPLING

During the blowdown line investigation, multiple samples were collected for tritium analyses from the vacuum breaker vaults, from nearby residential wells, from the blowdown line itself, from on-Site holding ponds, and from existing and newly installed monitoring wells on the Site.

For the Fleetwide tritium investigation, CRA will collect one additional complete round of groundwater samples from 41 monitoring wells on Exelon property. Table 3 summarizes the groundwater sampling program. These are the monitoring wells already being sampled during the blowdown line investigation. Groundwater samples will be collected using low flow purging techniques. Groundwater samples collected from the 22 monitoring wells owned by the Byron Salvage PRP Group will only be analyzed from tritium. The 19 monitoring wells owned by Exelon will be analyzed for the following parameters:

- Tritium (H-3);
- Strontium-89/90 (both together);
- Strontium-90 (only if Strontium 89/90 is detected above 2 pCi/L); and
- Gamma spec parameters which include:
  - Barium - 140,
  - Cesium - 134,
  - Cesium - 137,

- Cobalt - 58,
- Cobalt - 60,
- Ferrous Citrate - 59,
- Lanthanum - 140,
- Manganese - 54,
- Niobium - 95,
- Zinc - 65, and
- Zirconium - 95.

All samples will be shipped to a contract laboratory for analysis.

Prior to sampling, CRA will collect a full round of water level measurements from the monitoring wells using an electronic depth-to-water probe accurate to +/- 0.01 foot. The groundwater elevation will be calculated using the surveyed top-of-casing elevation at each well head.

4.2 TASK 2 - DATA ANALYSIS

Following the completion of field activities, all data will be compiled and reviewed. This will include review and analysis of the newly acquired data collected under this Work Plan along with the data acquired during the blowdown line investigation.

The data will be reviewed using one or more of the following techniques (but not limited to):

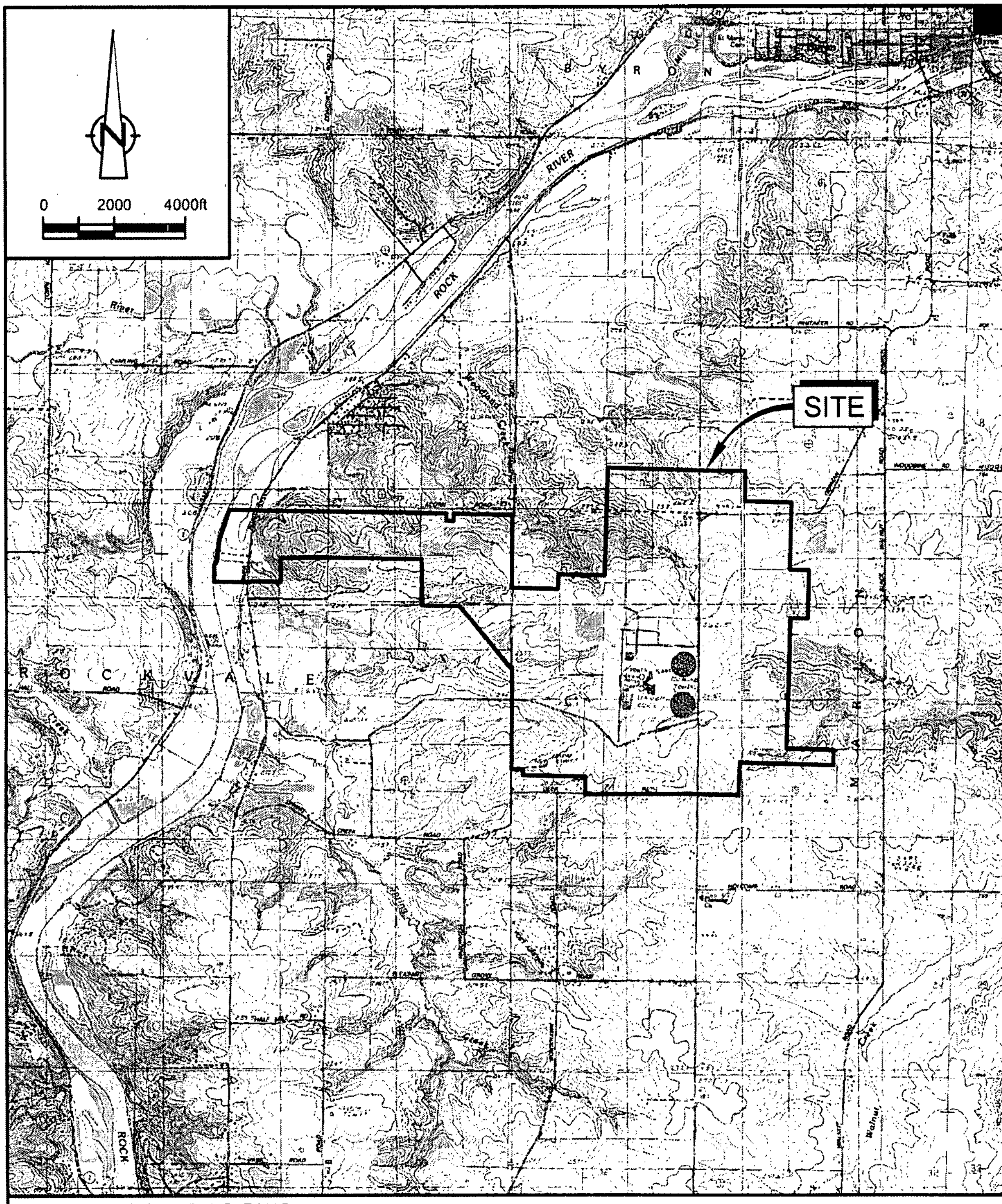
- Graphs (hydrographs and time versus concentration);
- Isoconcentration maps;
- Cross-sections;
- Hydraulic analysis;
- Statistical analysis; and
- Data trends.

4.3 TASK 3 - HYDROGEOLOGIC INVESTIGATION REPORT

Following completion of the above activities, a comprehensive Hydrogeologic Investigation Report will be submitted to Exelon that presents the results of the blowdown line investigation and the field activities conducted during the fleetwide tritium study. Further details regarding reporting and data validation are presented in Appendix F.

5.0 SCHEDULE

This hydrogeologic investigation will be implemented consistent with the Fleetwide Tritium Assessment project schedule as prepared by and reviewed daily by Exelon corporate, the Station, and CRA.



SOURCE: USGS QUADRANGLE MAP;
BYRON MOSAIC, ILLINOIS

figure 1

STATION LOCATION MAP
BYRON GENERATING STATION
EXELON GENERATION COMPANY, LLC
Byron, Illinois

Exelon

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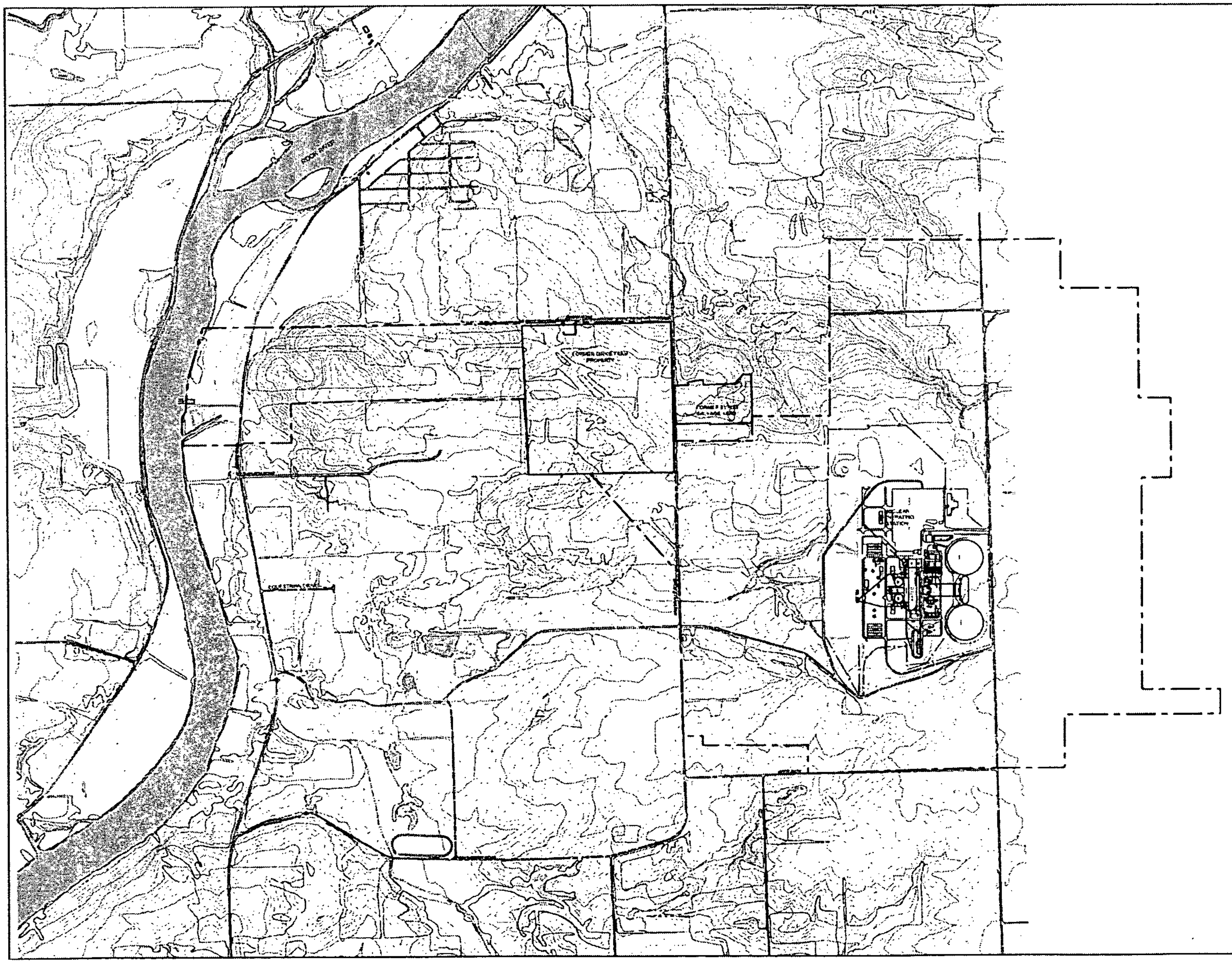


SCALE VERIFICATION

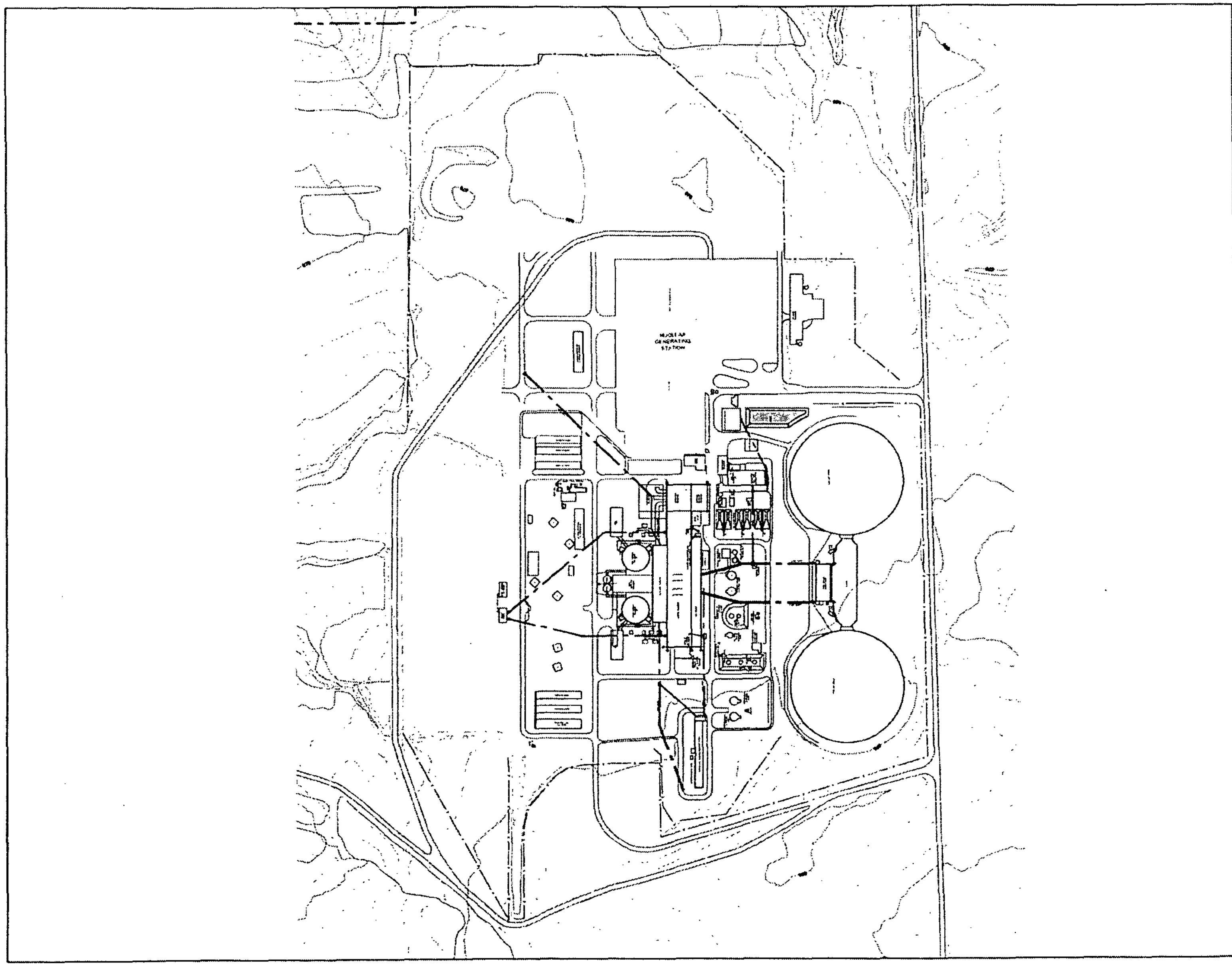
EXELON GENERATION COMPANY, LLC

FLEETWIDE TRITIUM ASSESSMENT

STATION PROPERTY MAP
BYRON GENERATING STATION
BYRON, ILLINOIS

Exelon.

	45136-21	002	figure 2



SCALE VERIFICATION

EXELON GENERATION COMPANY, LLC

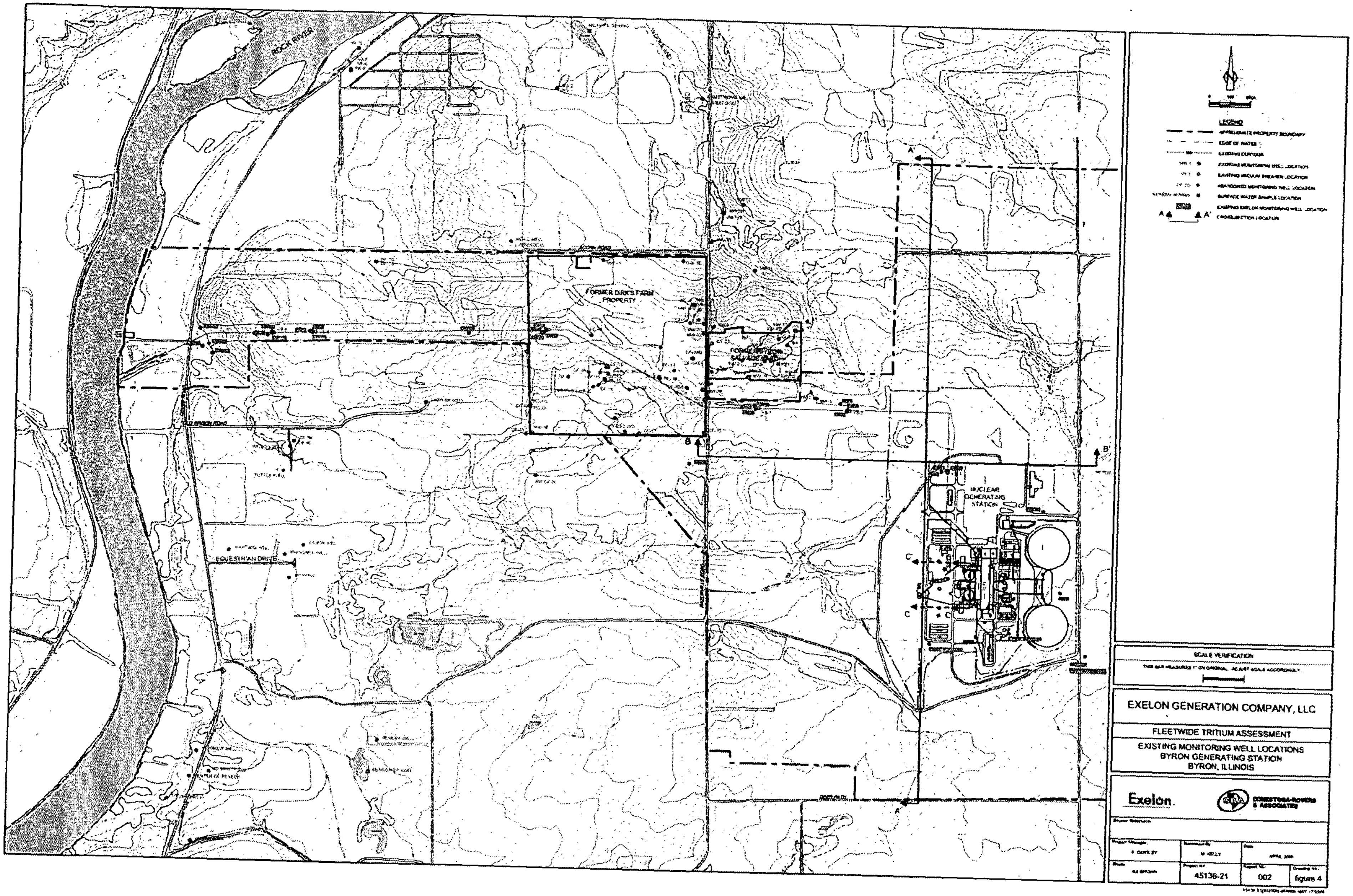
FLEETWIDE TRITIUM ASSESSMENT

STATION BASE MAP
BYRON GENERATING STATION
BYRON, ILLINOIS

Exelon.

CONESTOGA-ROVERS & ASSOCIATES

	45136-21	002	figure 3


ROCK RIVER
FORMER DIRK'S FARM PROPERTY
NUCLEAR GENERATING STATION
EQUESTRIAN DRIVE
LEGEND
SCALE VERIFICATION
EXELON GENERATION COMPANY, LLC
FLEETWIDE TRITIUM ASSESSMENT
EXISTING MONITORING WELL LOCATIONS
BYRON GENERATING STATION
BYRON, ILLINOIS
Exelon.
45136-21
002
figure 4

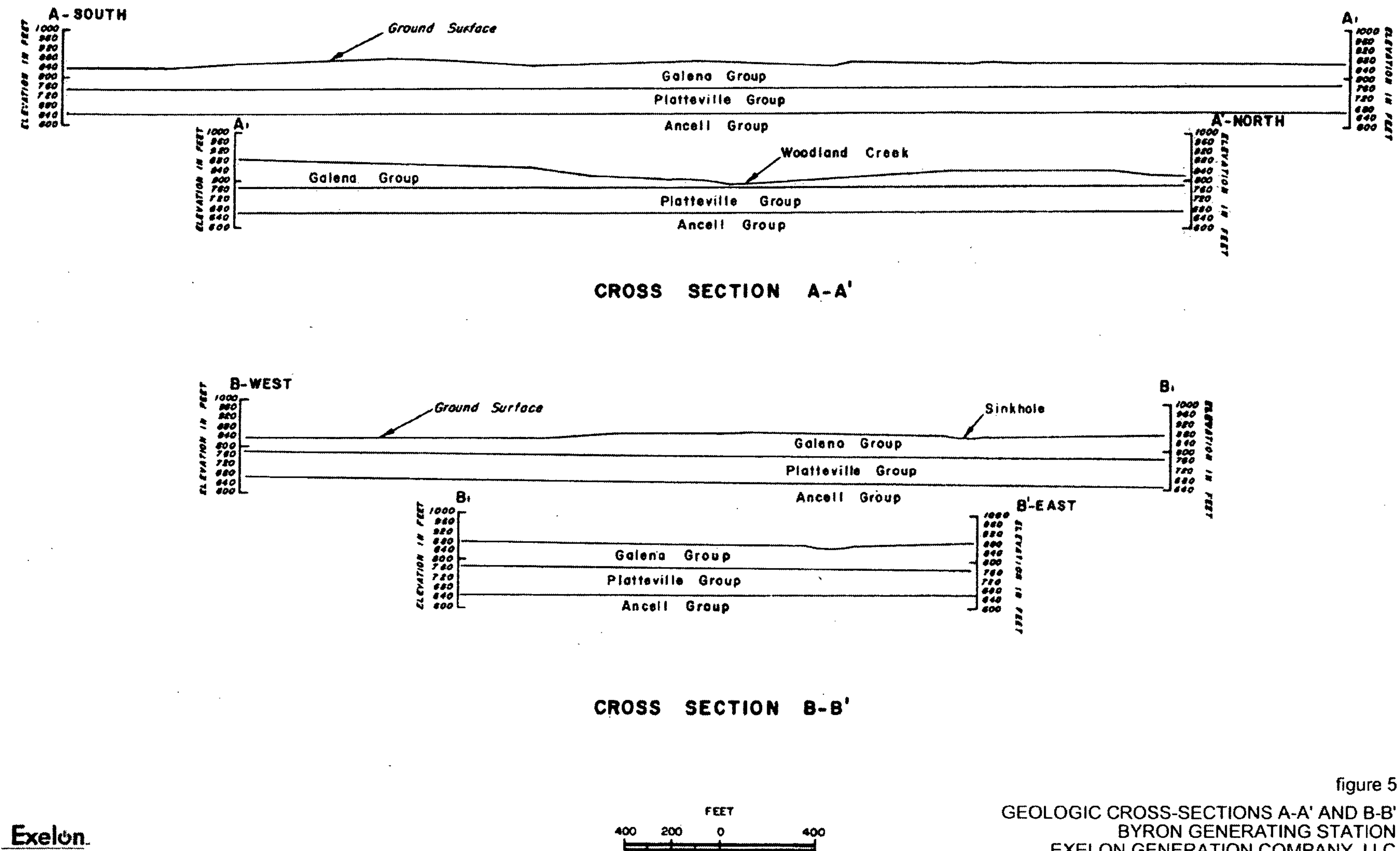
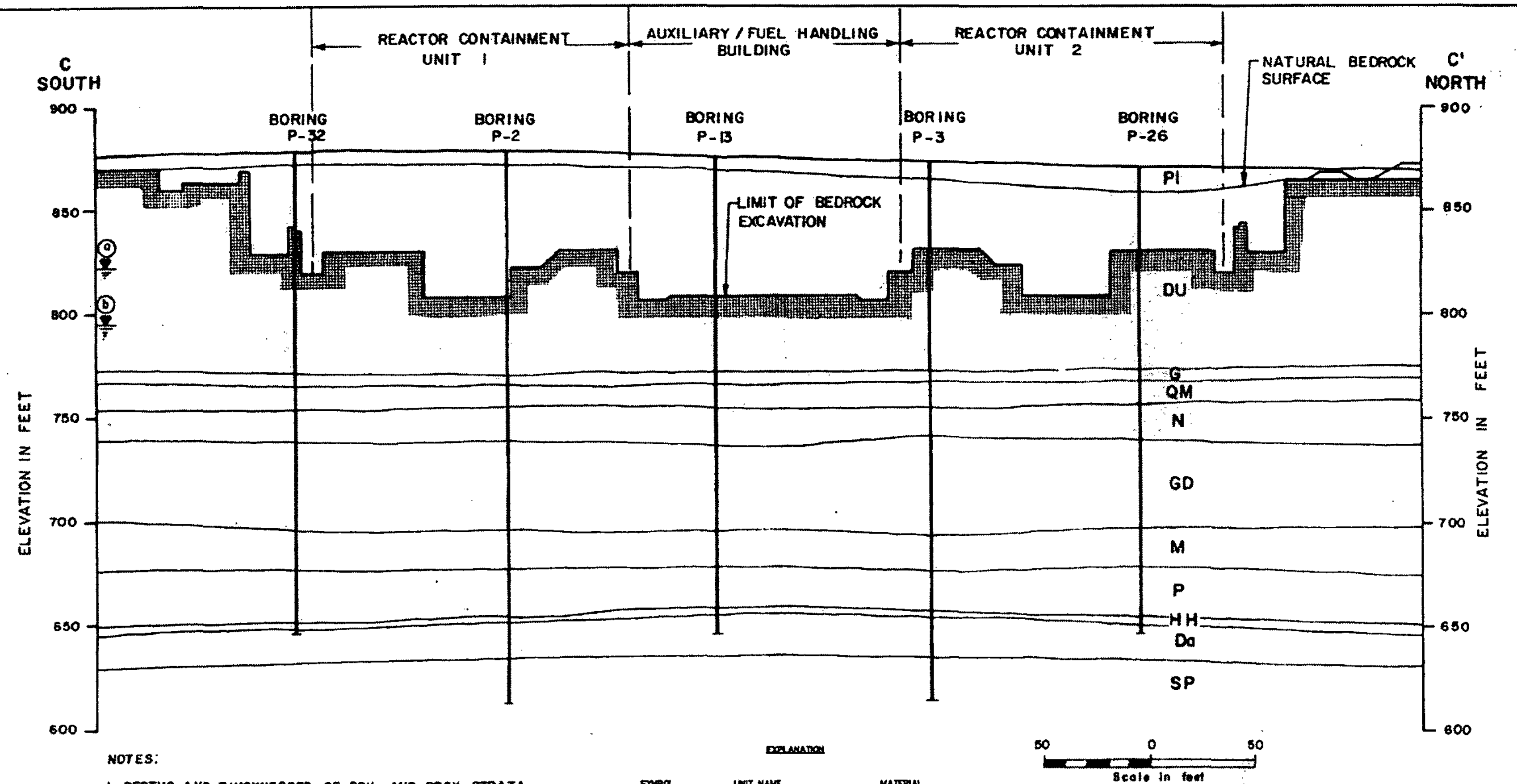


figure 5

GEOLOGIC CROSS-SECTIONS A-A' AND B-B'
BYRON GENERATING STATION
EXELON GENERATION COMPANY, LLC
Byron, Illinois

Exelon.

45136-21(002)GN-WA002 APR 12/2006



NOTES:

1. DEPTHS AND THICKNESSES OF SOIL AND ROCK STRATA ARE INTERPRETED FROM BORINGS P-44, P-26, P-3, P-13, P-2, P-32 AND P-14. ACTUAL SUBSURFACE CONDITIONS BETWEEN BOREHOLES MAY DIFFER FROM THAT WHICH IS SHOWN.
2. LOCATION OF SECTION IS SHOWN ON FIGURE 2.5-3.
3. (a) INDICATES PERCHED GROUND WATER LEVEL.
   (b) INDICATES GROUND WATER LEVEL IN GALENA-PLATTEVILLE AQUIFER.

EXPLANATION

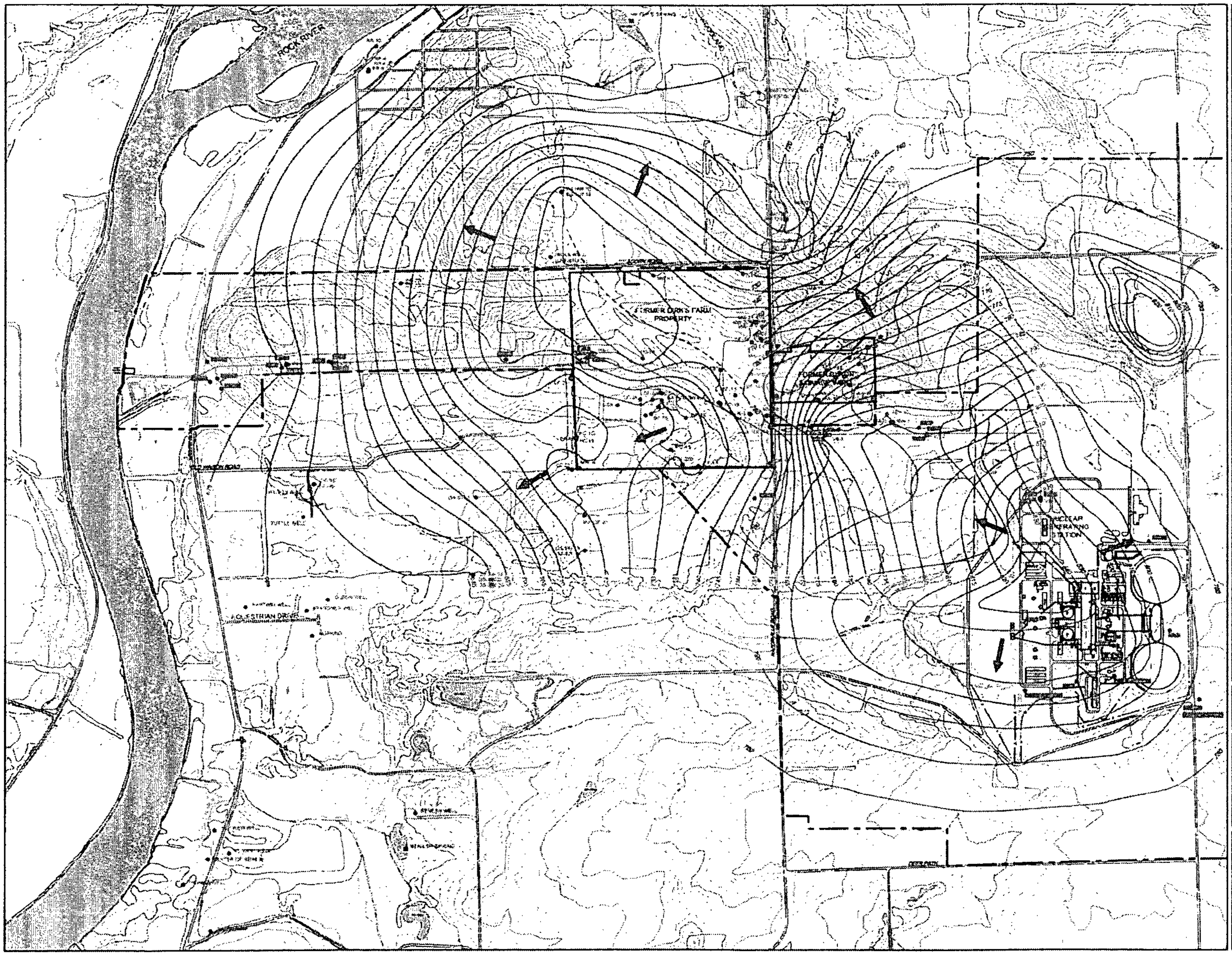
SYMBOL	UNIT NAME	MATERIAL
Pl	PLEISTOCENE OVERBURDEN	LOESS AND TILL
Du	DUNLEITH FORMATION	DOLOMITE
G	GUTTENBURG FORMATION	DOLOMITE
QM	QUIMBYS MILL FORMATION	DOLOMITE
N	NACHUSA FORMATION	DOLOMITE
GD	GRAND DETOUR FORMATION	DOLOMITE
M	MIFFLIN FORMATION	DOLOMITE
P	PECATONICA FORMATION	DOLOMITE
HH	GLENWOOD FORMATION, HARMONY HILL MEMBER	SHALE
Da	GLENWOOD FORMATION, DAYSVILLE MEMBER	SANDY SHALE, DOLOMITE AND SANDY DOLOMITE
SP	ST. PETER FORMATION	SANDSTONE

Exelon.

figure 6

GEOLOGIC CROSS-SECTION C-C'
BYRON GENERATING STATION
EXELON GENERATION COMPANY, LLC
Byron, Illinois

45136-21(002)GN-WA002 APR 12/2006



SCALE VERIFICATION

EXELON GENERATION COMPANY, LLC

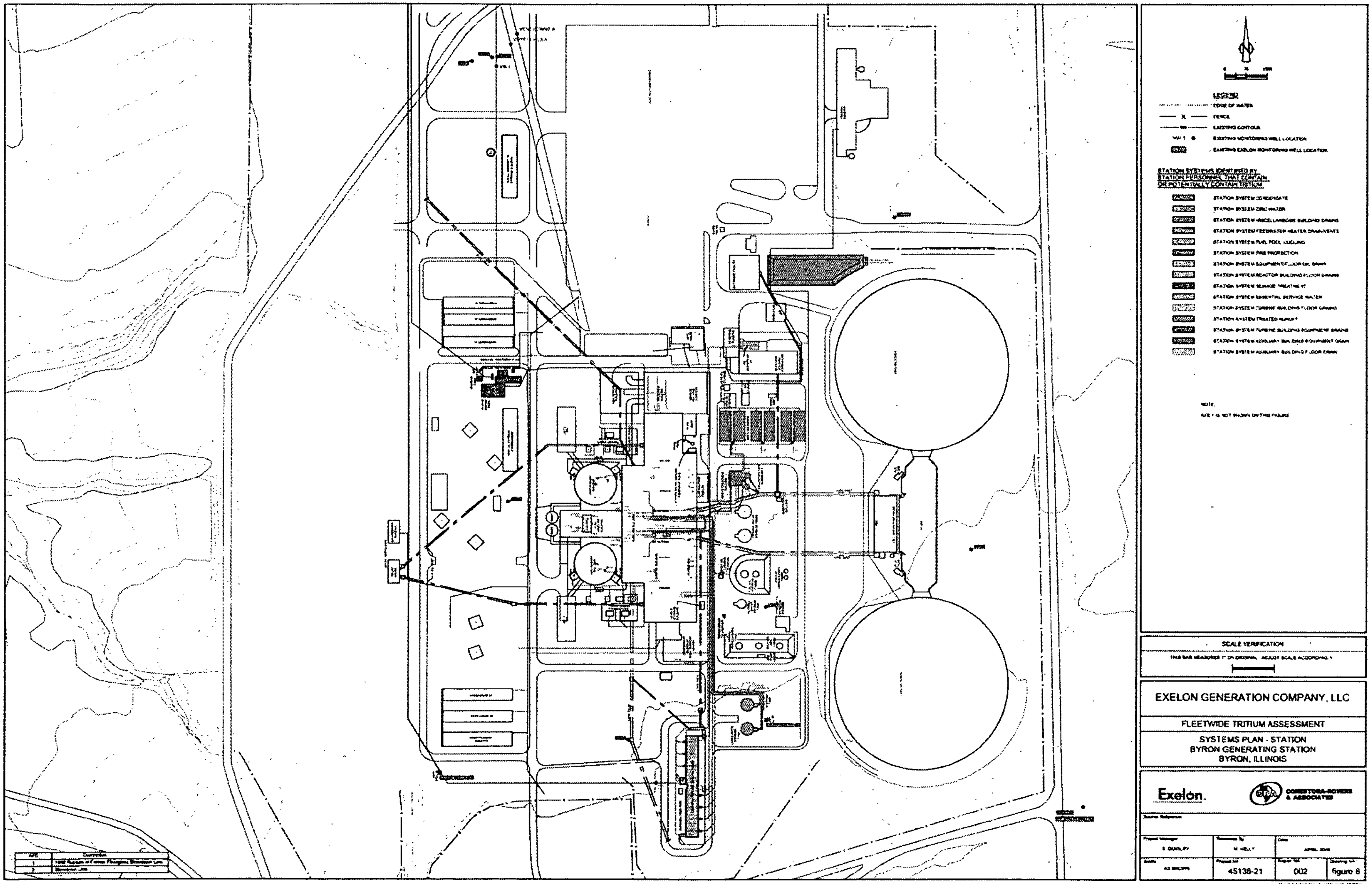
FLEETWIDE TRITIUM ASSESSMENT

GROUNDWATER CONTOUR MAP
BYRON GENERATING STATION
BYRON, ILLINOIS

Exelon.

CONESTOGA-ROVERS & ASSOCIATES

Scale	Project No.	Report No.	Drawing No.
AS SHOWN	45138-21	002	figure 7


LEGEND
EDGE OF WATER
FENCE
EXISTING CONTOUR
EXISTING MONITORING WELL LOCATION
EXISTING EXELON MONITORING WELL LOCATION
STATION SYSTEMS IDENTIFIED BY STATION PERSONNEL THAT CONTAIN OR POTENTIALLY CONTAIN TRITIUM
STATION SYSTEM CONDENSATE
STATION SYSTEM CIRC WATER
STATION SYSTEM MISCELLANEOUS BUILDING DRAINS
STATION SYSTEM FEEDWATER HEATER DRAINS/VENTS
STATION SYSTEM FUEL POOL COOLING
STATION SYSTEM FIRE PROTECTION
STATION SYSTEM REACTOR BUILDING FLOOR DRAINS
STATION SYSTEM SEWAGE TREATMENT
STATION SYSTEM ESSENTIAL SERVICE WATER
STATION SYSTEM TURBINE BUILDING FLOOR DRAINS
STATION SYSTEM TREATED RUNOFF
STATION SYSTEM TURBINE BUILDING EQUIPMENT DRAINS
STATION SYSTEM AUXILIARY BUILDING EQUIPMENT DRAIN
STATION SYSTEM AUXILIARY BUILDING FLOOR DRAIN
SCALE VERIFICATION
EXELON GENERATION COMPANY, LLC
FLEETWIDE TRITIUM ASSESSMENT
SYSTEMS PLAN - STATION
BYRON GENERATING STATION
BYRON, ILLINOIS
Exelon.
CONESTOGA-ROVERS & ASSOCIATES
45136-21
002
figure 8

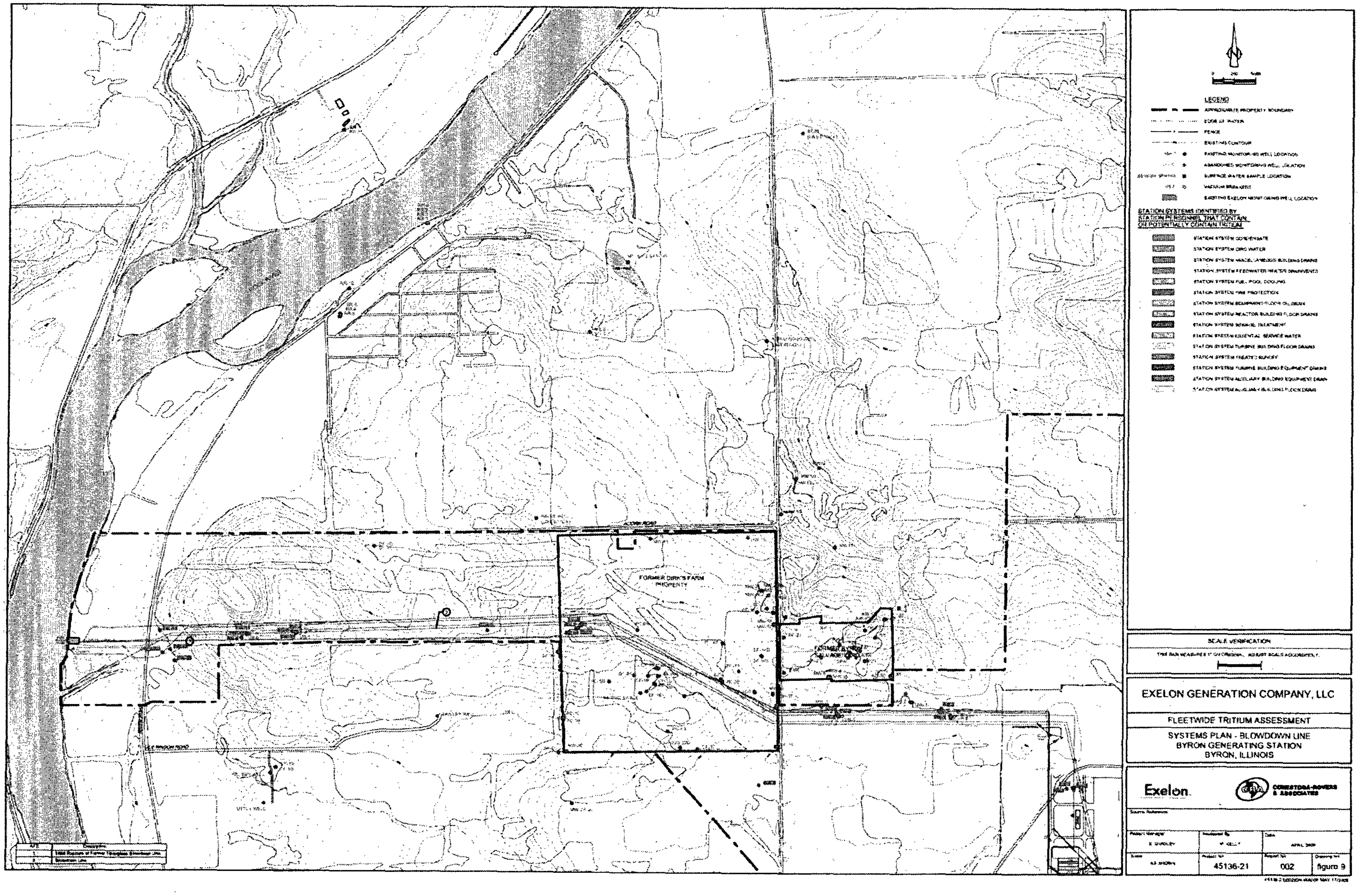

LEGEND
FORMER DIRK'S FARM PROPERTY
EXELON GENERATION COMPANY, LLC
FLEETWIDE TRITIUM ASSESSMENT
SYSTEMS PLAN - BLOWDOWN LINE
BYRON GENERATING STATION
BYRON, ILLINOIS
Exelon.
CONESTOGA-ROVERS & ASSOCIATES
45136-21
002
figure 9

TABLE 1

SUMMARY OF EXISTING WELL INFORMATION
FLEETWIDE TRITIUM ASSESSMENT
BYRON GENERATING STATION
BYRON, ILLINOIS

Well ID	Well Details: Hydrologic Unit Open To	Well Details: Screened Interval/Open Interval (ft bgs)	Well to be Sampled
Exelon-owned Wells			
AR-1	GPWT	50-70	Yes
AR-2	GPWT	71-81	Yes
AR-3	GPWT	60-70	Yes
AR-4	GPWT	99.5-119.5	Yes
AR-5	GPWT	102-122	Yes
AR-6	GPWT	95-115	Yes
AR-7	GPWT	102-112	Yes
AR-8	GPWT	30-50	Yes
AR-9	GPWT	55.5-65.5	Yes
AR-10	GPWT	19-29	Yes
AR-11	BGP	139.5-149.5	Yes
CAR-1	GPWT	45-55	Yes
CAR-2	GPWT	25-35	Yes
CAR-3	GPWT	43-63	Yes
TW-1	Shallow Overburden	3.5-8.5	
TW-2	Shallow Overburden	2-7	
TW-3	Shallow Overburden	5.5-10.5	
TW-4	Shallow Overburden	5.5-10.5	
TW-5	Shallow Overburden	3-8	
TW-6	Shallow Overburden	3.5-8.5	
TW-7	Shallow Overburden	6-11	
TW-8	Shallow Overburden	7-12	
TW-9	Shallow Overburden	3-8	
TW-10	Shallow Overburden	2.5-7.5	
TW-11	Shallow Overburden	5-10	
TW-12	Shallow Overburden	7-12	
TW-13	Shallow Overburden	13-18	Yes
TW-14	Shallow Overburden	24-34	Yes
TW-15	Shallow Overburden	24-29	Yes
GW-9	GPWT	Not Available	Yes
Well 7	Not Available	Not Available	Yes
Deep Well 1	Not Available	Not Available	
Deep Well 2	Not Available	Not Available	
Byron Salvage PRP Group-owned Wells			
DF-1D	BGP	76-94	Yes
DF-1S	GPWT	39-62	Yes
DF-2D	BGP	104-112	
DF-2S	GPWT	52-75	Yes
DF-3S	GPWT	43-66	Yes
DF-4DD	BGP	137-151	
DF-4DS	GPWT	41-64	Yes
DF-5S	GPWT	13-65	
DF-6	BGP	113-125	Yes
DF-7D	UAM	40-48	
DF-7S	UAWT	20-27	
DF-8	BGP	55-63	
DF-10	GPWT	62-84	Yes
DF-11	GPWT	65-84	
DF-12	BGP	122-134	Yes
DF-13	MGP	101-112	Yes
DF-14D	BGP	134-147	
DF-14S	GPWT	71-88	
DF-15	GPWT	7-115	
DF-17	BGP	97-123	
DF-18	GPWT	36-63	
DF-19	GPWT	48-65	Yes

TABLE 1

SUMMARY OF EXISTING WELL INFORMATION
FLEETWIDE TRITIUM ASSESSMENT
BYRON GENERATING STATION
BYRON, ILLINOIS

	Well Details		
Well ID	*Hydrologic Unit Open To*	*Screened Interval/Open Interval (ft bgs)*	*Well to be Sampled*
DF-22D	BGP	99-109	
DF-22S	GPWT	67-90	
DF-23	BGP	53-65	
DF-24	GPWT	19-102	Yes
DF-25	Not Available	Not Available	
MW-1	GPWT	13-71	Yes
MW-2	SS	219-231	Yes
MW-15	GPWT	73-86	
MW-16	BGP	107-120	
MW-20R	SS	172-191	
MW-21	SS	215-234	
MW-30	GPWT	24-37	Yes
MW-36	BGP	136-156	Yes
MW-37	SS	180-206	Yes
MW-39	SS	164-186	Yes
MW-41	BGP	102-121	
MW-42	BGP	135-152	
PC-1B	GPWT	32-48	Yes
PC-1C	SS	97-112	Yes
PC-2B	GPWT	85-103	Yes
PC-3B	GPWT	64-83	
PC-4B	GPWT	68-83	
PC-5B	GPWT	57-73	Yes
PC-6B	GPWT	82-103	Yes

Notes:

ft bgs - feet below ground surface

Hydrologic unit:
- GPWT, well open to the water table in the Galena-Platteville aquifer
- BGP, well open to the base of the Galena-Platteville aquifer
- MGP, well open to the middle of the Galena-Platteville aquifer
- UAWT, well open to the water table in the unconsolidated aquifer
- UAM, well open to the middle of the unconsolidated aquifer
- SS, well open to the St. Peter Sandstone aquifer

TABLE 2

SUMMARY OF AFEs
FLEETWIDE TRITIUM ASSESSMENT
BYRON GENERATING STATION
BYRON, ILLINOIS

AFE Description	*Monitoring Wells Installed*	*Approximate Well Locations*	*Rationale*
AFE Byron Station 1: Fiberglass Blowdown Line	TW-13 through TW-15, CAR-1	Base of Bluff east of River Road	To monitor the groundwater at the base of the bluff, in areas where past release likely migrated
AFE Byron Station 2: Vacuum Breakers and Blowdown Line	TW-1 through TW-12, AR-1 through AR-11, CAR-2	Adjacent to each Vacuum Breaker Vault, at Base of Bluff east of River Road, and inside PA	To assess the groundwater downgradient of each vacuum breaker vault, both in the overburden and in the bedrock, and also in the PA
Higher Priority System Area	CAR-3	Outside of Turbine Building	To monitor the south component of flow from the lines coming out of the Turbine Building
Downgradient of Higher Priority System Area	AR-7	West of Reactor Building	Hydraulically downgradient of the Spent Fuel Pool/Primary Refueling Water Storage Tanks/Reactors and close to the exit point of the blowdown line from the Radiation Waste Building
Downgradient of Higher Priority System Area	AR-8	South of Auxiliary Building	Hydraulically downgradient of the Turbine and Auxiliary Buildings and the condensate polishers
Downgradient of Higher Priority System Area	AR-9	East of the Circulating Water Pump House	Hydraulically downgradient of the Circulating Water Pump House
Downgradient of Higher Priority System Area	AR-10	North of the Treated Runoff Ponds	Hydraulically downgradient of the Treated Runoff Ponds

Note:
* Previously installed as part of blowdown line investigation.

TABLE 3

SAMPLING SUMMARY
FLEETWIDE TRITIUM ASSESSMENT
BYRON GENERATING STATION
BYRON, ILLINOIS

Groundwater Sampling - Existing Monitoring Wells

AR-1	TW-13	GW-9
AR-2	TW-14	Well 7
AR-3	TW-15	MW-1
AR-4	DF-1D	MW-2
AR-5	DF-1S	MW-3
AR-6	DF-2S	MW-30
AR-7	DF-3S	MW-36
AR-8	DF-4DS	MW-37
AR-9	DF-6	MW-39
AR-10	DF-10	PC-1B
AR-11	DF-12	PC-1C
CAR-1	DF-13	PC-2B
CAR-2	DF-19	PC-5B
CAR-3	DF-24	PC-6B

APPENDIX A

STATION-SPECIFIC DOCUMENTS REVIEWED

APPENDIX A - STATION-SPECIFIC DOCUMENTS REVIEWED

SELECT REPORTS

Byron Station Updated Final Safety Analysis Report (USFAR).

Byron Station Radiological Effluent Tracking Statistics (RETS) Reports from 1984 to 2005.

Byron Station Radiological Environmental Monitoring Program (REMP) Reports.

Byron Station 10 CFR 50.75 Reports from 1984 to 2005.

Byron Station Source Identification Worksheets.

APPENDIX B

STATION-SPECIFIC SAMPLING PLAN

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APPENDIX B - STATION-SPECIFIC SAMPLING PLAN

The investigation methodologies in this appendix describe the various soil boring and monitoring well installation techniques that will or may be used at the Station in both unconsolidated and consolidated deposits. Methodologies on monitoring well development and sampling are also included. These methods will be conducted in accordance with current Federal and State standards, and CRA's Standard Operating Procedures (SOPs). The SOPs are company-wide documents that detail the procedures for field staff to collect data correctly and consistently. Prior to conducting any work at the Station, all field staff are required to read, review, and sign CRA's Station-specific Health and Safety Plan (HASP). A copy of CRA's HASP is in Appendix C.

B.1 HEALTH AND SAFETY

The Hydrogeologic Investigation will involve drilling and sampling within the limits of the Station. During these operations, personnel may come in contact with potentially hazardous materials, physical hazards associated with Site operations, or physical hazards associated with the drilling and sampling equipment. Therefore a Station-Specific Health and Safety Plan (HASP) has been developed to ensure the following:

i. that Site personnel are not adversely exposed to the compounds of concern;

ii. that public welfare or the environment are not adversely impacted by off-Site migration of contaminated materials due to work activities at the Station; and

iii. compliance with applicable governmental [Title 29 Code of Federal Regulations (CFR) Part 1910.120] and non-governmental (American Conference of Governmental Industrial Hygienist) regulations and guidelines will be implemented for all Station work.

All sampling and investigative operations at the Station will be conducted in accordance with the provisions of this HASP (Appendix C). Subcontractors performing work at the Station will be responsible for providing a Station-Specific HASP to address hazards associated with the work they are performing. As a minimum, subcontractor HASPs are to be in accordance with the provisions of the HASP included in Appendix C of this Work Plan.

B.2 UTILITY AND SUBCONTRACTOR CLEARANCE METHODS

Prior to completing any subsurface activities, the proposed boring locations will be marked or staked and compared to overhead and subsurface utilities in the area. All borings to be installed during the investigation will be listed on CRA's Quality System Form QSF-019 (Property Access/Utility Clearance Data Sheet). The form will be completed by the CRA representative and reviewed and signed by appropriate Exelon personnel after reviewing each boring location. A copy of QSF-019 is presented in Appendix D. Soil boring activities will not proceed until the location is cleared by CRA's designated site engineer/geologist and appropriate Exelon personnel or an authorized Exelon representative. Each Station may also have its own Station-specific utility locate procedure that will be implemented.

Additionally, prior to initiating drilling activities, an air knife or similar device (e.g., vac-truck) will be utilized to verify utilities are not present at the proposed soil boring locations. All subsurface drilling locations on the property will be cleared with an air knife to a depth of approximately 10 feet below ground surface prior to soil boring installation.

In the event that soil borings will be completed off Station property, a private utility locate firm will be contacted at least three working days prior to installation to locate and mark all utilities in the area of the proposed soil borings.

All subcontractors and subcontractor vehicles and equipment will be subjected to Exelon security clearance procedures prior to gaining Station access.

B.3 DRILLING INSTALLATION METHODS

Borings completed in unconsolidated materials for soil samples or monitoring well installation will be installed using either hydraulic direct push or hollow-stem auger drilling techniques. Borings completed in consolidated materials (bedrock) will be installed by rotosonic or air rotary techniques. These drilling procedures are described fully in Appendix E.

Unless specified by Exelon or the CRA project manager or coordinator, all soil borings will be continuously sampled from ground surface through the total depth of the boring. All overburden soils will be classified using the Unified Soil Classification System (USCS), as required in Section 4.2.3 of CRA's SOPs.

Any soil boring not completed as a monitoring well will be abandoned using 3/8-inch bentonite chips or a bentonite slurry depending on the depth and type of formation encountered (and in accordance with applicable state regulations).

B.4 SOIL SAMPLE COLLECTION METHODS

Soil sampling will be completed by one or more of the following methods: discrete grab sample using a precleaned hand trowel (surficial soil sampling), continuous flight hollow-stem auger with split spoon method, or direct-push methods (dual tube systems, discrete soil sample systems) for soil sampling at depth. Each sample will consist of soil from the surface or the depth as specified within the Work Plan. All soil samples will be collected in accordance with the SOPs presented in Appendix E.

B.5 MONITORING WELL INSTALLATION METHODS

Monitoring wells installed at the Station will be completed in accordance with the SOPs presented in Appendix E. These include procedures for installing and developing permanent and temporary wells.

B.6 GROUNDWATER SAMPLE COLLECTION METHODS

Groundwater sampling will be conducted using the low-flow purging technique outlined in Appendix E. A peristaltic pump may be used when the depth to groundwater is less than 30 feet bgs. A bladder pump or Grundfos pump will be used if the depth to groundwater is greater than 30 feet below ground surface. All groundwater samples will be collected in accordance with the SOPs presented in Appendix E.

B.7 SURFACE WATER SAMPLE COLLECTION METHODS

Any equipment or sampling technique(s) (e.g., stainless steel, PVC, etc.) used to collect a sample is acceptable. If discrete samples are required from a specific depth, and the parameters to be measured do not require a Teflon-coated sampler, a standard Kemmerer, or Van Dorn sampler may be used. When collecting surface water samples, direct dipping of the sample container into the stream is acceptable. If the bottles are preserved, then precleaned unpreserved bottles should be used to collect the sample. The water sample should then be transferred to the appropriate preserved bottles.

When collecting samples, submerse the inverted bottle to the desired sample depth and then tilt the opening of the bottle upstream to fill. Surface water samples should usually be collected in areas of the surface water body that are representative of the surface water body conditions as directed by the Work Plan. All surface water samples will be collected in accordance with the SOPs presented in Appendix E.

B.8 SOIL/GROUNDWATER/SURFACE WATER SAMPLE ANALYSIS METHODS

Groundwater and surface water samples collected will be analyzed for tritium, gamma emitters, total radioactive strontium and strontium 90 according to approved methods. Soil samples, if collected, will be analyzed using USEPA approved methods. Specific soil analyses are specified in Section 4.0 of the Work Plan. Samples will be transferred in dedicated sample containers to an Exelon representative for internal and external distribution as appropriate, or to a contract laboratory using proper chain-of-custody protocols outlined in Appendix E.

B.9 AQUIFER CHARACTERIZATION METHODS

Aquifer characterization methodologies will vary depending on the type and saturated thickness of the formation. Standard single well hydraulic response tests will be conducted on at least four wells screened in the same hydraulic unit. If multiple saturated zones are identified, additional hydraulic response tests may be required. The tests will be conducted according to the Bouwer-Rice Method and the procedures outlined in Appendix E.

Methods for other types of aquifer characterization tests will be presented for Exelon's review and approval on a station-by-station basis. Other types of aquifer characterization include:

- bail-down testing;
- step-test/pump test;
- physical/geotechnical analysis of soils; and
- surface and downhole geophysics.

In the event Exelon requests additional aquifer characterization by one of the methodologies listed above, procedures for the selected methodology will be forwarded to Exelon prior to implementation.

B.10 DECONTAMINATION METHODS

Procedures for proper decontamination of personnel, drilling equipment, and non-dedicated sampling equipment will be implemented according to CRA's SOP for decontamination of field equipment. Alternate decontamination procedures will be implemented on an as needed basis, or as directed by Exelon personnel and/or CRA.

B.11 INVESTIGATION-DERIVED WASTE MANAGEMENT

Three types of investigation-derived waste (IDW) are expected:

- debris, such as PPE and trash;
- residual solids, such as drill cuttings; and
- residual liquids, such as decontamination water, monitoring well development water, monitoring well purge water.

IDW will be handled in the following manner.

Debris:	The field personnel will collect debris in plastic garbage bags, place in an designated dumpster at the Station, and the Station will dispose of it as non-hazardous waste.
Residual Solids/Liquids:	These materials will be contained in 55-gallon drums, labeled by Exelon, and staged in an area designated by Exelon. Exelon shall be responsible for characterization and disposal management of the contents of the drums.

APPENDIX C

CRA HEALTH AND SAFETY PLAN

SITE-SPECIFIC HEALTH AND SAFETY PLAN

EXELON GENERATION – BYRON FACILITY
BYRON, ILLINOIS

Prepared For:
EXELON NUCLEAR FACILITIES

FEBRUARY 2006
REF. NO. 19232 (4)

SITE-SPECIFIC HEALTH AND SAFETY PLAN

EXELON GENERATION – BYRON FACILITY
BYRON, ILLINOIS

Prepared For:
EXELON NUCLEAR FACILITIES

PRINTED ON:

FEBRUARY 21, 2006

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Health and Safety Plan
Signature Page

Site Name:	Exelon Generation Facility – Byron, Illinois		
Ref. No.	19232-21	CRA Office:	Chicago. IL
Anticipated Start Date:	2/22/06	Anticipated Project Duration:	2 Months
Prepared By (Signature):	[illegible]	Date:	2/20/06
Project Manager (Signature):	[illegible]	Date:	2/20/06
Reviewed By (Signature:)	[illegible]	Date:	2/20/06

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this site-specific health and safety plan (HASP) is to provide specific guidelines and establish procedures for the protection of personnel performing the activities described in Section 2.0 — Site Operations. The information in this HASP has been developed in accordance with applicable standards and is, to the extent possible, based on information available to date. The HASP is also living document in that it must continually evolve as site conditions and knowledge of the site work activities develop.

A vital element of CRA's Health and Safety Policies and Procedures is the implementation of a site-specific HASP for field activities. This HASP, as applicable to this project, includes the following measures:

- Communicate the contents of this HASP to site personnel.
- Eliminate unsafe conditions. Efforts must be initiated to identify conditions that can contribute to an accident and to remove exposure to these conditions.
- Reduce unsafe acts. Personnel shall make a conscious effort to work safely. A high degree of safety awareness must be maintained so that safety factors involved in a task become an integral part of the task.
- Inspect frequently. Regular safety inspections of the work site, materials, and equipment by qualified persons ensures early detection of unsafe conditions. Safety and health deficiencies shall be corrected as soon as possible, or project activities shall be suspended.

1.2 STOP WORK AUTHORITY

All CRA employees are empowered and expected to stop the work of co-workers, sub-contractors, client employees, or other contractors if any person's safety or the environment are at risk. NO repercussions will result from this action.

The discovery of any condition that would suggest the existence of a situation more hazardous than anticipated shall result in the removal of site personnel from that area and reevaluation of the hazard and the levels of protection.

1.3 PERSONNEL REQUIREMENTS

All personnel conducting activities on site must conduct their activities in compliance with all applicable Safety and Health legislation throughout North America to include but not limited to the Occupational Safety and Health Administration (OSHA) 29 CFR 1910, 29 CFR 1926, Provincial Canadian legislation, and CRA polices and procedures. **Project personnel must also be familiar with the procedures and requirements of this HASP.** In the event of conflicting safety procedures/requirements, personnel must implement those safety practices, which afford the highest level of safety and protection.

Any employee or sub-contractor performing a job within their probationary period or with less than 6 months of experience in the same job type/duty, whichever is greater, shall be deemed a Short Service Employee and must meet all the requirements under CRA's Short Service Employee requirements.

1.4 PROJECT MANAGEMENT AND SAFETY RESPONSIBILITIES

Project Manager – Dennis Hoyt

The CRA project manager (PM) shall be responsible for the overall implementation of the HASP, and for ensuring that all health and safety responsibilities are carried out in conjunction with this project. This shall include, but is not limited to, review and approval of the HASP and consultation with the Client/Owner regarding appropriate changes to the HASP. The PM will also ensure the appropriate resources are provided to support the project with respect to all operations.

Site Supervisor – To Be Determined

The Site Supervisor (SS) is the person who, under the supervision of the project manager, shall be responsible for the communication of the site requirements to site project personnel and subcontractors, and is responsible for carrying out the health and safety responsibilities by making sure that:

1. All necessary cleanup and maintenance of safety equipment is conducted by project personnel.
2. Emergency services are contacted.
3. Forms attached to the HASP are completed, filed, and submitted correctly.

4. A pre-entry briefing is conducted which will serve to familiarize on-site personnel with the procedures, requirements, and provisions of this HASP.

Other duties include overall implementation of the HASP, and ensuring all health and safety responsibilities are carried out in conjunction with this project. This shall include, but is not limited to, review and approval of the HASP, communication of site requirements to Subcontractor personnel, consultation with the Client/Site Representative regarding appropriate changes to the HASP.

The SS also has the responsibility of enforcing safe work practices for project employees. The SS watches for any ill affects on any crew member, especially those symptoms caused by heat stress or chemical exposure. The SS oversees the safety of any visitors who enter the site. The SS maintains communication with the Client/Site representative(s).

Other specific duties of the SS include:

- Orders the immediate shutdown of site activities in the case of a medical emergency, unsafe condition, or unsafe practice.
- Provide the safety equipment, personal protective equipment (PPE), and other items necessary for employees.
- Enforce the use of required safety equipment, PPE, and other items necessary for employee or community safety.
- Conduct job site inspections as a part of quality assurance for safety and health.
- Report safety and health concerns to site management as necessary.

Employee Safety Responsibility

CRA employees are responsible for their own safety as well as the safety of those around them. CRA employees shall use any equipment provided in a safe and responsible manner, as directed by their supervisor.

Employees are directed to take the following actions when appropriate:

- Suspend any operations which may cause an imminent health hazard to employees, subcontractors, or others.
- Correct job site hazards when possible to do so, without endangering life or health.

- Report safety and health concerns to the SS or Regional Safety & Health Manager (RSHM).

Subcontractors - CRA subcontractors are responsible for the implementation of their HASP and agree to comply with its contents. In the event of conflicting safety procedures/requirements, personnel must implement those safety practices, which afford the highest level of safety and protection. In addition, it is also understood that non-compliance with health and safety policies and procedures may subject the subcontractor to disciplinary action up to and including termination of their contract with CRA. Subcontractors will be required to attend an initial Site Orientation and attend subsequent safety meetings.

Equipment Operators - All equipment operators are responsible for the safe operation of heavy equipment. Operators are responsible for inspecting their equipment to ensure safe performance. Brakes, hydraulic lines, backup alarms, and fire extinguishers must be inspected routinely throughout the project. Equipment will be taken out of service if an unsafe condition occurs.

Authorized Visitors - Shall be provided with all known information with respect to the site operations and hazards as applicable to the purpose of their visit.

1.5 TRAINING REQUIREMENTS

All personnel conducting work at this site shall have completed the appropriate health and safety training as applicable to their job tasks/duties. The required training is referenced throughout the HASP and identified on each task hazard analysis sheet.

1.5.1 SITE-SPECIFIC TRAINING

An initial site-specific training session or briefing shall be conducted by the PM or SS prior to commencement of work activities. During this initial training session, employees shall be instructed on the following topics:

- personnel responsibilities;
- content and implementation of the HASP;
- site hazards and controls;
- site-specific hazardous procedures (e.g., drilling, etc.);

- training requirements;
- PPE requirements;
- emergency information, including local emergency response team phone numbers, route to nearest hospital, accident reporting procedures, and emergency response procedures;
- instruction in the completion of required inspections and forms; and
- location of safety equipment (e.g., portable eyewash, first aid kit, fire extinguishers, etc.).

The various components of the project HASP will be presented followed by an opportunity to ask questions to ensure that each attendee understands the HASP. Personnel will not be permitted to enter or work in potentially contaminated areas of the site until they have completed the site-specific training session. Personnel successfully completing this training session shall sign the HASP Training Acknowledgement Form, which is presented in Appendix A.

In addition to the initial site briefing conducted at the commencement of the project, supplemental brief safety meetings shall be conducted by the SS to discuss potential health and safety hazards associated with upcoming tasks, and necessary precautions to be taken.

In addition, CRA and its subcontractors will undergo Exelon - Byron Station orientation/training prior to work being started.

1.5.2 SAFETY MEETING/HEALTH AND SAFETY PLAN REVIEW

"Tailgate" safety meetings will take place each day prior to beginning the day's work. All site personnel will attend these safety meetings conducted by the SS. The safety meetings will cover specific health and safety issues, site activities, changes in site conditions, and a review of topics covered in the site-specific pre-entry briefing. The safety meetings will be documented with written sign-in sheets containing a list of topics discussed. This form is found in Appendix A.

2.0 SITE OPERATIONS

2.1 SCOPE OF WORK

This HASP covers the specific site activities that will be conducted by CRA personnel and their subcontractors. These activities are as follows:

- Mobilization of personnel, materials, and equipment to and from the sit;
- Drilling (soil boring and monitoring well installation);
- Collection of groundwater samples;
- Surveying activities; and
- Decontamination of personnel and equipment.

If site operations are altered or if additional tasks are assigned, an addendum to this HASP shall be developed to address the specific hazards associated with these changes. All addendums are to be developed in conjunction with project management and a CRA safety professional.

3.0 HAZARD EVALUATION

This section identifies and evaluates the potential chemical, physical, and biological hazards, which may be encountered during the completion of this project. Specific activity task hazard analysis (THA) tables (located in Appendix B) have been developed to address the hazards associated with the site operations outlined in Section 2.0.

3.1 CHEMICAL HAZARDS

The chemical hazards associated with conducting site operations include the potential exposure to on site contaminants encountered during field activities, such as, drilling, groundwater sampling, and surveying activities. The chemical hazards of concern that may be encountered during the tasks identified in the project's scope of work include tritium. A listing of the OSHA Permissible Exposure Limit (PEL) and a basic description of the contaminants of concern are found in Table 1.

3.1.1 TRITIUM

Tritium (chemical symbol H-3) is a radioactive isotope of the element hydrogen. Tritium is produced naturally in the upper atmosphere when cosmic rays strike air molecules. Tritium is also produced during nuclear weapons explosions, as a byproduct in reactors producing electricity, and in special production reactors, where the isotope lithium-7 and boron-10 is bombarded to produce tritium.

Although tritium can be a gas, its most common form is in water because, like nonradioactive hydrogen, radioactive tritium reacts with oxygen to form water. Tritium replaces one of the stable hydrogens in the water molecule and is called tritiated water. Like H_2O, tritiated water is colorless and odorless.

Under normal operating conditions at the Byron Facility, the principal radionuclide in the reactor coolant is tritium. Tritium (in large quantities) is formed when a neutron is captured by boron and/or lithium present in PWR coolant. Excess plant water that contains tritium is released periodically to the environment via the cooling lake blowdown line.

The United States Environmental Protection Agency (USEPA) has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. The average concentration of tritium that is assumed to yield 4 millirem per year is 20,000 picocuries per liter (pCi/l). If other radionuclides which emit beta particles and photon radioactivitiy are present in addition to tritium, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year.

As with all ionizing radiation, exposure to tritium increases the risk of developing cancer. However, tritium is one of the least dangerous radionuclides because it emits very weak radiation and leaves the body relatively quickly. Since tritium is almost always found as water, it goes directly into soft tissues and organs. The associated dose to these tissues are generally uniform and dependent on the tissues' water content.

3.1.2 CHEMICAL HAZARD CONTROLS

Exposure to potential on site contaminants, such as those listed in Table 1.0, shall be controlled by:

- Using proper PPE; and
- Engineering controls.

3.1.3 SKIN CONTACT AND ABSORPTION CONTAMINANTS

Skin contact with chemicals may be controlled by use of the proper PPE and good housekeeping procedures. The proper PPE (e.g., Tyvek, gloves) as described in Section 4.0 shall be worn for all activities where contact with potentially harmful media or materials is anticipated. Utilize manufacturer data on permeation and degradation to minimize skin contact potential (See Section 4.2.1 for additional information).

3.1.4 HAZARD COMMUNICATION

Personnel required to handle or use hazardous materials as part of their job duties will be trained and educated in accordance with the Hazard Communication standard as applicable. The training shall include instruction on the safe usage, and handling procedures of hazardous materials, how to read and access Material Safety Data Sheets (MSDSs), and the proper labeling requirements.

The Material Safety Data Sheet (MSDSs) with the appropriate MSDS for the chemicals in use at the site will be available to project personnel.

3.1.5 FLAMMABLE AND COMBUSTIBLE LIQUIDS

The storage, dispensing, and handling of flammable and combustible liquids must be in accordance with OSHA 29 CFR 1910.106, and NFPA guidelines. The specific flammable or combustible liquids used at the site may include gasoline, diesel, kerosene, oils, and solvents.

Flammable and combustible liquids are classified according to flash point. This is the temperature at which the liquid gives off sufficient vapors to readily ignite. Flammable liquids have flash points below 100°F. (37.8°C). Combustible liquids have flash points above 100°F (37.8°C) and below 200°F (93.3°C).

Storage

Many flammables can ignite at temperatures at or below room temperature. They are far more dangerous than combustibles when they are heated. As a result, these products must be handled very carefully. At normal temperatures, these liquids can release vapors that are explosive and hazardous to employee health. Exposure to heat can cause some of these liquids to break down into acids, corrosives, or toxic gases.

For this reason, flammable/combustible liquids should be stored in cool, well ventilated areas away from any source of ignition. Always consult the MSDS of the product for specific information.

Flammable and combustible liquids must be stored in designated areas. Such areas must be isolated from equipment and work activity, which may produce flames, sparks, heat or any form of ignition, including smoking. The most practical method is the use of one or more approved (commercially available) flammable/combustible liquid storage cabinets.

Cabinets must be labeled "Flammable – Keep Fire Away". Doors must be kept closed and labeled accordingly. Containers must be kept in the cabinet when not in use.

General Requirements

- Keep containers of flammable/combustible liquids closed when not in use.
- Keep flammable/combustible liquids in designated areas and approved cabinets.

- Do not allow use of unapproved containers for transfer or storage. Use only approved safety cans (5-gallon maximum) with a spring closing lid and spout cover, designated to safely relieve internal pressure when exposed to heat or fire.
- Use only approved self-closing spigots, faucets, and manual pumps when drawing flammable/combustible liquids from larger containers/barrels.
- Use only approved metal waste cans with lids for disposal of shop towels/oily rags.
- Designate "Smoking" and "No Smoking" areas.
- Designate fueling areas.
- Observe all signs indicating "No Smoking," "No Flames," "No Ignition."

Transferring Flammable/Combustible Liquids

- This seemingly routine task can be hazardous if certain precautions are not followed. Grounding and bonding must be observed at all times to prevent the accumulation of static electricity when transferring containers/barrels one to another.
- Drums should be grounded (#4 copper conductor) to a grounding rod.
- Bonding is necessary between conductive containers (e.g., a barrel and a 5-gallon container).

3.2 PHYSICAL HAZARDS

Physical hazards that may be present during project work include: potential for close proximity to drilling devices, noise, overhead or under ground utilities, slip/trip/hit/fall injuries, electrical energy, heat stress/cold stress, and other potential adverse weather conditions. In addition, personnel must be aware that the protective equipment worn may limit dexterity and visibility and may increase the difficulty of performing some tasks.

3.2.1 DRILLING SAFETY

The following practices shall be adhered to by drilling personnel:

- Equipment should be inspected daily by the operator to ensure that there are no operational problems.

- Before leaving the controls, shift the transmission controlling the rotary drive into neutral and place the feed level in neutral. Before leaving the vicinity of the drill, shut down the drill engine.
- Before raising the mast, check for overhead obstructions.
- Before the mast of a drill rig is raised, the drill rig must first be leveled and stabilized with leveling jacks and/or cribbing. Re-level the drill rig if it settles after initial setup. Lower the mast only when the leveling jacks are down, and do not raise the leveling jack pads until the mast is lowered completely.
- Employees involved in the operation shall not wear any loose-fitting clothing, which has the potential to be caught in moving machinery.
- During freezing weather, do not touch any metal parts of the drill rig with exposed flesh. Freezing of moist skin to metal can occur almost instantaneously.
- Personnel shall wear steel-toed shoes, safety glasses, hearing protection, and hard hats during drilling operations.
- The area shall be roped off, marked or posted, to keep the area clear of pedestrian traffic or spectators.
- Personnel should be instructed in the location and use of the emergency kill switch on the drill rig.

3.2.2 NOISE

Project activities, such as use of power tools and material handling equipment, that generate noise levels exceeding the decibel range (85dBA) will require the use of hearing protection with a Noise Reduction Rating (NRR) of at least 20 when noise levels exceed 85 dBA. Hearing protection (earplugs/muffs) will be available to personnel and visitors that would require entry into these areas.

When it is difficult to hear a coworker at normal conversation distance, the noise level is approaching or exceeding 85 dBA, and hearing protection is necessary. All site personnel who may be exposed to noise must also receive baseline and annual audiograms and training as to the causes and prevention of hearing loss as part of their Corporate Hearing Conservation Program.

3.2.3 UTILITY CLEARANCES

Elevated superstructures (e.g., drill rigs, back hoes, scaffolding, ladders, cranes) shall remain a distance of 10 feet away from utility lines (<50 kV) and 20 feet away from power lines. Underground utilities, if present, shall be clearly marked and identified prior to commencement of work. Follow local/state regulations with regards to utility locating requirements (i.e., One-Call, etc.).

Personnel involved in intrusive work shall:

- Review and adhere to CRA's Subsurface Utility Clearance Protocol.
- Utilize the Property Access/Utility Clearance Data Sheet (QSF-019).
- Be able to determine the minimum distance from marked utilities which work can be conducted with the assistance of the locator line service.

3.2.4 VEHICLE TRAFFIC AND CONTROL

The following safety measures are to be taken by CRA personnel that have the potential to be exposed to vehicle traffic:

- **A high visibility safety vest meeting ANSI Class II garment requirements is to be worn at all times.**
- **Employees will work using the "buddy system".**
- **Cones, etc. will be used to demarcate a safe work zone around the monitoring wells.**
- **Appropriate signage will be posted as necessary to inform roadway/parking lot users of any additional control measures necessary to protect the public and CRA employees.**

3.2.5 HEAVY LIFTING METHOD

When lifting objects, use the following proper lifting techniques:

- Feet must be parted, with one foot alongside the object being lifted and one foot behind. When the feet are comfortably spread, a more stable lift can occur and the rear foot is in a better position for the upward thrust of the lift.

- Use the squat position and keep the back straight - but remember that straight does not mean vertical. A straight back keeps the spine, back muscles, and organs of the body in correct alignment. It minimizes the compression of the guts that can cause a hernia.
- Grip is one of the most important elements of correct lifting. The fingers and the hand are extended around the object you're going to lift - using the full palm. Fingers have very little power - use the strength of your entire hand.
- The load must be drawn close, and the arms and elbows must be tucked into the side of the body. Holding the arms away from the body increases the strain on the arms and elbows. Keeping the arms tucked in helps keep the body weight centered.

The body must be positioned so that the weight of the body is centered over the feet. This provides a more powerful line of thrust and also ensures better balance. Start the lift with a thrust of the rear foot. Do not twist.

3.2.6 HAND AND POWER TOOLS

Hand Tools

- Hand tools must meet the manufacturer's safety standards.
- Hand tools must not be altered in any way.
- At a minimum, eye protection must be used when working with hand tools.
- Wrenches (including adjustable, pipe, end, and socket wrenches) must not be used when jaws are sprung to the point that slippage occurs.
- Impact tools (such as drift pins, wedges, and chisels) must be kept free of mushroom heads.
- Wooden handles must be free of splinters or cracks and secured tightly to the tool.

Power Tools

- All power tools must be inspected regularly and used in accordance with the manufacturer's instructions and the tool's capabilities.
- Electric tools must not be used in areas subject to fire or explosion hazards, unless they are approved for that purpose.
- Portable electric tools must be connected to a Ground Fault Circuit Interrupter (GFCI) when working in wet areas.
- Proper eye protection must be used when working with power tools.

- Personnel must be trained in the proper use of each specific tool.
- Any defective power tools must be immediately tagged and removed from service.

3.2.7 ELECTRICAL HAZARDS

No employee shall be permitted to work on any part of an electrical power circuit unless the person is protected against electric shock by de-energizing the circuit and grounding it, or ensure that it has been locked and tagged out:

- All electrical wiring and equipment shall be a type listed by Underwriters' Laboratories (UL) or Factory Mutual (FM) for the specific application.
- All installations shall comply with the National Electric Code (NEC) and the National Electric Safety Code (NESC).
- All electrical circuits shall be grounded according to NEC and NESC Code. GFCIs shall be used in the absence of properly grounded circuitry or when portable tools must be used around wet areas.
- Generators and like equipment will be grounded in accordance with NEC, unless exempted by NEC 250-6.
- All live wiring or equipment shall be guarded to protect all persons or objects from harm.

3.2.8 SLIP/TRIP/HIT/FALL

Slip/trip/hit/fall injuries are the most frequent of all injuries to workers. They occur for a wide variety of reasons, but can be minimized by the following prudent practices:

- spot check the work area to identify hazards;
- establish and utilize a pathway which is most free of slip and trip hazards;
- beware of trip hazards such as wet floors, slippery floors, and uneven surfaces or terrain;
- carry only loads which you can see over;
- keep work areas clean and free of clutter, especially in storage rooms and walkways;
- communicate hazards to on-site personnel;
- secure all loose clothing, ties, and remove jewelry while around machinery;
- report and/or remove hazards; and

- keep a safe buffer zone between workers using equipment and tools.

3.2.9 HEAT STRESS

Recognition and Symptoms

Temperature stress is one of the most common illnesses that project personnel face when working during periods when temperatures and/or humidity are elevated. Acclimatization and frequent rest periods must be established for conducting activities where temperature stress may occur. Below are listed signs and symptoms of heat stress. Personnel should follow appropriate guidelines if any personnel exhibit these symptoms:

Heat Rash	Redness of skin. Frequent rest and change of clothing.
Heat Cramps	Painful muscle spasms in hands, feet, and/or abdomen. Administer lightly-salted water by mouth, unless there are medical restrictions.
Heat Exhaustion	Clammy, moist, pale skin, along with dizziness, nausea, rapid pulse, fainting. Remove to cooler area and administer fluids.
Heat Stroke	Hot dry skin; red, spotted or bluish; high body temperature of 104°F, mental confusion, loss of consciousness, convulsions, or coma. Immediately cool victim by immersion in cool water. Wrap with wet sheet while fanning, sponge with cool liquid while fanning; treat for shock. **DO NOT DELAY TREATMENT. COOL BODY WHILE AWAITING AMBULANCE.**

Work Practices

The following procedures will be carried out to reduce heat stress:

- heat stress monitoring;
- acclimatization;
- work/rest regimes;
- liquids that replace electrolytes/salty foods available during rest; and
- use of buddy system.

Acclimatization

The level of heat stress at which excessive heat strain will result depends on the heat tolerance capabilities of the worker. Each worker has an upper limit for heat stress beyond which the resulting heat strain can cause the worker to become a heat casualty. In most workers, appropriate repeated exposure to elevated heat stress causes a series of physiologic adaptations called acclimatization, whereby the body becomes more efficient in coping with the heat stress. Work/rest regimes will be partially determined by the degree of acclimatization provided.

Worker Information and Training

All new and current employees who work in areas where there is a reasonable likelihood of heat injury or illness should be kept informed through continuing education programs:

- Heat stress hazards.
- Predisposing factors and relevant signs and symptoms of heat injury and illness.
- Potential health effects of excessive heat stress and first aid procedures.
- Proper precautions for work in heat stress areas.
- Worker responsibilities for following proper work practices and control procedures to help protect the health and safety of themselves and their fellow workers, including instruction to immediately report to the employer the development of signs or symptoms of heat stress overexposure.
- The effects of therapeutic drugs, over-the-counter medications, or social drugs may increase the risk of heat injury or illness by reducing heat tolerance.

3.2.10 COLD STRESS

Cold stress is similar to heat stress in that it is caused by a number of interacting factors including environmental conditions, clothing, workload, etc., as well as the physical and conditioning characteristics of the individual. Fatal exposures to cold have been reported in employees failing to escape from low environmental air temperatures or from immersion in low temperature water. Hypothermia, a condition in which the body's deep core temperature falls significantly below 98.6°F (37°C), can be life threatening. A drop in core temperature to 95°F (35°C) or lower must be prevented.

Air temperature is not sufficient to determine the cold hazard of the work environment. The wind-chill must be considered as it contributes to the effective temperature and insulating capabilities of clothing. The equivalent chill temperature should be used when estimating the combined cooling effect of wind and low air temperatures on exposed skin or when determining clothing insulation requirements to maintain the body's core temperature.

The body's physiologic defense against cold includes constriction of the blood vessels, inhibition of the sweat glands to prevent loss of heat via evaporation, glucose production, and involuntary shivering to produce heat by rapid muscle contraction.

The frequency of accidents increases with cold temperature exposures as the body's nerve impulses slow down, individuals react sluggishly, and numb extremities make for increased clumsiness. Additional safety hazards include ice, snow blindness, reflections from snow, and possible skin burns from contact with cold metal.

Pain in the extremities may be the first early warning of danger to cold stress. During exposure to cold, maximum severe shivering develops when the body temperature has fallen to 95°F (35°C). This must be taken as a sign of danger to the employees on site, and cold exposures should be immediately terminated for any employee when severe shivering becomes evident. Useful physical or mental work is limited when severe shivering occurs.

Predisposing Factors for Cold Stress

There are certain predisposing factors that make an individual more susceptible to cold stress. It is the responsibility of the project team members to inform the SHO/SS to monitor an individual, if necessary, or use other means of preventing/reducing the individual's likelihood of experiencing a cold related illness or disorder.

Predisposing factors that will increase an individual's susceptibility to cold stress are listed below:

- **Dehydration:** The use of diuretics and/or alcohol, or diarrhea can cause dehydration. Dehydration reduces blood circulation to the extremities.
- **Fatigue During Physical Activity:** Exhaustion reduces the body's ability to constrict blood vessels. This results in the blood circulation occurring closer to the surface of the skin and the rapid loss of body heat.
- **Age:** Some older and very young individuals may have an impaired ability to sense cold.
- **Poor Circulation:** Vasoconstriction of peripheral vessels reduces blood flow to the skin surface.

- **Heavy Work Load:** Heavy work loads generate metabolic heat and make an individual perspire even in extremely cold environments. If perspiration is absorbed by the individual's clothing and is in contact with the skin, cooling of the body will occur.
- **The Use of PPE:** PPE usage that traps sweat inside the PPE may increase an individual's susceptibility to cold stress.
- **Lack of Acclimatization:** Acclimatization, the gradual introduction of workers into a cold environment, allows the body to physiologically adjust to cold working conditions.
- **History of Cold Injury:** Previous injury from cold exposures may result in increased cold sensitivity.

Prevention of Cold Stress

There are a variety of measures that can be implemented to prevent or reduce the likelihood of employees developing cold related ailments and disorders. These include acclimatization, fluid and electrolyte replenishment, eating a well balanced diet, wearing warm clothing, the provision of shelter from the cold, thermal insulation of metal surfaces, adjusting work schedules, and employee education.

- **Acclimatization:** Acclimatization is the gradual introduction of workers into the cold environment to allow their bodies to physiologically adjust to cold working conditions. However, the physiological changes are usually minor and require repeated uncomfortably cold exposures to induce them.
- **Fluid and Electrolyte Replenishment:** Cold, dry air can cause employees to lose significant amounts of water through the skin and lungs. Dehydration affects the flow of blood to the extremities and increases the risk of cold injury. Warm, sweet, caffeine-free, non-alcoholic drinks and soup are good sources to replenish body fluids.
- **Eating a Well Balanced Diet:** Restricted diets including low salt diets can deprive the body of elements needed to withstand cold stress. Eat high-energy foods throughout the day.
- **Warm Clothing:** It is beneficial to maintain air space between the body and outer layers of clothing in order to retain body heat. However, the insulating effect provided by such air spaces is lost when the skin or clothing is wet.

The parts of the body most important to keep warm are the feet, hands, head, and face. As much as 40 percent of body heat can be lost when the head is exposed.

Recommended cold weather procedures include:

- Inner layers (t-shirts, shorts, socks) should be of a thin, thermal insulating material.
- Wool or thermal trousers. Denim is not a good protective fabric.
- Felt-lined, rubber-bottomed, leather-upper boots with a removable felt insole is preferred. Change socks when wet.
- Wool shirts/sweaters should be worn over inner layer.
- A wool cap is good head protection. Use a liner under a hard hat.
- Mittens are better insulators than gloves.
- Face masks or scarves are good protection against wind.
- Tyvek/poly-coated Tyvek provides good wind protection.
- Wear loose fitting clothing, especially footwear.
- Carry extra clothing in your vehicle.
- Shelters with heaters should be provided for the employees' rest periods, if possible. Sitting in a heated vehicle is a viable option. Care should be taken that the exhaust is not blocked and that windows are partially open to provide ventilation.
- At temperatures of 30°F (-1°C) or lower, cover metal tool handles with thermal insulating material if possible.
- Schedule work during the warmest part of the day if possible, rotate personnel and adjust the work/rest schedule to enable employees to recover from the effects of cold stress.

3.2.11 ADVERSE WEATHER CONDITIONS

The SS shall decide on the continuation or discontinuation of work based on current and pending weather conditions. Electrical storms, tornado warnings, and strong winds (approximately 40 mph) are examples of conditions that would call for the discontinuation of work and evacuation of site.

In addition, no work with elevated super structures (e.g., drilling, crane operations, etc.) will be permitted during any type of electrical storm or during wind events that have wind speeds exceeding 40 mph.

3.2.12 SPECIAL WORK CONDITIONS/SITUATIONS

CRA may be asked to conduct work that requires special precautions/considerations due to the following factors:

- Remote work locations.
- Project site is in an area known for high crime or violence activity.
- Entry into abandoned buildings.
- Entry into wooded areas during hunting season.

If these situations are a potential, please consult with your Regional Safety Manager to develop a plan.

3.3 BIOLOGICAL HAZARDS

3.3.1 TICK-BORNE DISEASES

Lyme disease is caused by a bacterial parasite called spirochete, and is spread by infected ticks that live in and near wooded areas, tall grass, and brush. The ticks that cause the disease in the Northeast and Midwest are often no bigger than a poppy seed or a comma in a newsprint. The peak months for human infection are June through October. There are many other tick borne diseases such as Rocky Mountain Spotted Fever, which can be carried by a variety of ticks. The prevention and treatment of these diseases are similar to those of Lyme disease.

Prevention

Ticks hang on blades of grass or shrub waiting for a host to come by. When a host brushes against the vegetation, the tick grabs on. They usually first climb onto a persons legs and then crawl up looking for a place to attach. Preventative measures include wearing light-colored clothing, keeping clothing buttoned, tucking pant legs in socks, and keeping shirttails tucked in. Periodic checks for ticks should be made during the day, and especially at night. Hair should also be checked by parting it and combing through it to make sure that no ticks have attached to the scalp. Also, check clothing when it is first removed, before ticks have a chance to crawl off.

The most common repellent recommended for ticks is N,N-dimethyl-m-toluamide, or DEET. It is important to follow the manufacturer's instructions found on the container for use with all insecticides especially those containing DEET.

In general, DEET insect repellent should only be applied to clothing, not directly on the skin. Do not apply to sunburns, cuts, or abrasions. Use soap and water to remove DEET once indoors.

Removal

The best way to remove a tick is removal by tweezers. If tweezers are not available, cover your fingers (tissue paper) while grasping the tick. It is important to grasp the tick as close as possible to the site of attachment and use a firm steady pull to remove it. When removing the tick, be certain to remove all the mouth parts from your skin so as not to cause irritation or infection. Wash hands immediately after with soap and water, and apply antiseptic to the area where tick was removed. Get medical attention if necessary.

Symptoms of Lyme Disease

The first symptoms of Lyme Disease usually appear from 2 days to a few weeks after a person is bitten by an infected tick. Symptoms usually consist of a ring-like red rash on the skin where the tick attached, and is often bull's eye-like with red on the outside and clear in the center. The rash may be warm, itchy, tender, and/or "doughy" and appears in only 60 to 80 percent of infected persons. An infected person also has flu-like symptoms of fever, fatigue, chills, headaches, a stiff neck, and muscle aches and pains (especially knees). Rashes may be found some distance away from original rash. Symptoms often disappear after a few weeks.

3.3.2 POISONOUS PLANTS

Common ***Poison Ivy*** (Rhus radicans) grows as a small plant, a vine, and a shrub. Poison Ivy occurs in every state. The leaves always consist of three glossy leaflets. ***Poison Sumac*** (Rhus vernix) grows as a woody shrub or small tree 5 to 25 feet tall. It usually contains nine leaves, with eight paired leaves and one on top, and is common in swampy areas. The plants are potent sensitizes and can cause a mild to severe allergic reaction, referred to as "contact dermatitis".

Dermatitis, in Rhus-sensitive persons, may result from contact with the milky sap found in the roots, stems, leaves, and fruit, and may be carried by contacted animals, equipment or apparel.

The best form of prevention is to avoid contact. Wearing long sleeves and gloves, and disposable clothing, such as Tyvek®, is recommended in high-risk areas to avoid exposure from contaminated apparel. Barrier creams and cleaners are also recommended.

3.3.3 INSECTS

Mosquitoes

Mosquitoes are common pests that can be found in any state and any work environment where warm, humid conditions exist. They belong to the order Diptera and are distinguished from flies by the scales along their wings. Mosquitoes principally feed on nectar and other similar sugar sources. However, females require a blood meal for egg production, hence the contact with human flesh. Mosquitoes can pass along diseases such as West Nile virus and Malaria. Several different methods can be used to control adult mosquito populations: repellants such as DEET, mosquito traps, foggers, and vegetation and water management.

Wasps

Wasps belong to the order Hymenoptera. They generally range in size from ½ to 1 ½ inches in length and are reddish-brown in color. They are characterized by two pairs of membranous wings and an ovipositor for laying eggs. Most stinging wasps are predators and scavengers capable of delivering several stings to its prey. Wasp venom releases histamine, which dissolves red blood cells and causes temporary pain and swelling. Some individuals may experience an allergic reaction and require medical attention. Wasp nests may be located along the ground or above ground, and these nests should be professionally removed.

Carpenter Bees

Carpenter Bees **(Xylocopa)** are a large insect with a hairy yellow thorax and a shiny black, sometimes metallic abdomen, and somewhat resembles yellow and black female bumble bees. Carpenter bees bore in wood and make a long tunnel provisioned with pollen and eggs. They prefer to enter unpainted wood and commonly tunnel in redwood and unpainted deck timber. Stings from carpenter bees are rare.

Cicada Killer Wasps

Cicada killers are very large yellow and black relatives of mud daubers; however, they do not look like mud daubers. More than 1 inch long, they look like "monster" yellowjackets. Female Cicada have a stinger and can sting; however, stings are extremely uncommon.

Honey Bees

Honey bees **(Apis mellifera)** are highly social insects and communicate with each other, relaying direction and distance of nectar and pollen sources. A honey bee colony in a house wall can cause major problems. The bees can chew through the wall and fly inside. Their storage of large amounts of honey invites other bees and wasps. Their detritus (e.g., dead bees, shedded larval skins, wax caps from combs, and other material) attracts beetles and moths. When a bee colony is found in a building wall, it must be killed and the nest removed.

Paper Wasps

Paper wasps (Family Polistes) nests are often found near doorways and other human activity areas without occupants being stung. Colonies can become problems, but when they do, Paper wasps can be controlled easily. When attracted to fallen ripe fruit, these wasps sting people who venture into the same area. Colonies in trees, out buildings, hollow fence posts, and other protected places are not as easy to control as those are from nests on structures.

Mud Dauber Wasps

Mud Dauber wasps **(Family Sphecidae)** are slender; shiny black or brown, orange or yellow, with black markings. Many have long slender thread waists. They are not aggressive and will not sting unless pressed or handled. Mud Daubers place their mud nests (long clay tubes or large lumps) in protected places like electric motors, sheds, attics, against house siding, and under porch ceilings.

The **Giant Hornet** is reddish-brown and yellow and almost an inch long. It builds its nest mainly in hollow trees, and in wall voids of barns, sheds and sometimes houses. An open window or door is an invitation to hornet workers, and they frequent buildings under construction. They will sting humans, and the sting is painful.

The **Yellowjacket**, or stinging wasp, has primarily yellow bands cover a dark abdomen. These species are in the genus Vespula. Some yellowjacket nests hang in trees and shrubs, and some are developed underground. Most yellowjackets have very slightly barbed stingers that often sticks in the skin and when the insect is slapped off, the stinger may remain. Yellowjackets are sometimes responsible for injections of anaerobic bacteria (organisms that cause blood poisoning). When yellowjackets frequent wet manure and sewage they pick up the bacteria on their abdomens and stingers. In essence, the stinger becomes a hypodermic needle. A contaminated stinger can inject the bacteria beneath the victim's skin. Blood poisoning should be kept in mind when yellowjacket stings are encountered.

Poisonous Spiders

Black widow spiders (genus Latrodectus) are not usually deadly (especially to adults) and only the female is venomous. The female spider is shiny black, usually with a reddish hourglass shape on the underside of her spherical abdomen. Her body is about 1.5 inches long while the adult male's is approximately half that. The spider's span ranges between 1-3 inches. The adult males are harmless, have longer legs and usually have yellow and red bands and spots over their back and the young black widows are colored orange and white. The bite of a black widow is often not painful and may go unnoticed. However, the poison injected by the spider's bite can cause severe reactions in certain individuals. Symptoms that may be experienced include abdominal pain, profuse sweating, swelling of the eyelids, pains to muscles or the soles of the feet, salivation and dry-mouth (alternating), and paralysis of the diaphragm. If a person is bitten, they should seek immediate medical attention. Clean the area of the bite with soap and water. Apply a cool compress to the bite location. Keep affected limb elevated to about heart level. Ask doctor if Tylenol or aspirin can be taken to relieve minor symptoms. Additional information can be obtained from the Poison Center (1-800-222-1222).

Brown recluse spiders are usually light brown in color, but in some instances, they may be darker. The brown recluse can vary in size, but some can obtain bodies of 5/8 inches in length with a leg span of 1 ½ inches in diameter. They can be identified by their three pairs of eyes along the head area and their fiddle shaped markings on the back. Most brown recluse bites are defensive rather than offensive. They generally only bite when they feel threatened. If bitten by a brown recluse, an individual may experience open, ulcerated sores, which when left untreated may become infected and cause tissue necrosis. If an individual believes a spider has bitten them, they need to seek medical attention as soon as possible. In order to minimize the occurrence of brown recluse bites, individuals should shake their clothing and shoes thoroughly, eliminate the presence of cluttered areas, and spray the building perimeters with pesticides.

3.3.4 RODENTS

Rodentia: (rats, mice, beavers, squirrels, guinea pigs, capybaras,coypu)

Rodents, or Rodentia, are the most abundant order of mammals. There are hundreds of species of rats; the most common being the black and brown rat.

The **Brown Rat** (Rattus norvegicus) has small ears, blunt nose, and short hair. It is approximately 14 to 18 inches long (with tail). They frequently infest public tips, slaughterhouses, domestic dwellings, warehouses, shops, supermarkets, in fact anywhere there is an easy meal and potential nesting sites.

The **Black Rat** (Rattus rattus) can be identified by it's tail, which is always longer than the combined length of the head and body. It is also slimmer and more agile than the Norwegian or Brown rat. Its size varies according to its environment and food supply.

The **House Mouse** (Mus musculus) has the amazing ability to adapt and it now occurs more or less in human dwellings. In buildings, mice will live anywhere and they are very difficult to keep out. Mice are also totally omnivorous; in other words they will eat anything.

Rats and mice often become a serious problem in cold winter months when they seek food and warmth inside buildings. They may suddenly appear in large numbers when excavation work disturbs their in-ground nesting locations, or their food source is changed.

There are six major problems caused by rats and mice:

1. They eat food and contaminate it with urine and excrement.
2. They gnaw into materials such as paper, books, wood, or upholstery, which they use as nest material. They also gnaw plastic, cinder blocks, soft metals such as lead and aluminum, and wiring which may cause a fire hazard.
3. Rats occasionally bite people and may kill small animals.
4. They, or the parasites they carry, (such as fleas, mites, and worms) spread many diseases such as: salmonella, trichinosis, rat bite fever, Hantavirus, Weils disease, and the bubonic plaque.
5. Rats can damage ornamental plants by burrowing among the roots, or feeding on new growth or twigs. They also eat some garden vegetables, such as corn and squash.

6. Rats and mice are socially unacceptable. These rodents have been a problem for centuries, chiefly because they have an incredible ability to survive and are so difficult to eliminate. In addition, they are extremely compatible with human behavior and needs.

3.3.5 SNAKES

Rattlesnakes, copperheads, and cottonmouths (water moccasins) are included in the pit viper family. Members of this family have a depression or "pit" located between the eye and nostril on each side of the head. Each pit contains heat-sensitive nerve endings which enable the snake to detect warm-blooded prey, even at night. Venom of pit vipers is primarily *hematoxic* because it acts upon the victim's blood system. This venom breaks down blood cells and blood vessels and affects heart action. Bite victims experience severe burning pain, localized swelling, and discoloration for the first 3 to 30 minutes, followed by nausea, vomiting, and occasional diarrhea and usually shock.

Copperheads (*Agkistrodon contortrix)* are found in wet wooded areas, high areas in swamps, and mountainous habitats, although they may be encountered occasionally in most terrestrial habitats. Adults usually are 2 to 3 feet long. Their general appearance is light brown or pinkish with darker, saddle-shaped crossbands. The head is solid brown. Their leaf-pattern camouflage permits copperheads to be sit-and-wait predators, concealed not only from their prey but also from their enemies. Copperheads feed on mice, small birds, lizards, snakes, amphibians, and insects, especially cicadas. Like young cottonmouths, baby copperheads have a bright yellow tail that is used to lure small prey animals.

The Canebrake and Timber Rattlesnake (*Crotalus horridus)* occupies a wide diversity of terrestrial habitats, but is found most frequently in deciduous forests and high ground in swamps. Heavy-bodied adults are usually 3 to 4, and occasionally 5 feet long. Their basic color is gray with black crossbands that usually are chevron-shaped. Timber rattlesnakes feed on various rodents, rabbits, and occasionally birds. These rattlesnakes are generally passive if not disturbed or pestered in some way. When a rattlesnake is encountered, the safest reaction is to back away--it will not try to attack you if you leave it alone.

Preventing Snake Bites

Watching where you step, put your hands, or sit down is one of the best ways to prevent snake bites. Poisonous snakes live on or near the ground and often like rocks, wood piles, and other spots that offer both a place to sun and a place to hide. Snakes avoid your huge body, but will definitely bite if stepped on or otherwise trapped. Most bites occur in and around the ankle. About 99 percent of all bites occur below the knee, except when someone accidentally picks up or falls on the snake.

The fangs of venomous snakes, though long and sharp, are relatively fragile and easily deflective or broken. These fangs usually don't penetrate canvas tennis shoes and almost never penetrate leather shoes or boots. Watching where you step and wearing boots in tall grass can prevent most snake bites.

Snakes are not something to be feared, but rather a creature to be respected as a fascinating member of the outdoors.

Emergency First Aid for Poisonous Snakebite

Although it is important to obtain medical aid immediately, emergency first aid can slow the spread of poison from the bite. Remain calm and avoid unnecessary movement, especially if someone is with you. The rate of venom distribution throughout your body will be slower if you are still and quiet. *Do not* use home remedies, and *do not* drink alcoholic beverages.

In addition, learn the following procedures so you do not waste time before getting medical attention.

1. If less than 60 minutes is required to reach a hospital or other medical aid, follow this procedure:

   a. Apply a constricting band 2 to 4 inches on each side of the bite. The band should be loose enough to slip your finger under without difficulty, so that you do not cut off circulation completely. Properly applied, the constricting band can be left safely in place for 1 hour without adjustment.

   b. If ice is available, place some in a towel, shirt, or other piece of cloth and apply it to the bite area. Do not bind it to the bite, but keep it loosely in place. Do not use the ice pack for more than *1 hour*. The objective is to cool the venom and slow its action, but not to freeze the tissue.

   c. The primary function of the constricting band and ice pack is to slow the spread of venom through your body. Remove them slowly so there will not be a sudden rush of venom through your blood stream.

4.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

4.1 GENERAL

This section shall cover the applicable personal protective equipment (PPE) requirements, which shall include eye, face, head, foot, and respiratory protection.

The purpose of PPE is to shield or isolate individuals from the chemical and physical hazards that may be encountered during work activities.

4.2 TYPES OF PERSONAL PROTECTIVE EQUIPMENT (PPE)

If required for a task, the following types of PPE will be available for use at the project site: hard hat, safety glasses (with permanently affixed side shields), goggles, face shield, steel toed rubber boots, gloves (nitrile, cotton, leather, butyl rubber, neoprene), full face respirators and cartridges, protective clothing (coveralls, Tyvek®, polycoated Tyvek®), ear plugs, ear muffs, and reflective safety vests.

4.2.1 TYPES OF PROTECTIVE MATERIAL

Protective clothing is constructed of a variety of different materials for protection against exposure to specific chemicals. No universal protective material exists. All will decompose, be permeated, or otherwise fail to protect under certain circumstances.

Fortunately most manufacturers list guidelines for the use of their products. These guidelines usually concern gloves or coveralls and, generally, only measure rate of degradation (failure to maintain structure). It should be noted that a protective material may not necessarily degrade but may allow a particular chemical to permeate its surface. For this reason, guidelines must be used with caution. When permeation tables are available, they should be used in conjunction with degradation tables.

In order to obtain optimum usage from PPE, the following procedures are to be followed by all site personnel using PPE:

1. When using disposable coveralls, don a clean, new garment after each rest break or at the beginning of each shift.
2. Inspect all clothing, gloves, and boots both prior to and during use for:
    - imperfect seams;

- non-uniform coatings;
- tears; and
- poorly functioning closures.

3. Inspect reusable garments, boots, and gloves both prior to and during use for:
   - visible signs of chemical permeation;
   - swelling;
   - discoloration;
   - stiffness;
   - brittleness;
   - cracks;
   - any sign of puncture; and
   - Any sign of abrasion.

Reusable gloves, boots, or coveralls exhibiting any of the characteristics listed above will be discarded. PPE used in areas known or suspected to exhibit elevated concentrations of chemicals will not be reused.

4.2.2 RADIONUCLIDE PROTECTIVE CLOTHING

There is minimal external hazard with tritium, i.e., the vial containing the tritium provides sufficient shielding from the beta particles. If the skin is contaminated with tritium, the beta emissions will not have sufficient energy to be able to penetrate through the dead layer of skin. However, if tritium is absorbed into the body via ingestion or cuts in the skin, it can cause a radiation dose.

Tritium cannot be detected using a Geiger-Muller or NaI survey meter. Film badges and dosimeter rings are not appropriate for monitoring tritium exposure. The maximum range in Air is 0.6 cm. The maximum range in Water/Tissue: 0.0006 cm.

[Smear surveys, using liquid scintillation counters, are required to detect tritium contamination. The test for exposure is a urine test followed by running the urine through a scintillation counter].

Clothing and protective gloves should always be worn when working with tritium to keep skin free from contamination, and gloves should be changed often if suspected of contamination.

4.3 LEVELS OF PROTECTION

The level of protection must correspond to the level of hazard known, or suspected, in the specific work area. PPE has been selected with specific considerations to the hazards associated with site activities. The specific PPE to be used for each activity is outlined in each THA table located in Appendix B.

- All PPE will be disposed of and/or decontaminated at the conclusion of each workday as described below. Decontamination procedures will follow the concept of decontaminating the most contaminated PPE first.
- All disposable equipment shall be removed before meal breaks and at the conclusion of the workday and replaced with new equipment prior to commencing work.
- Eating, drinking, chewing gum or tobacco, and smoking are prohibited while working in area where the potential for chemical and/or explosive hazards may be present. Personnel must wash thoroughly before initiating any of the aforementioned activities.

4.3.1 REASSESSMENT OF PROTECTION LEVELS

Protection levels provided by PPE selection shall be upgraded or downgraded based upon a change in site conditions or the review of the results of air monitoring or the initial exposure assessment monitoring program, if one was conducted.

When a significant change occurs, the hazards shall be reassessed. Some indicators of the need for reassessment are:

- commencement of a new work phase;
- change in job tasks during a work phase;
- change of season/weather;
- when temperature extremes or individual medical considerations limit the effectiveness of PPE;
- chemicals other than those expected to be encountered are identified;
- change in ambient levels of chemicals; and
- change in work scope which effects the degree of contact with areas of potentially elevated chemical presence.

All proposed changes to protection levels and PPE requirements will be reviewed and approved prior to their implementation by the SS.

5.0 SITE CONTROL

The purpose of site control is to minimize potential contamination of workers and protect the public from hazards found on site. Site control is especially important in emergency situations.

One pathway should be established for heavy equipment and one for personnel decontamination.

5.1 COMMUNICATION

Each member of the site entry team will be able to communicate with another entry team member at all times. Communications may be by way of an air horn, walkie-talkie, telephone, or hand signals.

The primary means for external communication are telephones and radio. If telephone lines are not installed at a site, all team members should:

- know the location of the nearest telephone; and
- have the necessary telephone numbers readily available.

The following standard hand signals will be mandatory for all employees to understand regardless of other means of communication:

- Hand gripping throat - Cannot breathe.
- Hands on top of head - Need assistance.
- Thumbs up - OK, I'm all right, I understand.
- Thumbs down - No, negative.
- Gripping partner's wrist, or gripping both of your own hands on wrist (if partner is out of reach) - Leave area immediately.

5.2 BUDDY SYSTEM

5.2.1 RESPONSIBILITIES

A buddy system shall be implemented when conducting intrusive activities on this site. This buddy shall be able to:

- provide his or her partner with assistance;
- observe his or her partner for signs of chemical exposure or temperature stress;
- periodically check the integrity of his or her partner's protective clothing; and
- notify emergency personnel if emergency help is needed.

5.3 SITE SECURITY

Site security is necessary to prevent the exposure of unauthorized, unprotected people to site hazards and to avoid interference with safe working procedures. Security shall be maintained in the support zone.

5.4 DECONTAMINATION

It is the responsibility of the SS to ensure that all personnel and pieces of equipment coming off site are properly decontaminated according to the procedures outlined below. Documentation of decontamination must be made in the field log notebook that will become part of the permanent project file.

5.4.1 PERSONNEL AND EQUIPMENT DECONTAMINATION PROCEDURES

All PPE will be disposed of and/or decontaminated at the conclusion of each work day as described below. Decontamination procedures will follow the concept of deconning the most contaminated PPE first.

All disposable equipment shall be doffed before meal breaks and at the conclusion of the workday and replaced with new equipment prior to commencing work.

Procedures for decontamination must be followed to prevent the spread of contamination and to eliminate the potential for chemical exposure.

Personnel: Decontamination will take place prior to exiting the contaminated work area.

Modified Level D: Remove outer protective wear, remove and dispose of gloves. Wash hands and face.

Handle all clothing inside out when possible.

Equipment: All equipment must be decontaminated with Alconox/Liquinox solution or discarded upon exit from the contaminated area in a well-ventilated area. A temporary decon pad will be setup on site during drilling operations. All decon materials will be drummed for subsequent disposal.

6.0 EMERGENCY PROCEDURES

6.1 ON-SITE EMERGENCIES

Emergencies can range from minor to serious conditions. Various procedures for responding to site emergencies are listed in this section. The PM or SS is responsible for contacting local emergency services, if necessary, for specific emergency situations. Various individual site characteristics will determine preliminary action to be taken to assure that these entry procedures are successfully implemented in the event of an emergency. Address necessary Facility/Client emergency protocols to ensure compatibility between this document and Facility/Client programs and/or expectations.

An Emergency Information Sheet containing the hospital location, directions, government agency phone numbers, emergency phone numbers, and a map with directions to the Hospital is located in Appendix A.

6.1.1 ACCIDENT, INJURY, AND ILLNESS REPORTING AND INVESTIGATION

Any work-related incident, accident, injury, illness, exposure, or property loss must be reported to your supervisor, the SS, and ***within 1 hour*** through the CRA Accident Reporting System. Motor vehicle accidents must also be reported through this system. CRA's Accident Report Form, located in Appendix A, must also be filled out and provided to the SS. The report must be filed for the following circumstances:

- accident, injury, illness, or exposure of an employee;
- injury of a subcontractor;
- damage, loss, or theft of property; and/or
- any motor vehicle accident regardless of fault, which involves a company vehicle, rental vehicle, or personal vehicle while the employee is acting in the course of employment.

Occupational accidents resulting in employee injury or illness will be investigated by the SS. This investigation will focus on determining the cause of the accident and modifying future work activities to eliminate the hazard.

All employees have the obligation and right to report unsafe work conditions, previously unrecognized safety hazards, or safety violations of others. If you wish to make such a report, it may be made orally to your supervisor or other member or management, or you may submit your concern in writing, either signed or anonymously.

6.2 EMERGENCY EQUIPMENT/FIRST AID

Safety equipment will be available for use by site personnel, will be located within 30 feet of the work area(s) and maintained at the site. The safety equipment will include, but is not limited to, the following: a 10-unit first aid kit (dependant upon the number of personnel), emergency alarm (i.e., air horn), emergency eyewash, an ABC fire extinguisher (2A/10BC), potable water, anti-bacterial soap, and telephone.

6.3 SPILL AND RELEASE CONTINGENCIES

If a spill has occurred, the first step is personal safety, then controlling the spread of contamination if possible. CRA personnel will immediately contact site management to inform them of the spill and activate emergency spill procedures.

7.0 RECORDKEEPING

The SS shall establish and maintain records of all necessary and prudent monitoring activities as described below:

- name and job classification of the employees involved on specific tasks;
- air monitoring/sampling results and instrument calibration logs as applicable;
- records of training acknowledgment forms; and

emergency reports describing any incidents or accidents.

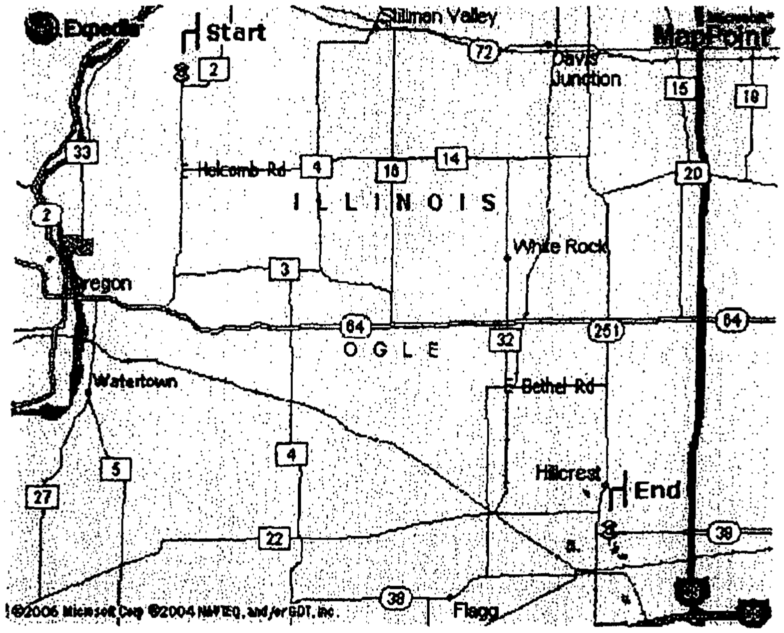
APPENDIX A

FORMS

1. EMERGENCY CONTACT SHEET
2. HASP ACKNOWLEDGEMENT FORM
3. TAILGATE SAFETY MEETING FORM
4. CRA ACCIDENT REPORTING FORM
5. PROPERTY ACCESS/UTILITY CLEARANCE DATA SHEET

Print this page using the print function in your browser.

From: N German Church Rd, Byron, IL, 61010
To: 900 N 2nd St, Rochelle, IL, 61068



Directions	Distance	Time
Start: Depart Start on CR-2 [N German Church Rd] (South)	4.5	0:07
1: Keep STRAIGHT onto CR-2 [S German Church Rd]	0.9	0:01
2: Turn LEFT (East) onto SR-64	11.4	0:14
3: Turn RIGHT (South) onto SR-251	4.6	0:08
4: Keep STRAIGHT onto SR-251 [N 7th St]	0.5	0:01
5: Keep STRAIGHT onto SR-251 [SR-38]	0.3	0:01
6: Turn LEFT (East) onto 10th Ave	0.3	0:01
End: Arrive End	< 0.1	< 1min
Total Route	**22.5 mi**	**33 mins**

Exelon Byron Generation Facility

EMERGENCY INFORMATION		
Contact	**Phone Number**	**Hospital Directions**
Local Police	911	
Fire Department	911	
Ambulance	911	
Local Hospital: Rochelle Community Hospital 900 N. Second St. Rochelle, IL 61068		Head south on N. German Church Rd. (CR-2) approximately 5 miles. Turn left into SR-64. Follow SR-64 for approximately 11.4 miles. Turn right (south) onto SR-251 / N 7th St. Follow SR-251 / N 7th St. / SR-38 for approximately 5.5 miles. Turn left (east) onto 10th Ave. Follow 10th Ave. approximately 0.3 miles. Arrive at Rochelle Community Hospital near Intersection of 10th Ave and N 2nd St. Driving Time: 33 minutes Driving Distance: 22.5 miles
National Poison Center	800-222-1222	CRA – Accident Reporting System Please call **(866) 529-4886** and provide: • Name and location of caller • Description of incident • Name of any injured persons • Description of injuries • Phone number for return call.
Project Manager Dennis Hoyt Work Cell	716-297-6150 (b)(6)	
Site Supervisor To Be Determined Work Cell		
CRA Regional S&H Manager Bill Doyle Work Cell	743-453-5123 (b)(6)	
Site Contact David Starke Work	815-406-3207	
Client Contact Stan Kerns Work	815-406-3200	

* Hospital Route must be field validated before site work commences.

HASP ACKNOWLEDGMENT SHEET

This is to certify that I have received a pre-entry briefing regarding this HASP for the Exelon Byron Generation Facility and I understand its contents. My failure to follow and comply with the requirements contained in this plan may result in disciplinary action and/or termination.

Print Name	Signature	Date

TAILGATE SAFETY MEETING FORM

Exelon Byron Generation FAcility

Date: ______________________ Time: ____________

Site Location: ______________________________________

Site Personnel in attendance:

Print Name	Signature	Company

Safety Topics/Items discussed:

____

____

____

____

____

Supervisor

Name: ______________________ Date: ____________

19232 (4)

CRA 200016 QSF-013 - Rev. 0 - 06/15/2005

CONESTOGA-ROVERS & ASSOCIATES (CRA) ACCIDENT REPORTING FORM

Report all accidents immediately by calling 1-866-529-4886

Instructions: For Personal Injuries and Property Damage Complete Sections 1 and 2.
For Vehicle Accidents, Complete Sections 1, 2, and 4. Form must be completed within 24 hours.

SECTION 1

A. Employee Identification ( ) CRA Employee ( ) Temporary Employee ( ) Subcontractor

Employee No.	Last Name	First Name	Middle Name/Initial	M or F

Area Code	Telephone Number	Address (Street, City, State, Province, Zip Code)
( )		

Date of Hire	Position/Title	Supervisor	Employee's Company/Office Location
/ /			

B. General Information

Where did the accident occur?
( ) Office ( ) Project Site
( ) Canada ( ) United States

Type of Occurrence
( ) Employee Injury ( ) Vehicle Accident ( ) Property Damage Only

Date and Hour of Accident		Date and Hour Reported to Employer		Date and Hour Last Worked		Time Employee Began Work
Month Day Year	a.m. p.m.	Month Day Year	a.m. p.m.	Month Day Year	a.m. p.m.	a.m. p.m.

Normal Work Hours on Last Day Worked		Witnesses?	Witness Name and Telephone Number
From: To:	a.m. p.m.	( ) Yes ( ) No	

C. Project Information (Project Related Accidents/Near Misses Only)

Project #	Project Name	Project Manager	Site Telephone Number	Employee Cell Number
			( )	( )

Was the Client Advised of the Accident?
( ) Yes ( ) No
Name:

Project Address (Street, City, State, Province, Zip Code)

Specific Location of Accident

SECTION 2

A. Details of the Accident/Near Miss

1. What job/task was being performed when the accident occurred? (Example: collecting groundwater samples).
2. Describe the employee's specific activities at the time of the accident. Include details of equipment/materials being used, including the size and weights of objects being handled.
3. For injuries, identify the part of body injured, and specify left or right side.
4. Identify the object or substance that directly injured employee and how.
5. Identify Property Damaged (include owner of property, nature and source of damage, model and serial number, if appropriate).

B. Health Care/Medical Treatment

Employee received health care?
( ) Yes ( ) No

Identify the type of health care provided and where it was performed. (Check all that apply).
( ) First Aid ( ) Medical treatment other than first aid (sutures, etc.) ( ) Hospitalized
( ) Clinic ( ) Hospital emergency room ( ) On location by self or CRA employee) ( ) On site by EMT

Name of Health Care Provider, Physician's Name, Address (Street, City, Province/State, and Postal/Zip Code)

Section 2 (Continued)

C. Accident Investigation	
H&S plan prepared and on site? ( ) Yes ( ) Not applicable	Did the safety plan identify and provide safety procedures for the specific tasks the employee was conducting when injured? ( ) Yes ( ) No If no, why not? (Explain).

Did the employee have the proper safety training to conduct these tasks or use the equipment? ( ) Yes ( ) No If not, why not?

Identify all of the potential contributing factors and how they led to the occurrence of the accident. (Lack of attention, wrong use of equipment, lack of training, etc.)

What contributing factor above was the underlying root cause of the accident.

Is any training or retraining recommended? If yes, describe.

What actions have been or will be taken to correct this accident from reoccurring?

Additional information: Attach photos, accident diagrams, as applicable.

Report Date Month Day Year	Report Prepared by: (please print)	Report Prepared by: (signature)

Fax Completed Form to CRA's Accident Reporting Fax: (716) 297-3389
Send Original to CRA's Accident Reporting Department, Niagara Falls, New York

SECTION 3

D. Agency Reporting and Recording Information (To be completed by the Regional Safety and Health Manager)			
CANADA			
Form 7 Sent to WSIB? ( ) Yes ( ) Not required	Employee Injury Information (Injury met the following criteria) ( ) First Aid ( ) Medical Treatment ( ) Critical Injury ( ) Modified Duty ( ) Lost Time Injury If medical treatment, what?		
Joint Safety and Health Committee Notified? ( ) Yes ( ) No	Total days of modified duty If exceeds 7 days, report to WSIB.	Total days of lost time (if any)	Date employee returned to work Month Day Year
UNITED STATES			
OSHA Recordable Injury? ( ) Yes ( ) No	Employee Injury Information (Injury met the following OSHA 300 Log criteria) ( ) First Aid ( ) Medical Treatment ( ) Restricted Duty ( ) Lost Time Injury If medical treatment, what?		
Total days of restricted duty	Total days of lost time (if any)		Date employee returned to work Month Day Year

VEHICLE ACCIDENT SECTION
(Complete this Section for all Vehicle Accidents)

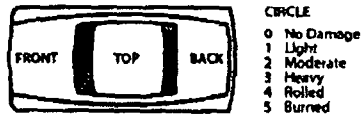
SECTION 4

A. CRA Vehicle

License Plate No.	State/Province	Police Department	City	State/Province

Vehicle Year/Make/Model	Odometer Reading at Time of Accident	Police Report Number	Weather Conditions

Name of Person Operating Vehicle	"X" IN AREA OF VEHICLE DAMAGE
Address	
City State/Province Zip Code	
Telephone: Area Code ( )	



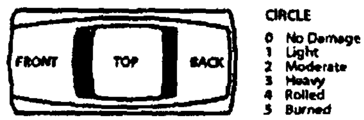
Vehicle Type: ( ) Personal ( ) Rental ( ) CRA-Own

Description of Vehicle Damage:

B. Other Vehicles Involved

Name of Owner	Address	City/State/Prov./Zip	Area Code and Telephone Number
			( )
Operator's Name (if different from above)	Address	City/State/Prov./Zip	Area Code and Telephone Number
			( )

Year/Make/Model	Description of Property Damage:	"x" IN AREA OF VEHICLE DAMAGE
Insurance Co. Name & Telephone		
License Plate No./State/Province		



C. Injured Persons

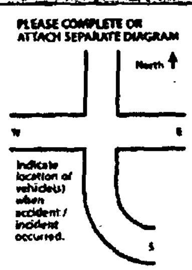
Name	Address Street, City, State/Prov./Zip Code	Phone Number	Nature of Injury	Indicate if Injured was a Vehicle Driver/ Passenger, CRA Employee, Other, or Pedestrian
1.				
2.				
3.				

D. Witnesses

Name	Address Street, City, State/Prov./Zip Code	Area Code and Telephone Number
1.		( )
2.		( )

E. Description of Accident

PLEASE COMPLETE OR ATTACH SEPARATE DIAGRAM



Was Ticket Issued:
- Other Operator ☐
- CRA Operator ☐

Reason:

Report Date Month Day Year	Report Prepared by: (please print)	Report Prepared by: (signature)

Note: If Additional Space is Required to Complete this Report, Use Separate Sheet of Paper and Attach.
Fax Completed form to CRA's Accident Reporting Fax: (716) 297-3389
Send Original to CRA's Accident Reporting Department, Niagara Falls, New York

APPENDIX B

TASK HAZARD ANALYSIS TABLES

TASK HAZARD ANALYSIS
CRA

Activity: Mobilization and Demobilization

Description of Tasks	*Potential Hazards*	*Preventive Measures and Controls*	*Action Levels*
Mobilization of equipment to include set up of work zones, drill rig set up and staging.	Slip, trip, fall	Use three points to board machinery. Continuously inspect work areas for slip, trip & fall hazards. Be aware of surroundings.	Initiate in Level D
	Noise	Wear appropriate hearing protection if noise levels exceed 85 dBA.	
	Utilities	Maintain proper utility clearances as specified in HASP.	
	Pinch points	Keep hands, feet, & clothing away from moving parts/devices.	
	Heavy lifting	Follow safe lifting practices outlined in HASP. Lift items within your capabilities. Ask for assistance with heavy items.	
	Use of hand and power tools	Follow manufacturers safety precautions, inspect tools regularly, replace defective tools, wear the appropriate eye and foot protection.	
	Set up of drill rig/heavy equipment and moving rig/heavy equipment	Raise and lower mast of drill rig slowly. Maintain proper utility clearances. Do not wear loose clothing jewelry. Follow guidelines in HASP. Inspect work area and secure drill rig before moving to another location.	
	Steam cleaning of equipment	Use Modified Level D PPE	
	Heat/cold stress	Dress appropriately and follow guidelines in HASP	
	Dangerous weather conditions	Consult local weather reports daily, watch for signs of severe weather, etc.	
	Biological hazards	Inspect work areas carefully, void contact with insects and poisonous plants. Follow procedures in HASP.	

Personal Protective Equipment	**Training Requirements**
Level D: Hard hat, safety glasses, steel toed boots and leather work gloves.	Safety introduction/briefing, safety meetings HazCom Personal protective equipment
Modified Level D: Hard hat, safety glasses, face shield, steel toed boots, hearing protection, Neoprene or Nitrile gloves and Neoprene or Butyl Rubber overboots.	

TASK HAZARD ANALYSIS
CRA

Activity: Drilling (Soil Borings and Monitoring Well Installation)

Description of Task	*Potential Hazards*	*Preventive Measures and Controls*	*Action Levels*
Installation of monitoring well and soil borings; collection of soil samples; and P & A activities	Slip, trip, fall	Use three points to board machinery. Continuously inspect work areas for slip, trip & fall hazards. Be aware of surroundings.	Initiate in Modified Level D
	Chemical hazard		
	Noise	Wear appropriate hearing protection if noise levels exceed 85 dBA.	
	Utilities	Maintain proper utility clearances as specified in HASP.	
	Pinch points	Keep hands, feet, & clothing away from moving parts/devices.	
	Heavy lifting	Follow safe lifting practices outlined in HASP. Lift items within your capabilities. Ask for assistance with heavy items.	
	Use of hand and power tools	Follow manufacturers safety precautions, inspect tools regularly, replace defective tools, wear the appropriate eye and foot protection.	
	Operating drilling equipment	Keep clear of augers, do not wear loose clothing jewelry, instruct personnel on use of emergency kill switch, follow guidelines in HASP.	
	Moving drilling equipment	Inspect work area and secure the drill rig before moving to other location.	
	Heat/cold stress	Dress appropriately and follow guidelines in the HASP.	
	Dangerous weather conditions	Consult local weather reports daily, watch for signs of severe weather, etc.	
	Biological hazards	Inspect work areas carefully, void contact with insects and poisonous plants. Follow procedures in HASP.	

Personal Protective Equipment	Training Requirements
Modified Level D: Hard hat, safety glasses, steel toed boots, hearing protection, Neoprene or Nitrile gloves and Neoprene or Butyl Rubber overboots.	Safety introduction/briefing, safety meetings HazCom Personal protective equipment Use of emergency kill switch on drill rig

TASK HAZARD ANALYSIS
CRA

Activity: Surveying

Description of Tasks	*Potential Hazards*	*Preventive Measures and Controls*	*Action Levels*
Set up survey equipment and perform survey activities.	Slip, trip, fall	Use three points to board machinery. Continuously inspect work areas for slip, trip & fall hazards. Be aware of surroundings.	Initiate in Level D
	Heavy lifting	Follow safe lifting practices outlined in HASP. Lift items within your capabilities. Ask for assistance with heavy items.	
	Use of hand and power tools	Follow manufacturers safety precautions, inspect tools regularly, replace defective tools, wear the appropriate eye and foot protection.	
	Heat stress	Dress appropriately and follow guidelines in HASP	
	Dangerous weather conditions	Consult local weather reports daily, watch for signs of severe weather, etc.	
	Biological hazards	Inspect work areas carefully, void contact with insects and poisonous plants. Follow procedures in HASP.	

Personal Protective Equipment	Training Requirements
Level D: safety glasses, steel toed boots and leather work gloves.	Safety introduction/briefing, safety meetings HazCom Personal protective equipment

TASK HAZARD ANALYSIS
CRA

Activity: Collection of Groundwater Samples

Description of Task	*Potential Hazards*	*Preventive Measures and Controls*	*Action Levels*
Purge groundwater monitoring well, obtain water levels and collect groundwater sample	Slip, trip, fall	Use three points to board machinery. Continuously inspect work areas for slip, trip & fall hazards. Be aware of surroundings.	Initiate in Modified Level D
	Noise	Wear appropriate hearing protection if noise levels exceed 85 dBA.	
	Chemical hazard		
	Pinch points	Keep hands, feet, & clothing away from moving parts/devices.	
	Heavy lifting	Follow safe lifting practices in HASP. Lift items within your capabilities. Ask for assistance with heavy items.	
	Use of hand and power tools	Follow manufacturers safety precautions, inspect tools regularly, replace defective tools, wear the appropriate eye and foot protection.	
	Operating generator	Use GFCI for all electrical connections and ensure generator is grounded.	
	Heat/cold stress	Dress appropriately and follow guidelines in HASP	
	Dangerous weather conditions	Consult local weather reports daily, watch for signs of severe weather, etc.	
	Biological hazards	Inspect work areas carefully, void contact with insects and poisonous plants. Follow procedures in HASP.	

Personal Protective Equipment	Training Requirements
Modified Level D: Safety glasses, steel toed boots, and Nitrile gloves for sampling.	Safety introduction/briefing, safety meetings HazCom Personal protective equipment

TASK HAZARD ANALYSIS
CRA

Activity: Decontamination of Personnel and Equipment

Description of Task	*Potential Hazards*	*Preventive Measures and Controls*	*Action Levels*
Cleaning of heavy equipment/vehicles, PPE, sampling equipment, etc.	Slip, trip, fall	Use three points to board machinery. Continuously inspect work areas for slip, trip & fall hazards. Be aware of surroundings.	Initiate in Modified Level D
	Noise	Wear appropriate hearing protection if noise levels exceed 85 dBA.	
	Chemical hazard	Wear proper PPE levels	
	Electrical Hazards/Stored Energy	Use GFCIs to reduce electric shock. Inspect all equipment prior to use. Do not stand in water when using electrical equipment. Insure LOTO procedures are implemented.	
	Fueling Equipment	No smoking, allow equipment to cool before refueling, follow storage requirements (reference MSDS)	
	Moving Heavy Equipment	Inspect work area and be aware of surroundings at all times. Establish traffic patterns and wear safety vests. Use a spotter around moving equipment.	
	Pinch points	Keep hands, feet, & clothing away from moving parts/devices.	
	Heavy lifting	Follow safe lifting practices. Lift items within your capabilities. Ask for assistance with heavy items.	
	Use of hand and power tools	Follow manufacturers safety precautions, inspect tools regularly, replace defective tools, wear the appropriate eye and foot protection.	
	Steam cleaning	Use Modified Level D PPE	
	Heat stress	Dress appropriately and follow guidelines in HASP	
	Dangerous weather conditions	Consult local weather reports daily, watch for signs of severe weather, etc. Suspend or reduce operations during severe weather.	
	Biological hazards	Inspect work areas carefully, void contact with insects and poisonous plants.	

Personal Protective Equipment	**Training Requirements**
Modified Level D: Hard Hat, Face Shield, Nitrile/Rubber Gloves, Safety Glasses, Steel Toe Boots and Rain Gear	Safety introduction/briefing, safety meetings HazCom Personal protective equipment

APPENDIX C

MATERIAL SAFETY DATA SHEETS

APPENDIX D

PROPERTY ACCESS/UTILITY CLEARANCE DATA SHEET

PROPERTY ACCESS/UTILITY CLEARANCE DATA SHEET

(QSF-019)

PROJECT NAME: ______________________ PROJECT NUMBER: __________

CRA REPRESENTATIVE: ______________________

CLIENT: __________ CLIENT REPRESENTATIVE: __________ PHONE: __________

ON-SITE PROPERTY ACCESS APPROVAL __________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

OFF-SITE PROPERTY ACCESS APPROVAL (if applicable) __________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

UTILITY CLEARANCE APPROVAL __________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

CONTRACTOR VERIFICATION APPROVAL __________ (OWNER OR AUTHORIZED AGENT SIGNATURE)

UTILITIES (INDICATE THAT LOCATION/UTILITY PRESENCE WAS CHECKED) *												
Borehole/ Excavation Location	Date (m/d/y)	Telephone	Water	Storm Sewer	Sanitary Sewer	Process Sewer	Gas	Electrical	Cable	Overhead Utilities	* Other	Comments/Warnings

Additional Comments:

____

____

____

White: Field Office

Yellow: Field File

Pink: Owner/Client/Agent

* Note as appropriate, Contractor, Client or Owner, or Agent to sign, indicating no utilities are at the selected borehole/excavation locations.

APPENDIX E

CRA STANDARD OPERATING PROCEDURES

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4.0 FIELD METHODS GUIDELINES

The following Field Methods Guidelines (FMG) specified herein are considered by CRA to be the minimum acceptable level of care and quality assurance for field activities on all CRA projects. In some instances (specific geographical areas), these requirements may exceed the typical industry standard, and accordingly, CRA guidelines should be followed. Significant procedural changes should be reviewed by CRA management and the Client prior to implementation. Conversely, more stringent requirements may exist, imposed by Client protocols or regulatory agencies, which exceed CRA's guidelines; in these cases, the more stringent requirements will prevail.

Caution: CRA's field activities occur across North America and on occasion within international locales. Regulations vary from state to state, province to province, or within different Regulatory Administrative areas. These guidelines do not and cannot present each and every regulatory nuance as they apply to field activities undertaken. CRA management and CRA staff conducting field activities must determine on a project-specific basis the appropriate field activity requirements. Usually these requirements will be established through the Work Plan preparation process which eventually receives Regulatory approval. In the absence of an established Work Plan, the guidelines within will likely be adequate in most areas to successfully complete a field related activity.

4.1 DRILLING PROGRAM • PREPARATION/CLOSURE

4.1.1 GENERAL

A significant portion of CRA's field activities relates to sampling/investigative activities that involve subsurface drilling. This typically requires CRA to contract or subcontract with a drilling firm to penetrate the ground for sample collection or well installation using mechanical systems. The following discussion is generic in nature, does not detail specific drilling methods, but describes the typical drilling program preparation and drilling program closure activities that should be followed for most CRA managed programs.

4.1.2 PRIOR PLANNING AND PREPARATION

When preparing for a drilling program a number of setup and logistical activities must take place before ground is broken. The following are the tasks undertaken once a contractor is selected and a program start has been established.

The following does not address contractual arrangements, Work Plan development, or Health and Safety Plan (HASP) development which must be completed well before project startup.

i) Site selections for proposed drill and/or sampling locations.
ii) Utility clearances (see Section 2.13 for detailed discussion).
iii) Arrange access to the site. Assemble well keys and site keys.
iv) Contact CRA Quality Assurance/Quality Control (QA/QC) analytical group to arrange:
   - laboratory;
   - glassware/sample jars;
   - cooler(s);
   - shipping details;
   - start date; and
   - expected duration.

v) Contractor mobilization, equipment and material check.
vi) Contractor Health and Safety Orientation/Hazard review.
vii) Site selection of decontamination pad and drum staging area (if applicable).
viii) Pre-plan methods for handling and disposal of drill cuttings, wash waters, and spent decontamination fluids.

4.1.3 PROCEDURES

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

- locating and marking of boring location [see Section 4.2.3, item i)];
- decontamination of sampling and drilling equipment (see Sections 4.10 and 4.12 for detailed discussion);
- advance borehole utilizing the approved method as outlined in the work program (see Section 4.3.3);
- logging of the borehole by CRA protocol [see Section 4.2.3, item vi)];
- soil collection and field screening [see Section 4.2.3, item iii) and Section 4.2.3, item v)];
- monitoring well installation (if applicable) (see Section 4.3 for detailed discussion);
- collection of groundwater samples (if monitoring well installed) (see Section 4.5 for detailed discussion); and
- surveying of borehole location and elevations (see Section 4.2.3, item xii) and Section 4.28).

4.1.4 FOLLOWUP ACTIVITIES

The following shall be performed once field activities are complete:

i) Make sure that the site is secured and that the site and well keys are returned.
ii) Notify the contract laboratory as to when to expect samples. The chain-of-custody and cover letter, indicating the parameters and numbers of samples, shall be enclosed in the sample cooler.
iii) File all completed field notes and forms.
iv) Complete the Subcontractor and Supplier Evaluation Form (QSF-012) and return to file and Project Manager, or refer to QSL-004 to determine if your choice of calibration is already approved.

4.1.5 CONTACT INFORMATION

The following CRA personnel may be contacted regarding drilling program preparation and closure activities for additional information:

Contact	*Office*	*Phone Number*	*Fax Number*
Brian Carter	Baton Rouge	(225) 292-9007	(225) 292-3614
Tim Powers	Baton Rouge	(225) 292-9007	(225) 292-3614
Walt Pochron	Chicago	(773) 380-9933	(773) 380-6421
Scott Green	Detroit	(734) 942-0909	(734) 942-1858
Peter Storlie	Minneapolis	(651) 639-0913	(651) 639-0923
Dave Hill	Nashville	(615) 315-9927	(615) 315-9934
Doug Oscar	Niagara Falls	(716) 297-2160	(716) 297-2265
Jeff Ratliff	Titusville	(407) 269-9891	(407) 269-9872
Mike Mateyk	Waterloo	(519) 725-3313	(519) 725-1394

4.1.6 REFERENCES

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

i) ASTM D420. Guide for Site Characterization for Engineering, Design, and Construction Purposes.

4.2 BOREHOLE/COREHOLE INSTALLATION AND SAMPLING (OVERBURDEN AND BEDROCK)

4.2.1 GENERAL

The following FMG presents the methods CRA generally employs for the installation of boreholes (overburden) or coreholes (bedrock). The basic soil and bedrock description techniques are discussed; as well as the collection procedures for subsurface samples (both soils and bedrock). Boreholes/coreholes are typically installed to define geologic conditions for hydrogeologic and geotechnical evaluation; to allow the installation of monitoring wells and piezometers; and to allow the collection of subsurface samples for chemical analysis; and for soil/bedrock record retention purposes.

Several manual methods are available for the collection of shallow subsurface soil samples (e.g., hand augers, post-hole augers). However, the most common method used by CRA to advance boreholes are drill rigs equipped with hollow-stem augers (HSA) and split-spoon samplers, or direct-push drilling units equipped with solid tube soil samplers. Bedrock core samples are typically collected using a rotary drill rig equipped with a core-barrel or other tooling. Bedrock boreholes are also advanced without collecting core, using drill bits that chip out the bedrock. FMG 4.3 describes the monitoring well design and construction methods for both overburden and bedrock well installations.

Other related soil sampling activities are described in FMG Sections 4.13 (Surficial Soil Sampling) and 4.16 (Test Pits).

4.2.2 PRIOR PLANNING AND PREPARATION

The following activities must be undertaken prior to undertaking a borehole installation and subsurface soil sampling program.

i) Review the work program, project documents, and the health and safety requirements with the Project Coordinator.

ii) Complete an equipment requisition form (see attached equipment and supply checklist). Assemble all equipment and supplies as per the Borehole Installation/Soil Sampling Equipment and Supply Checklist (Form SP-15).

iii) Obtain a site plan and any previous stratigraphic logs. Determine the exact number and location of boreholes to be installed and the depths of samples for chemical analysis.

iv) Contact CRA's analytical group to arrange/determine:
- laboratory;
- glassware/sample jars;
- cooler;
- shipping details;
- start date; and
- expected duration.

v) Establish borehole locations in field using available landmark or by surveying methods if necessary.

vi) Arrange for utility clearance of franchised utilities and site utilities. Complete property access/utilities clearance data sheet.

vii) Determine notification needs with the Project Coordinator. Have the regulatory groups, Client, landowner, CRA personnel, and laboratory been informed of the sampling event?

viii) Establish a water source for drilling and decontamination activities. Determine the methods for handling and disposal of drill cuttings, wash waters, and spent decontamination fluids.

4.2.3 PROCEDURE

Once the prior planning and preparation activities are completed, the drilling and subsurface sampling program can proceed. A checklist for drilling and well installation activities is included on Form SP-15A. The typical series of events which takes place is:

- locating and marking of borehole locations (if not already completed);
- final visual examination of proposed drilling area for utility conflicts;
- equipment decontamination;
- advancement of borehole and collection of soil samples and/or advancement of corehole and the collection of bedrock core samples;
- field screening of soil sample;
- description of soil and /or bedrock core samples;
- sample preparation and packaging;
- abandonment of boreholes/coreholes or installation of monitoring wells (FMG Section 4.3);
- surveying of drilling locations and elevations; and
- field note completion and review.

i) 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.

Any borehole (and all the records thereof) which is completed with casing as a temporary or permanent monitor well, will be designated by the monitor well number only (i.e., MW-1). 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., BH-1).

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 last visual check 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 should clear the area to the full diameter of the drilling equipment which will follow.

CAUTION: DO NOT ASSUME PLAN DETAILS REGARDING PIPE ALIGNMENTS/POSITION. 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 any proposed borehole due to terrain, utilities, access, etc., the Project Coordinator must be notified and an alternate location will be selected.

ii) Equipment Decontamination for Environmental Sites

Prior to use and between each borehole location at an environmental site, the drilling and sampling equipment must be decontaminated. All decontamination must be conducted in accordance with the project-specific plans or the methods presented in Section 4.10.

The minimum wash procedures for decontamination of drilling equipment is:

- high pressure hot water detergent wash (brushing as necessary to remove particulate matter); and
- potable, hot water, high pressure rinse.

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

On environmental sites, the split-spoon soil sampler is cleaned as follows:

- wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates;
- rinse with tap water;
- rinse with deionized water;
- rinse with 10 percent nitric acid (only if samples are to be analyzed for metals);
- rinse with deionized water;
- rinse with appropriate solvent (pesticide grade isopropanol, methanol, acetone, hexane, if required);
- rinse again with deionized water;
- air dry as long as possible; and
- wrap split-spoon samplers in aluminum foil to prevent contamination.

CAUTION: Check the Quality Assurance Project Plan to confirm the cleaning protocol. Use of incorrect cleaning protocol could invalidate chemical data.

iii) Sample Collection

The boring is advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the depth intervals for sampling is 2.5 to 5 feet [0.75 to 1.5 metres (m)] or less in homogeneous strata with at least one test and sampling location at every change of strata. In some cases samples are taken continuously (i.e., 2 feet long samples at 2 feet intervals).

For environmental sampling, always change gloves between collecting subsequent soil samples to prevent cross-contamination. All tools (e.g., samplers, spatulas, etc.) must be field cleaned prior to use on each sample to prevent cross-contamination.

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

- continuous flight hollow-stem auger method (with inside diameter between 2.2 and 6.5 inches);
- continuous flight solid auger method (with auger diameter between 2.2 and 6.5 inches);
- direct-push methods (dual tube systems, discrete soil sample systems);
- open-hole rotary drilling method; and
- wash boring method.

Several drilling methods are not acceptable. These include: jetting through an open tube sampler and then sampling when the desired depth is reached; use of continuous flight solid auger equipment below the groundwater table in non-cohesive soils; casing driven below the sampling depth prior to sampling; and advancing a borehole with bottom discharge bits. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling when performing standard penetration testing (the open hole must be larger in diameter than the split-spoon sampler).

The following subsections describe the specific protocol for Standard Penetration Test sampling and Shelby Tube sampling.

Standard Penetration Testing (SPT) Sampling and Testing Procedure

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 accurate SPT values.

SPT sampling is performed by using a split barrel sampler in accordance with ASTM D1586. The split barrel sampler, or split-spoon, consists of an 18- or 24-inch (45 or 60 cm) long, 2-inch (5 cm) outside diameter tube, which comes apart length wise into two halves.

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

- the split-spoon sampler should be inspected to ensure it is properly cleaned and decontaminated. The driving shoe (tip) should be relatively sharp and free of severe dents and distortions;
- 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;
- 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; and
- mark the drill rods in three or four successive 6-inch (0.15 m) 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 (0.15 m) increment.

The sampler is then driven continuously for either 18 or 24 inches (0.45 or 0.60 m) 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 inches) (760 mm, ±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 (0.15 m) increment is counted until one of the following occurs:

- a total of 50 blows have been applied during any one of the 6-inch (0.15 m) increments described above;
- a total of 100 blows have been applied;
- 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); or
- the sampler has advanced the complete 18 or 24 inches (0.45 or 0.60 m) 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.

On the field form, record the number of blows required to drive each 6-inch (0.15 m) increment of penetration. The first 6 inches is considered to be a seating drive. The sum of the number of blows required for the second and third 6 inches (0.15 m) 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 representing its supposedly empty length, the spoon fills completely before the end of the drive interval. Two problems arise:

1. *the top part of the sample is not representative of the in-place soil at that depth; and*
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.*

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, 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 SPT sampling below the groundwater table, particularly in sand or silt. These soils tend to heave or "blow back" into the hollow-stem augers 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 water or drilling mud. The drilling fluid level within the boring or hollow-stem augers 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.

Heaving conditions and the use of water or mud and volume used should be noted on the field logs. The volume of water added generally must be removed during well development prior to groundwater sampling. This practice may not be acceptable if environmental samples are to be collected.

SPT sampling below the water table in sands and silt occasionally results in low SPT values being obtained due to the heaving effect disturbing the soil especially if the water level in the hole has not been maintained at the in situ water level. Suspect 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 SPT method, except that the borehole is not pre-augered. Cones may be driven 20 to 40 feet through a formation without augering. Blow counts are recorded for each foot (0.3 m) of advancement. Consult the Project Manager if such conditions are unexpectedly encountered.

A variation of split barrel sampling involves the use of a longer larger diameter barrel in conjunction with hollow stem augers. The sampling barrel is installed inside the auger with a swivel attachment to limit rotation of the barrel. After completion of a 5-foot auger penetration, the auger is left in place and the barrel retrieved from the borehole. The sampler should be handled and the sample retrieved in the same way as described above for SPT sampling.

Another variation involves the use of resonant sonic drilling methods that drives a core sampler by vibration means and recovers a tube that can contain a 10- to 20-foot soil sample core. The cores are handled in the same manner as the SPT sampler.

<u>Thin-Walled Samplers (Shelby Tubes)</u>

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 and is 3 feet 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.

- 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 the sampler;
- clean out the borehole to the sampling elevation using whatever method is preferred 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;
- 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. Remove loose material from the center of a casing or hollow-stem auger as carefully as possible to avoid disturbance of the material to be sampled;
- 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;
- 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;

- 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.
- 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.
- withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample;
- package and transport the sample in accordance with Paragraph ix.

Occasionally, the Project Manager/Coordinator may require extraction of the sample from the tube in the field. The following procedure should be followed.

- 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 mounted on the side of the rig. To prevent cross-contamination, be certain that the extruder is field cleaned between each sample;
- 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 PVC pipe cut lengthwise. Be certain that the carrying tray is field cleaned between each sample. The sample is carried to the work station to describe the sample, trim the potentially cross contaminated exterior, and place it in the appropriate container. Figure 4.2 indicates the method for obtaining a soil sample from a Shelby tube soil core; and
- the Shelby tube may then be 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 any which are significantly damaged should be rejected.

Direct-Push Sampling Systems

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

Direct-push methods are widely used for UST investigations and property investigations. This method is used extensively for initial site screening activities to establish site geology, and delineate vertical and horizontal plume presence. Small dimension wells (3/4 or 1-inch diameter (2 cm or 2.5 cm)) can be installed using direct-push methods. SPT values can not be obtained when sampling with the direct – push discrete soil samplers.

This method is becoming more popular due to the limited cuttings that are produced during the sampling process and the sampling process speed.

Discrete 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 the "open-mode" (when borehole collapse is not a concern), or in the "closed-mode" (when minimization of sample "slough " is desired). Closed-mode operations involve 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.

Use caution when opening interval liners with knives, as severe cuts may result from the knife slipping. A special 2-blade hooked knife is available for opening the liners. Generally the driller/helper will open the liner for you.

Resonant Sonic Systems

A variant of the direct push sampling system involves the use of a drilled core barrel. The drilling method used to drive the core barrel is the resonant sonic drilling method. This method uses a drill head that imparts a high-frequency, high bounce vibration into a steel drill pipe that advances to the desired depth. The drill pipe is usually advanced in 10 to 20 foot increments and can retrieve a continuous, relatively undisturbed soil core through virtually any formation. The soil core is retrieved in a disposable liner similar to that for the direct push methodology. The advantage of the resonant sonic drilling methods are:

- limited drill water is used
- no drill cutting are produced
- depths in excess of 500 feet are possible.

iv) Field Vane Shear Strength Testing in Clay Soils

This test is used to measure the undrained shear strength of very soft to stiff saturated clays. The test should not be used for other types of soils (i.e., silt, sand, gravel, till), or if sand or silt laminations are encountered. Additional information on the method can be reviewed in ASTM D2573.

This method should be used to measure clay shear strengths when geotechnical considerations are an integral aspect of the project, as directed by the Project Manager/Coordinator.

In summary, the field vane shear strength test measures the torsional force required to shear a clay stratum about a cylindrical surface, at the rotational perimeter of a four-bladed "vane". The clay shear strength is calculated using the measured torsional force and a vane constant developed based on the shape/dimensions of the vane.

Equipment:

An understanding of the equipment dimensions and capabilities is an essential part of developing accurate torque measurements, which will subsequently be used to calculate the clay shearing strength.

The equipment required for the test includes the following:

- a field vane;

- sufficient length of drill rods to install the vane at the desired depth; and
- a device to apply torque.

Figure 4.3 presents the geometry of two standard field vanes; a rectangular vane and a tapered vane. It is unlikely that a vane used in the field will meet all of the dimensional requirements of the standard vanes. However, the essential dimension which must be met is that the height shall be a minimum of two times the diameter. Where a choice of vanes is available, selection of the vane should be based on the anticipated soil strength. Larger vanes should be used where soft clay soils are anticipated.

Steel drill rods are provided by the selected drilling contractor. Drill rods are joined using steel couplings. Ensure that rods and couplings are firmly tightened, shoulder to shoulder, so that rotation during testing is not the result of rods turning. The ASTM method requires the measurement of the shearing torque of the rods in contact with the soils, without the vane. However, in the following method the rods will not come into contact with the soils, and as a result this additional measurement is unnecessary. Seek advice from a geotechnical engineer if a method to install the shear vane is proposed which does not conform to that described below.

Several devices are available to apply torque. The device used should have an accuracy of ±1.2 kPa or ± 25 lb./ft2. Torque must be applied without lateral movement, to ensure that the rods do not contact the inside of the casing or borehole side resulting in additional torque being generated. ASTM recommends the use of geared drive, but most drilling contractors do not have this device. Torque is usually applied by means of a torque wrench or a pair of spring scales combined with a vane handle assembly (see Figure 4.4). Torque measuring devices should be calibrated using standardized laboratory weights.

Method

The following presents the series of steps required to conduct a shear vane test:

i) Make arrangements with the contractor to ensure that all necessary equipment will be available at the site when required. Determine if contractor has a vane and torque application device appropriate for the work proposed, and whether it has been properly calibrated.

ii) If you are providing the torque application device, it should be calibrated using standardized laboratory weights or other appropriate means.

iii) Accurately measure the dimensions of the vane, even if measurements have been previously provided. Essential measurements include; shaft height and diameter, vane diameter, length, and the length and width of any tapered sections. Ensure the vane is not bent or twisted from past use.

iv) Advance a hole using conventional drilling equipment to the vane insertion depth. The vane insertion depth shall be the desired testing depth minus the sum of the length of the shaft and half the length of the vane.

v) Connect the vane to the rods and securely tighten using wrenches. Also ensure that all rods are similarly coupled. Advance the vane tip from the insertion depth to the test depth in one even thrust. Ensure that no torque is applied during vane installation.

vi) Connect the torque application device, and apply torque slowly and evenly, carefully noting the reading that causes the vane to rotate. If a torque wrench is used, install a low friction bearing over the borehole casing or augers to ensure that the rods do not contact the inside of the casing or augers. If a vane handle and spring scales are used, the application of force should be coordinated between two individuals to ensure that loads are applied and measured evenly. Also, if the vane handle permits the application of force at different distances from the center, the locations closest to the center should be used first, and if failure is not achieved, the next location out should be used. Record the results of the test including; load application methods, measured loads, length of torque arm (if applicable), and units of measure used.

vii) After the initial shearing has occurred, rapidly rotate the vane ten complete revolutions and wait for no more than 1 minute before repeating the shear test to determine remolded clay shear strength. The strength of the clay under this test will be less than for the undisturbed test, and as such the loads should be applied slowly from zero as was previously done. Record the results as described above.

viii) Carefully remove the vane and advance the borehole past the tip of the last test, if additional tests are required.

v) <u>Field Sample Screening</u>

When sampling for environmental cases, it is often required to measure the soil for evidence of chemical presence. 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 or Microtip) for the presence of organic vapor. This is accomplished by running the PID along the length of the soil sample. Record the highest reading.

Note: *The PID measurement must be done 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 measurements. 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 shall only be partially filled. The jar shall be 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 poly bag.

Note: *Perform all 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, van, etc.).*

vi) <u>Soil/Bedrock Descriptions</u>

a) Soils

The criteria and procedures for identifying and describing soil include:

i) Standard field identification method based on visual examination and manual tests.

ii) A standard method of describing the soil by name and group symbol.

iii) Verifying field description through inspection of representative soil samples by the person responsible for interpretation of subsurface conditions at the site.

iv) Confirming descriptive information by laboratory determination of selected soil characteristics for representative soil samples.

v) Factual stratigraphic logs confirmed by the person responsible for interpreting the subsurface conditions.

The stratigraphic log is a factual description of the soil at the borehole location and is relied upon to interpret the soil characteristics, and their influence and significance in the subsurface environment. The accuracy of the stratigraphic log is to be verified by the person responsible for interpreting subsurface conditions. An accurate description of the soil stratigraphy is essential for a reasonable understanding of the subsurface conditions. Confirmation of the field description by examination of representative soil samples by the project geologist, hydrogeologist, or geotechnical engineer (whenever practicable) is recommended.

The ability to describe and classify soil correctly is a skill that is learned from a person with experience and by systematic training and comparison of laboratory results to field descriptions.

Attendance at the soil identification course provided by CRA is a training requirement.

The description for natural undisturbed soil is recorded on the Stratigraphy Log (SP-17) and an example completed form is presented as Figure 4.1. Descriptions are completed in the following order:

- Unified Soil Classification System (USCS) group symbol(s) (e.g., SM) of primary soil components or dual and borderline symbols;
- name and adjective description of primary, secondary, and minor grain size components;
- relative density (for non-cohesive soil) or consistency (for cohesive soil);
- gradation and soil structure (for non-cohesive soil) or structure and plasticity (for cohesive soil);
- color;
- moisture condition; and
- other physical observations such as presence of stains or odors.

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, gasoline or C-56 odor) is usually unnecessary and often inaccurate as a detailed analysis commonly shows an array of chemistry present!*

Note: *When describing vegetative matter presence in the soil column, do not use the term "organic" as this often leads to confusion with regards with organic chemical (i.e., NAPL) presence.*

The description of fill soil is similar to that of natural undisturbed soil except that it is identified as fill and not classified by USCS group, relative density, or consistency (i.e., SP/GP-Sand and Gravel (Fill)).

It is necessary to identify and group soil samples consistently to determine the subsurface pattern or changes and non-conformities in soil stratigraphy in the field at the time of drilling. The stratigraphy in each borehole during drilling is to be compared to the stratigraphy found at the previously completed boreholes to ensure that pattern or changes in soil stratigraphy are noted and that consistent terminology is used.

Visual examination, physical observations and manual tests (adapted from ASTM D2488, visual-manual procedures) are used to classify and group soil samples in the field and are summarized in this subsection. ASTM D2488 should be reviewed for detailed explanations of the procedures. Visual-manual procedures used for soil identification and classification include:

- visual determination of grain size, soil gradation, and percentage fines;
- dry strength, dilatancy, toughness, and plasticity (thread or ribbon test) tests for identification of inorganic fine grained soil (e.g., CL, CH, ML, or MH); and
- soil compressive strength and consistency estimates based on thumb indent and pocket penetrometer (preferred) methods.

The three main soil divisions are: coarse grained soil (e.g., sand and gravel), fine grained soil (e.g., silt and clay), and soil with high natural organic matter content (e.g., peat and marl). A brief description of the criteria, procedures, and terminology used to identify and describe coarse and fine grained soil is presented here and in the reference data contained in Appendix B.

Coarse Grained Soil

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

The grain size classification that is used in describing soil types in terms of particle size and sieve size (e.g., gravelly sand, trace silt) is presented in Appendix B. Coarse grained soil is made up of more than 50 percent, by weight, sand size, or larger (75 μm diameter, No. 200 sieve size or larger). It is noted that there are other definitions for coarse grained or coarse textured soil and for sand size such 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").

Descriptions for grain size distribution of soil include; poorly graded (i.e., soil having a uniform grain size, SP and GP) and well graded (i.e., poorly sorted; having wide range of particle sizes with substantial intermediate sizes, SW and GW).

Coarse grained soils are further classified based on the percentage of silt and clay they contain (fines content). Coarse grained soils containing greater than 12 percent fines are commonly described as dirty. This description arises from the soil particles that adhere when the soil is rubbed between the hands or adhere to the sides of the jar after shaking or rolling the soil in the jar. The jar shake test which results in segregation of the sand and gravel particles is also used as a visual aid in determining gravel and sand 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) or Sandy Gravel trace silt (less than 10 percent silt), and SP - Sand, uniform. A further description of name terminology and the corresponding percentage composition the terms represent is presented in Appendix B (Conventional Soil Description page).

Relative density is an important parameter in establishing the engineering properties and behavior of coarse grained soil. Relative density of non-cohesive (granular) soil is determined from standard penetration test (SPT) blow counts (N values) (after ASTM Method D1586). A detailed discussion of the SPT N values is presented in Section 4.2.3 iii). The correlation between relative density and SPT N values is presented in the reference data contained in Appendix B (Conventional Soil Description page).

The SPT gives a reliable indication of relative density in sand and fine gravel. N values in coarse grained soil are influenced by a number of factors that can result in overestimates of relative density (e.g., in coarse gravel and dilatent silty fine sand) and can be conservative and underestimate the relative density (e.g., sand below the groundwater table and uniform coarse sand). These effects will be assessed by the project geotechnical engineer, if required, and need not be taken into account by field personnel.

Other dynamic 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. The details of all modifications to the SPT or substitute methods should be recorded as they are required to interpret test results and correlate to relative density.

Fine Grained Soil

A soil is fine grained if it is made up of half or more of clay and silt (i.e., fines greater than 50 percent by weight passing the 75 μm (No. 200) sieve size). A description of visual-manual field methods and criteria (after ASTM D2488 included in Appendix B) that are used to further characterize and group fine grained soil (e.g., CL, CH, ML, or MH) including dry strength, dilatancy, toughness, and plasticity (thread or ribbon test) follows.

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	A 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

A requirement for positive classification by USCS group symbols (as described in ASTM D2487) is laboratory determination of particle size characteristics, liquid limit and plasticity index. The need for this type of testing will be determined by the project geologist, hydrogeologist, or geotechnical engineer.

A statement of qualification (method used) is required if group symbols are not determined by appropriate laboratory testing.

Examples of name terminology that accompanies the group symbols are ML - Sandy Silt (e.g., 30 percent sand) and CL - Lean Clay with sand (e.g., 15 to 29 percent sand). A further description of name terminology and the corresponding percentage composition the terms represent is presented in Appendix B.

The USCS group symbols require the use of Lean Clay (CL) and Fat Clay (CH), depending on the plasticity of the soil. Classifications such as silty clay can only be used for a very narrow set of conditions, and should probably only be used if Atterberg Limit results are available. The Lean and Fat Clay designations are not universally used, but strict adherence to the USCS requires their use.

The correlation between N value and consistency for clays is rather unreliable. It is preferable to determine consistency using more appropriate static test methods, particularly for very soft to stiff clay soil. N value estimates of consistency are more reasonable for hard clay.

Unconfined compressive strength (Su) may be estimated in the field from the pocket penetrometer test method. To obtain a pocket penetrometer estimate of consistency and compressive strength, the soil core is cut perpendicular to the core length, the length of core (minimum 4 inches) is held in the hand and a moderate confining pressure is applied to the core (not sufficient to deform the core); the penetrometer piston tip is slowly inserted into the perpendicular face of the core until the penetrometer indents into the soil core to the mark indicated on the tip of the penetrometer piston; the penetrometer estimate of soil compressive strength (Su) is the direct reading of the value mark on the graduated shaft (in tons per square foot or other unit of pressure as indicated) indicated by the shaft ring marker, or in some models, by the graduated piston reading at the shaft body. To obtain an average estimate, this procedure is completed several times on both ends and mid cross-section of the core. For Shelby Tube (or thin wall sampler) samples the pocket penetrometer tip is applied to the exposed bottom of the sample at several locations.

Estimates of compressive strength for clay soil of very soft to stiff consistency are better established by in situ shear vane tests or other static test methods.

The description of consistency (or strength) is an important element in determining the engineering properties and strength characteristics of fine grained cohesive soil. Consistency terms (e.g., soft, hard) are based on the unconfined compressive strength (Su) and shear strength or cohesion (cu) of the soil. The field methods for describing consistency including manual methods and correlation between consistency, compressive strength, and, to a less reliable degree, SPT N values is presented in Appendix B.

The ease and pattern of soil vapor and groundwater movement in the subsurface is influenced by the natural structure of the soil. Soil structure, for the most part, depends on the deposition method and, to a lesser extent, climate. A definition of terms used to describe natural soil structure is presented in the reference table (Criteria for Describing Structure) in Appendix B. The identification of fill soil (soil altered by man) is equally important in determining behavioral characteristics of the subsurface.

b) Bedrock

In typical bedrock drilling programs, a steel surface casing is initially installed through the overburden soils to minimize groundwater migration/penetration and isolate the bedrock zone from the overburden regime. Surface casings are sealed using cement, cement-bentonite, or bentonite grout, depending on the depth of installation and regulatory requirements (see also FMG 4.3 Monitoring Well Design and Construction). Regardless of the type of grout, the grout should be allowed to set for a minimum of 24 hours prior to resuming drilling. A field test of the grout seal is often performed by filling the inside of the steel casing with water and recording any decline in water level with time. The test should have a decline of less than 0.1 feet over 5 minutes.

Bedrock drilling is typically performed either using rotary methods or less commonly rotosonic methods (see FMG 4.3); advancing reaming tools (roller-bits or equivalent), or coring tools (core barrels). Rotary drilling with reaming tools breaks the rock into small fragments (drill cuttings), the size is dependent on the style of drill bit, formation characteristics, and drilling rate. The description of rotary/reamed drill cuttings is difficult to do in detail due to the small size of the cuttings/destructive nature of this technique. However, an experienced geologist can often detect the presence of major fractures and other geologic changes through careful observation of the drill penetration and drill cuttings. Coring methods produce a continuous cylindrical drill core that is then described as discussed below.

The following are standard core drilling diameters, although other sizes may also be available, depending on the manufacturer.

Core Size	*Core Diameter (inches, mm)*	*Corehole Diameter (inches, mm)*
AQ	1.06", 27.0 mm	1.89", 48.0 mm
BQ	1.43", 36.5 mm	2.236", 60.0 mm
NQ	1.88", 47.6 mm	2.98", 75.7 mm
HQ	2.50", 63.5 mm	3.78", 96.0 mm
PQ	3.35", 85 mm	4.83", 122.6 mm

Rotary drill bits come in numerous sizes depending on the bit style and manufacturer.

The description of bedrock features typically requires geologic training, or extensive field experience under the supervision of an experienced geologist. If you do not already know how to differentiate bedrock types or have not had extensive training, you should not be doing bedrock drilling. The teaching of mineralogy and sedimentology is beyond the scope of this FMG.

There is no USCS classification for bedrock. Bedrock units are defined by rock type and formal unit names are assigned by the *North American Commission on Stratigraphic Nomenclature* and the *International Commission on Stratigraphy*. The rock type and unit names are generally found on bedrock geology maps or other published geologic resources for the area. The major terms used to describe bedrock and a suite of terminology for fractures are described in the following paragraphs. However, there are literally hundreds of types of bedrock (sedimentary, metamorphic, and igneous), and the brief general description provided below does not cover all types of bedrock.

The following generic discussion of bedrock core logging is based on the bedrock logging form (SP-17A) and an example completed form is presented as Figure 4.5. This form does not include special features that may be unique or specific to certain areas or rock types. Many of these descriptions can also be used for logging of drill cuttings.

Formation Name: The unit name from geologic maps or other resources. The unit name is critical for defining the context of other rock and fracture features. Usually listed as a name followed by Group/Formation/Member or rock type. A Group is composed of named Formations. A Formation may be composed of named Members.

Rock Type: The type of rock (sedimentary, metamorphic, and igneous). Common rock types include:

Sedimentary	Clastic	Conglomerate, Breccia, Sandstone, Graywacke, Shale, Siltstone, Mudstone, etc
	Non-clastic	Limestone (sometimes with clastic or bioclastic component), Dolomite, Gypsum, Salt, etc
Metamorphic		Quartzite, Slate, Phyllite, Schist, Gneiss, Marble, etc
Igneous	Intrusive	Granite, Grandiorite, Diorite, Tonalite, Syenite, Gabbro, Monzonite, Anorthosite, Norite, Pyroxenite, Dunite, Peridotite, etc
	Extrusive	Rhyolite, Porphyry, Dacite, , Trachyite, Diabase, Andesite, Basalt, Tephrite, Obsidian, Pumice, etc

Bedding: Thickness of bedding or range of thickness of bedding for sedimentary rocks. Bedding planes are planar features that often have a slight change in color or grain size in the plane of bedding or between different beds. Metamorphosed sedimentary rocks may retain the original bedding under low grade metamorphism. At high grade metamorphism, original bedding is destroyed by the mobilization of fluids and crystallization of minerals. Extrusive igneous rocks sometimes exhibit bedding planes between depositional events (e.g., lava flows). Metamorphic and igneous rock may exhibit foliation or banding due to mineralogical layering.

Thick Bedded (or massive)	>60 cm (2 feet)
Thin Bedded	1 cm to 60 cm (1/2 inches to 2 feet)
Thick Laminated	0.5 to 1 cm (1/4 to 1/2 inch)
Thin Laminated	<0.5 cm (1/4 inch)

Grain Size: The size and shape of particles in sedimentary rocks or mineral grains in metamorphic and igneous rocks. Descriptive terms include coarse-, medium-, and fine-grained, coarse-, medium-, fine, and micro-crystalline, amorphous, etc.

Texture/Fabric: Physical appearance, distribution and arrangement of grains/minerals. Commonly a preferred arrangement of grains/minerals is noticeable.

Weathering: Weathering results in a decomposition of the rock. The degree of weathering can be visually determined by discoloration, decomposition, and disintegration. Slightly weathered rock is discolored only along and in the vicinity of fractures. Moderately weathered rock is stained and discolored throughout but still retains original bedding and other details. Highly weathered rock is completely discolored and decomposed, destroying original bedding and other details. Moderately and highly weathered rock are not common in temperate climates. Other weathering features are disintegration (i.e., mechanical weathering) producing friable rock. Alteration of the rock from the original type to the degraded occurs primarily by chemical weathering.

Karstification of soluble bedrock (i.e. limestone, dolomite, gypsum, salt, etc) is a type of chemical weathering. Karstification may form solution widened fractures and interconnected voids, solution channels, pockets and caves within soluble bedrock.

<u>Cementation:</u> Cements are precipitated compounds that bind the sedimentary grains together. Most common cements are calcite and silica. Cements are typically amorphous or microcrystalline.

<u>Fossils:</u> Indicate the general type of fossil present, such as brachiopod, bryozoan, horn coral, colonial coral, crinoid, gastropod, etc. If you know the specific name of a fossil, and can identify that fossil, especially where a fossil is used to define a rock unit, then list the fossil explicitly. Fossils are sometimes only present as a fossil mold, where the original fossil has been dissolved, leaving a mold of the outer portion of the fossil. Internal casts are also sometimes present.

<u>Porosity:</u> Porosity in the bedrock consists of intergranular, intercrystalline, or interfragmental, where the porosity occurs between grains, crystals, or fossil fragments, respectively. Porosity that occurs by dissolution of fossils or crystals takes the form of voids or vugs. The size, shape and type of porosity should be described.

Dolomite typically forms from the migration of formation fluids through limestone causing the replacement of Ca ions by Mg ions and recrystallization of the rock. This process results in an approximate 4 percent increase in porosity, which occur as intercrystalline porosity in the rock. As well, dolomitization usually results in the dissolution of fossils, leaving fossil molds.

Infilling or partial infilling of vugs should also be described. The filling material is typically crystalline. Silty and clayey infilling material is deposited by flowing water indicating an interconnection of the vug with a water transmissive fracture.

<u>Supplementary Descriptors:</u> A number of other descriptors can be used when describing bedrock. Carbonate bedrock commonly exhibits stylolites. A stylolite is a contact marked by irregular penetration of the adjoining sides forming teeth-like projections. Stylolites form from pressure solution and are usually marked by a dark line caused by insoluble residues in the stylolite plane.

The following section is for the description of fractures. A fracture is a crack, joint, break or fault in a rock. In drill core, the term fracture is used as the dimension and source of the discontinuity are unknown. Fractures occur from natural breakages in the rock, such as stress relief forming open fractures, usually oriented approximately parallel to bedding and at right angles to bedding, faulting (shear movement) where one side of the rock moved against the other side (often marked by slickensides), and dissolution along planes of weakness. Fractures also occur by the drilling process. Mechanical fractures are marked by sharp, unweathered edges, very close fitting of the two sides to each other, and lack of dissolution, discoloration, or precipitation along the fracture plane.

Fracture Type: Natural fractures consist primarily of bedding-plane fractures (parallel to bedding), fractures that are cross-cutting or angled to bedding, and faults (parallel to or cross-cutting bedding) where movement has occurred along the fracture plane. The fracture shape is typically planar or arcuate.

Fracture Orientation: The orientation of the fracture relative to the center axis of the drill core; such as horizontal, dipping (give angle from horizontal), near-vertical (cuts core along core for at least three times core diameter, which is approximately 70° from horizontal), or vertical (cuts core for a much longer distance). In undeformed bedrock, fractures are commonly nearly horizontal (bedding-plane) and nearly vertical with much fewer inclined fractures. In deformed bedrock, bedding-plane fractures are no longer horizontal and the numerous fracture can form fracture sets of common fracture orientations, oriented with respect to historic and current stress directions and other planes of weakness in the bedrock.

Spacing: The spacing and range of spacing of fractures. The spacing of fractures is often related to bedding and bed thicknesses.

Very Close	<5 cm (2 inches)
Close	5 to 30 cm (2 inches to 12 inches)
Moderate	0.3 m to 1 m (1 foot to 3 feet)
Wide	1 to 3 m (3 feet to 10 feet)
Very Wide	>3 m (10 feet)

Roughness: Roughness and unevenness of the fracture surfaces, generally caused by dissolution or precipitation on the fracture surface. Typically rough, smooth, slickensided (shear movement), wavy.

Aperture: The aperture is the perpendicular distance between the walls of the fracture. Apertures are tight (<0.25 mm) or open (>0.25 mm). Note that drill core pieces cannot be fit together (if broken apart) to get an accurate aperture width. Apparent aperture width is a function of the degree of dissolution or infilling and weathering, along with breakage, spinning, and plucking of the fracture surface during drilling. Since a fracture cannot be open for great distances without support from adjoining fracture surfaces touching (asperities), true effective aperture cannot generally be determined from drill core.

Weathering: Weathering of the adjoining bedrock along a fracture (same as above) and weathering of fracture filling materials.

Infilling: Fracture infilling materials are typically brought in by flowing water such as silts and clays, or are crystalline from precipitation out of flowing water. Describe color, grain size, stiffness, moisture content of sedimentary infilling and crystal size and mineralogy (if known) for crystalline infilling. If crystalline infilling mineralogy is uncertain or unknown, describe shape and color of crystals, and any other aspects that are visible.

Core Recovery: This is the length of drill core recovered in the core run. It is possible to get a longer piece of drill core than the length of the core run. This happens as the core bit is several inches in front of the core barrel. The drill core usually breaks near the end of the core barrel but may break at the core bit, if the rock is weaker at that point. As well, if core is lost due to falling out of the core barrel during core retrieval or the natural break within the core barrel, the core barrel may ride over the lost core when dropped down the drill rods resulting in retrieving at least some of the lost core. In some soft formations, expansion of the drill core occurs after removal from the core barrel resulting in an increased core length.

__Rock Quality Designation (RQD):__ RQD is an engineering calculation designed to give an approximate measure of soundness of a rock. The RQD is the sum of the length of all core pieces in a core run greater than 10 cm (4 inches) long divided by the length of the core run, expressed as a percentage. Core length is measured along the center axis of the drill core. For near-vertical fractures, the core is generally considered to be unfractured for RQD calculation purposes (ASTM D6032-96).

RQD is always equal to or smaller than the core recovery.

__Fracture Index:__ The fracture index is the number of fractures per foot of core drilled in each core run. This measure is similar to RQD but takes away the bias caused by specified minimum intact core lengths. For fragmented core, use non-intact (NI).

Both RQD and Fracture Index may be biased depending on the orientation of the drill hole relative to fracture sets.

__Core Box Labelling__: Core box lids should be labelled on the inside with the drill hole number, date, depth of top and bottom of the core run, core recovery, RQD and fracture index. When bedrock dries out, the rock may become friable and the original intact RQD/fracture index cannot be remeasured. The ends of the core box on the inside should be labelled with top and bottom depths for each row of drill core in the core box. The core boxes should be tied or taped shut to prevent core falling out. Labels should be written on the outside tops and ends of the core boxes, however most labels exposed to sunlight and weathering fade with time.

When drill core is removed for testing or a significant space exists in the core box due to length of core run or loss of drill core, a spacer consisting of a cylinder of foam or similar material is suggested to be put in place to prevent mixing and breakage of the drill core. If core is removed, a note should be placed in the core box indicating the section removed, date, samplers name.

vii) __Chemical Description__

During soil examination and logging the sampler shall carefully check for the presence of light or dense Non-Aqueous Phase Liquids (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); and
- 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 an 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 (use with care);
- centrifugation; and
- 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.

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) 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 or be placed in storage at a CRA office.

viii) 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). On occasion, composite samples are collected from a borehole over a greater depth interval (e.g., 5 to 15 feet).

The following describes the collection of grab samples for chemical analysis (all soil from one split spoon). Figure 4.2 shows the split-spoon sample selection details.

Clayey Soils

- discard upper and lower ends of sample core (3 inches ±);
- use a precleaned stainless steel knife;
- cut the remaining core longitudinally;
- with a sample spoon remove soil from the center portion of the core and place in a precleaned stainless steel bowl;
- remove large stones and natural vegetative debris; and
- homogenize the soil and place directly into the 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: *All soil samples collected for chemical analysis shall be placed immediately in a cooler with ice.*

All soil samples shall be recorded in the sample log book as described in Section 3.4. Labeling of samples shall be consistent with Section 3.9.1.2.

EPA recently adopted new methods for sampling soils for volatile organic compound (VOC) analysis. Method 5035 calls for collecting soil using a coring device. 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.

ix) Geotechnical/Hydrogeologic Sample Preparation and Packaging

a) Soils

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). On occasion, composite samples are collected from the borehole over a greater depth interval (e.g., 5 to 15 feet).

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

Split-Spoon Sample

Following completion of PID screening, 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. Measure length of sample and record as the recovered length. If cohesive, perform pocket penetrometer reading and describe soil as discussed in Paragraph vi. Carefully transfer 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 segments. Roll the sample in the tin foil and fold over the ends to seal. Wrap in a second layer of tin foil. Identify the top, middle, and bottom segments with a T, M, and B using an indelible marker. For each segment record the "up" direction with an arrow. 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 a jar is also acceptable, provided the jar is filled to eliminate air space which could result in the soil sample drying out.

Thin Wall (Shelby Tube) Sample

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. 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. 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. Once this is cooled, remove approximately 1/2 inch of soil from bottom of sample (unless there is already a cavity at bottom of sample) and seal similarly. 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. 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.

Direct - Push Discrete Soil Sample

Once removed to the ground surface the discrete soil sampler is opened by removal of the cutting shoe, and the soil liner (with recovered soil) is extracted from the sampler body. The soil liner is placed into a holder and cut lengthwise (using a liner knife), to expose the collected soil core. Perform PID screening for organic vapors/record readings.

Measure length of sample and record as the recovered length. If cohesive, perform pocket penetrometer reading and describe soil as discussed in Paragraph vi. Carefully transfer 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 segments. Roll the sample in the tin foil and fold over the ends to seal. Wrap in a second layer of tin foil. Identify the top, middle, and bottom segments with a T, M, and B using an indelible marker. For each segment record the "up" direction with an arrow. 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 a jar is also acceptable, provided the jar 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/possibly geotechnical testing if required.

b) Bedrock Cores

Bedrock cores are typically collected for descriptive purposes. Occasionally sections of bedrock cores are removed for laboratory analyses. In which case, the preparation of the sample for the laboratory should follow laboratory directions. Generally, the bedrock core removed for analysis will be handled similarly to a soil core (i.e., wrapped in foil and marked accordingly).

Bedrock core samples are typically retained in labelled core boxes at the site, in a sheltered location. On large or complex sites, the bedrock core should be retained for several years, to allow review of the core at a later date. On some smaller short term projects, the core is immediately discarded.

NAPL is uncommon in drill core as it is often flushed from the core by the drilling process. If NAPL is present and is noted seeping out of the drill core while handling/logging, special storage/handling requirements are required and should be discussed with the Project Coordinator.

x) <u>Communication of Field Findings</u>

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; to alter procedures and sampling protocol if soil conditions are markedly different from those assumed; and to 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.

xi) Borehole Abandonment

Following completion of the borehole it must be properly abandoned in accordance with the project documents. Some locales have requirements or standards of practice that require filling the borehole with bentonite or 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 shall be returned to the borehole to within 1 foot of the ground surface. The remainder of the borehole should be 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 project documents.

When abandoning bedrock borings, the integrity of any water producing zones should be maintained. In highly transmissive zones, the borehole should be filled with permeable material rather than bentonite or cement-bentonite grout. Some locales have requirements or standards of practice that require filling the borehole with bentonite or grout or preserving the integrity of transmissive zones.

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

> Note: *Always include the method of abandonment on the field log book.*

xii) Borehole Tie-In/Surveying

The recording of the locations of boreholes on the site plan is extremely important. This 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, etc.). Diagrams with measurements should be included 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.

> 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 of a survey crew to locate positions using a grid system. This becomes important when trying to locate flushmount wells buried by snow or soils.*

xiii) Field Notes

The field notes must document all the events, equipment used, 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 later for future reference.

The field notes will be recorded on the field stratigraphy log or when approved by the Project Coordinator/Manager in a standard bound 'survey' type field book issued for general note taking/field records and available from all CRA equipment administrators.

Note: *Use Stratigraphic Log Form for recording field notes unless otherwise approved by the Project Coordinator/Manager.*

All field book/form entries must be made in black ink and any changes/corrections shall be stroked out with a single line and initialed and dated to indicate who and when the correction was made.

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

- identification of borehole;
- depth;
- static water level depth and measurement technique;
- time started and completed;
- measured field parameters;
- sample appearance;
- sample odors (if respiratory protection is not required);
- types of sample containers and sample identification numbers;
- parameters requested for analysis;
- field analysis data and method(s);
- sample distribution and transporter;
- laboratory shipped to;
- chain-of-custody number for shipment to laboratory;
- field observations on sampling event;
- name of collector(s);
- climatic conditions including air temperature; and
- problems encountered and any deviations made from the established sampling protocol.

4.2.4 FOLLOWUP ACTIVITIES

The following shall be performed once field activities are complete.

i) Double check Work Plan to ensure all samples have been collected and confirm this with the Project Coordinator.

ii) Equipment shall be cleaned and returned to the equipment administrator and the appropriate form dated and signed.

iii) Complete water disposal (if required), and cleaning fluid disposal requirements per the Work Plan.

iv) Notify the contract laboratory as to when to expect the samples. The chain-of-custody and covering letter, indicating the parameters and number of samples, shall be enclosed in the sample cooler.

v) File all field notes and forms completed.

vi) Return site/well keys.

vii) Prepare and distribute the program completion checklist described in Section 4.3.6.

4.2.5 COMPLETION CHECKLIST

At the completion of the soil sampling program, the Borehole Installation and Subsurface Soil Sampling • Completion Checklist (Form SP-16) must be completed to document activities conducted and serves to remind personnel of the various tasks required. This form must be signed and filed at the respective field office, regional CRA office, and issued to the Project Coordinator.

4.2.6 CONTACT INFORMATION

The following CRA personnel may be contacted regarding borehole installation and soil sampling procedures or for additional information:

Contact	*Discipline*	*Office*	*Phone Number*	*Fax Number*
Brian Carter	H	Baton Rouge	(225) 292-9007	(225) 292-3614
Walt Pochron	C	Chicago	(773) 380-9933	(773) 380-6421
Peter Storlie	C	Minneapolis	(651) 639-0913	(651) 639-0923
Peter Hayes	H	Waterloo	(519) 884-0510	(519) 884-0525
Mike Mateyk	H	Waterloo	(519) 725-3313	(519) 725-1394
Walter van Veen	G	Sydney	(519) 725-3313	(519) 725-1394

C - Chemical
H - Hydrogeologic
G - Geotechnical

4.2.7 REFERENCES

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

ASTM PS 89	Guide for Expedited Site Characterization of Hazardous Waste Contaminated Sites
D5434	Guide for Field Logging of Subsurface Explorations of Soil and Rock
D2487	Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488	Practice for Description and Identification of Soils (Visual-Manual Procedure)
D5781	Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D5782	Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
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
D5784	Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5872	Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D5875	Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D5876	Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D2113	Practice for Diamond Core Drilling for Site Investigation
D4700	Guide for Soil Sampling from the Vadose Zone
D1586	Test Method for Penetration Test and Split-Barrel Sampling of Soils
D1587	Practice for Thin-Walled Tube Geotechnical Sampling of Soils
D4220	Practices for Preserving and Transporting Soil Samples
D5079	Practices for Preserving and Transporting Rock Core Samples
D6001	Guide for Direct-Push Water Sampling for Geoenvironmental Investigations
D6032	Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core

4.3 MONITORING WELL DESIGN AND CONSTRUCTION

4.3.1 GENERAL

The design and installation of monitoring wells involve the drilling of boreholes into various types of geologic formations. Designing and installing monitoring wells may require several different drilling methods and installation procedures.

It is important that the drilling method or methods used minimize disturbance of subsurface materials, do not contaminate the subsurface soils and groundwater, and do not provide a hydraulic link between different hydrogeologic units. Samples collected from installed monitoring wells must not be contaminated by drilling fluids or by the drilling procedures. The drilling equipment shall be decontaminated before use and between borehole locations to prevent cross-contamination of contaminants between monitoring wells where contamination has been detected or is suspected. In reality, it is always best to decontaminate the drilling equipment between each use. The only case where decontamination is not required occurs when drilling for geologic information in known clean areas. Additionally, precleaned monitoring well construction materials shall be used in order to prevent potential introduction of contaminants into the formation.

4.3.2 PRIOR PLANNING AND PREPARATION

When designing and constructing monitoring wells the following questions shall be considered:

i) What contaminants are to be monitored?
ii) What kinds of analyses are needed?
iii) What are the geologic/hydrogeologic conditions at the site?
iv) What is the anticipated total depth of the well?
v) What are the potential health and safety hazards?
vi) Are wells going to serve for monitoring, pumping test, or extraction purposes?
vii) What types of well construction materials are to be used?

4.3.3 DRILLING METHODS

The following drilling methods are listed in order of preference; however, final selection will be based on actual site conditions.

Hollow-Stem Auger

The hollow-stem continuous-flight auger (HSA) is among the most frequently used in the drilling of monitoring wells.

The primary advantages of hollow-stem augering are that:

- generally, no additional drilling fluids are introduced into the formation;
- representative geologic soil samples can be easily obtained using split-spoon samples in conjunction with the hollow-stem augers; and
- monitoring wells can be installed through the augers eliminating the need for temporary borehole casings.

Information on split-spoon sampling is covered in Section 4.2 of this manual.

Installing monitoring wells through hollow-stem augers is a relatively simple process although precautions need to be taken to ensure that the well is properly backfilled. This can be particularly problematic in cases where flowing sand is present.

Hollow-stem augers are available with inside diameters of 2.5, 3.25, 4.0, 4.25, 6.25, 8.25, and 10.25 inches. The most commonly used are 4.25 inches for 2-inch (5 cm) monitoring wells and 6.25 inches for 4-inch (10 cm) monitoring wells. Boreholes can usually be drilled with hollow-stem augers to depths up to 100 feet (30 m) in unconsolidated clays, silts, and sands. Removing augers in flowing sand conditions while installing monitoring wells may be difficult since the augers have to be removed without being rotated. A bottom plug or pilot bit assembly should be utilized to keep out soils and/or water that have a tendency to plug the bottom of the augers during drilling. If flowing sands are encountered, potable water (analyzed once for contaminants of concern) may be poured into the augers to equalize the pressure to keep the formation materials and water from coming up into the auger once the bottom plug is removed.

Dual-Wall Reverse Circulation Air Method of Drilling

This method consists of two concentric strings of drill pipe (an outer casing and a slightly smaller inner casing). The outer drill pipe is advanced using rotary drilling with a donut-shaped bit attached to the dual casing string cuts an area only the width of the two casings and annulus between. Compressed air is continually forced down the annulus between the inner casing carrying the drill cuttings and groundwater. At the surface, the inner casing is connected to a cyclone hopper where the drill cuttings and groundwater fall out the bottom of the hopper, and air is disbursed out the top. The dual wall provides a fully cased borehole in which to install a monitoring well. The only soil or groundwater materials exposed at any time are those at the drill bit. Therefore, the potential for carrying contamination from one stratum to another is minimal. Depth-specific groundwater samples can be collected during drilling; however, since the groundwater is aerated, analysis for volatile compounds may not be valid.

Rotosonic Drilling

This method consists of a combination of rotation with high frequency vibration to advance a core barrel to a desired depth. Once the vibration is stopped, the core barrel is retrieved, and the sample is vibrated or hydraulically extracted into plastic sleeves or sample trays. Monitoring wells shall be installed through an outer casing. Rotosonic drilling generally requires less time than more traditional methods. Continuous, relatively undisturbed samples can be obtained through virtually any formation. Conventional sampling tools can be employed as attachments (i.e., hydropunch, split spoon, shelby tube, etc.). No mud, air, water, or other circulating medium is required. The rotosonic method can drill easily through formations such as rock, sand, clay, or glacial till. The main limitation of this method is the availability of equipment.

Rotary Method

This method consists of a drill rod attached to a drill bit (soils: tricone, drag; rock: button studded, diamond studded) that rotates and cuts through the soils and rock. The cuttings produced are forced to the surface between the borehole wall and the drill rod by drilling fluids which generally consist of water, drilling mud, or air. The drilling fluids not only force the cuttings to the surface but also keep the drilling bit cool. Using rotary methods for well installations can be difficult as it usually requires several steps to complete the installation. First, the borehole is drilled; then temporarily cased; then the well is installed; and then the temporary casing is removed. In some cases, the borehole may remain open without installing a casing but this will only occur in limited instances (i.e., cohesive soils).

i) Water Rotary

When using water rotary, the potable water supply shall be analyzed for contaminants of concern. Water rotary is the preferred rotary method since the potable water is the only fluid introduced into the borehole during drilling. However, the use of water as a fluid is generally only successful when drilling in cohesive soils. The use of potable water also reduces well development time.

ii) Air Rotary (typically used in rock)

When using air rotary, the air compressor must have an in-line oil filter system assembly to filter the oil mixed with the air coming from the compressor. This will help eliminate contaminant introduction into the formation. The oil filter system shall be regularly inspected. Air compressors not having an in-line oil filter system are not acceptable for air rotary drilling. A cyclone velocity dissipater or similar air containment system shall also be used to funnel the cuttings to one location rather than letting the cuttings blow uncontrolled out of the borehole. Air rotary may not be an acceptable method for well installation where certain contaminants are present in the formation. Alternatively, it may be necessary to provide treatment for the air being exhausted from the borehole during the installation process.

iii) Mud Rotary

In some states, mud rotary is the least preferred rotary method because contamination can be introduced into the borehole from the constituents in the drilling mud (i.e., Ohio, Michigan). The drilling muds are generally non-toxic and do not introduce contaminants into the borehole, however, it is possible for mud to commonly infiltrate and affect water quality by sorbing metals and polar organic compounds (Aller et al., 1991). Chemical composition and priority pollutants analysis may be obtained from the manufacturer. Mud rotary shall utilize only potable water and pure (no additives) bentonite drilling muds. The viscosity of the drilling mud shall be kept as low as possible in order to expedite well development. Proper well development is essential to ensure the removal of all the drilling mud and to return the formation to its previously undisturbed state.

Well Point

In some limited cases, well points (sand points) are driven into place without the use of augers. This method provides no information on the geologic condition (other than the difficulty of driving which may be related to formation density). Well points are most often used simply to provide dewatering of a geologic unit prior to excavation in the area. Well points are also used in monitoring shallow hydrogeologic conditions such as in stream beds.

4.3.4 FIELD PROCEDURES

The following presents the field procedure requirements and techniques for the completion of overburden and bedrock monitoring well installations. Typical well installation details are provided on Figures 4.5 and 4.6 for overburden and bedrock wells respectively.

4.3.4.1 INSTALLATION REQUIREMENTS

i) Annular Space

The borehole diameter shall be sufficient that well construction may proceed without any major difficulties. To assure adequate size, a minimum 2-inch (5 cm) annular space is required between the well casing and borehole wall (or the hollow-stem auger wall). The 2-inch (5 cm) annular space will allow a minimum 1.5-inch (4 cm) tremie tube for placing the filter pack, seal, and grout at the specified intervals. An annular space less than 2 inches (5 cm) is not acceptable. When installing a well inside of hollow-stem augers, the inside diameter (ID) of the augers is the area to be considered when determining the 2-inch (5 cm) annular space.

ii) Instrumentation Details

Prior to insertion into the augers or borehole, the well assembly (i.e., well screen and riser components) must be measured to record its exact total length, and the length of each component.

Once this length is known, well placement may proceed. Placement problems are easily identified by measuring the amount of riser stick-up during installation.

iii) Filter Pack Placement [Primary Filter Pack (see ASTM D5092)]

When placing the primary filter pack into the borehole, a minimum of 6 inches (0.15 m) of the primary filter pack material shall be placed under the bottom of the well screen to provide a firm footing. In cases where DNAPL is present, it may not be desirable to have a filter pack "sump" beneath the well and therefore this requirement may be deleted. The elevation for the top of the filter pack is to be selected in the field based upon the geologic conditions encountered. For shallow overburden wells, it is common to extend the filter pack to the top of the water table plus a few extra feet to account for the anticipated fluctuation of the water table due to seasonal effects. For deeper overburden wells, it is common to select a specific hydrogeologic unit to monitor. The filter pack should span that specific hydrogeologic unit only. The filter pack should never extend through a confining layer causing two or more separate permeable layers to become connected. Where practical, the filter pack should extend a minimum of 2 feet above the top of the well screen. The filter pack should be placed by the tremie method. Placing the primary filter pack by "pouring" may be acceptable if you are sure that the filter pack is reaching the assigned depth.

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

Primary filter pack placement is typically a 'delicate' operation, requiring a careful balance between: placement of too much sand and locking the well components within the augers, or an insufficient amount of sand which then allows formation materials to collapse around the well screen area. A good well installer constantly checks the filter pack level as the augers are removed, adjusting the amount and rate of filter pack placement accordingly.

On occasion, it may be necessary to add potable water within the augers to maintain a positive pressure head on the formation materials which (when certain conditions are encountered), will flow into the auger string in an effort to equilibrate with exterior levels. Typically, this condition exists when sandy/silty soils are encountered below the static groundwater level. If potable water is added, the volume used must be recorded and additional purging volumes may be required.

Secondary Filter Pack (see ASTM D5097 and D5092)

A secondary filter pack is a layer of material placed in the annulus between the primary filter pack and the bentonite seal, and between the bentonite seal and the grout backfill. The secondary filter pack shall be uniformly graded fine sand with a 100 percent by weight passing the No. 30 U.S. Standard sieve, and less than 2 percent by weight passing the 200 U.S. Standard sieve. Blasting sand or "sugar" sand is typically used for this purpose. The purpose of the first secondary filter pack is to prevent the intrusion of bentonite grout seal into the primary filter pack. The purpose of the final secondary filter pack is to limit the migration of the grout material into the bentonite seal.

iv) <u>Bentonite Seal (Plug)</u>

A seal shall be placed on top of the filter pack. This seal shall consist of a high solids, pure bentonite material. Bentonite in either pellet or granular form is acceptable. The method of placing bentonite is by the tremie method. Pouring of the bentonite is acceptable in shallow boreholes [less than 50 feet (15 m)] where the annular space is large enough to prevent bridging and to allow measuring to insure that the bentonite has been placed at the proper intervals. The bentonite seal shall be placed above the filter pack to the designated depth or a minimum of at least 2 feet (0.6 m) above the filter pack. It is necessary to allow the bentonite to hydrate before initiating the next backfilling operation (grouting). If for some reason, the water table is temporarily below the bentonite seal interval, potable water shall be used to hydrate the bentonite.

v) <u>Grouting</u>

The annular space between the well casing and the borehole wall shall be filled with either a neat cement grout or cement/bentonite grout or bentonite grout. The grout shall be placed into the borehole, using positive displacement techniques and the tremie method. The grout shall be placed from the top of the bentonite seal to within 2 feet (0.6 m) of the ground surface or below the frost line, whichever is greater. The grout shall be allowed to "set" for a minimum of 24 hours before the concrete surface pad is installed. Check grout level and regrout, if necessary. All grout shall be prepared in accordance with the manufacturer's specifications.

In cases where concrete surface pads are not used, the grout should be brought to within 6 to 12 inches of the ground surface with the remaining height to be backfilled to match the surrounding surface conditions (i.e., asphalt, topsoil, etc.). This method reduces surface water infiltration and well lifting due to frost conditions.

vi) <u>Aboveground Riser Pipe and Outer Protective Casings</u>

The well casing, when installed and grouted, shall extend above the ground surface a minimum of 2.5 feet (0.75 m). A protective casing shall be installed over the completed well and grouted into place. The outer protective casing shall be of steel construction with a hinged, locking cap that is waterproof and tamper proof. The protective casing shall have sufficient clearance around the inner well casing, so that the outer protective casing will not come into contact with the inner well casing after installation. A concrete security collar shall be installed flush with the ground surface around the outer protective casing at a depth below the frost penetration. Typically a sonatube may be used to fill the concrete around the protective casing. The collar will be sloped to promote surface drainage away from the monitoring well. The protective casings shall have a minimum of two weep holes for drainage. These weep holes shall be a minimum 1/4 inch (6.4 mm) in diameter and drilled into the protective casing just above the top of the level of concrete inside to prevent standing water inside the protective casing. The weep holes will also allow internal air pressure to be in equilibrium with the atmospheric conditions.

Dry bentonite pellets, granules, or chips shall be placed in the annular space below ground level within the protective casing. Coarse sand or pea gravel shall be placed in the annular space above the dry bentonite pellets and above the weep hole to prevent entry of insects.

In cases where wells must be located in traffic areas, the wells will have to be flush-mount installations. For these wells, a waterproof protective casing is essential to ensure the integrity of the groundwater formation. The protective casings are grouted in place and usually fitted with bolts and rubber gaskets. For flush-mount installations, the well tops are usually fitted with locking caps. Well caps shall be watertight screw-on connections as referenced in ASTM F-480. For at-grade completions, well caps shall provide a means of locking using a standard padlock. Preferred product for at-grade completions is a cap manufactured by OPW (OPW 634 TTM-7087), Cincinnati, Ohio. For above-grade completions, the well cap or well casing shall be vented with a 1/4-inch (6.4 mm) drilled hole. Typical Protective Casing Installations are shown on Figure 4.7.

Flush mount well installations are typically more problematic and maintenance intensive than above-grade installations and therefore should be avoided where possible.

vii) Protective Posts

Protective posts, if required shall consist of either Schedule 40, 4-inch diameter carbon steel pipe or 4-inch by 4-inch untreated wooden posts. The post shall be 5 feet (1.4 m) in overall length, and installed at least 3 feet (0.86 m) above grade. Up to four posts shall be provided for each monitoring well and they shall be installed in concrete separate from the concrete security collar. The posts shall be located at the corners of the concrete collar, 4 feet radially from the center of the monitoring well at 90-degree increments.

viii) Well Locations

Well locations will primarily be selected in the Work Plan to provide a good geographical distribution across the site given the site conditions anticipated and to suit the intended purpose of the study. Most often, the locations are not pre-verified to confirm clearance from underground or overhead utilities or to match the site's specific characteristics (i.e., traffic patterns, drainage patterns, etc.). Consequently, it is the Field Coordinator's task to select the exact location for each well consistent with all of the site and study requirements. If a well must be moved more that 20 feet (5.7 m) from the initially identified location, the Field Coordinator must confirm the selected location's suitability with the Project Coordinator.

To the extent practicable, wells should be located adjacent to permanent features (i.e., fences, buildings, etc.) that offer some form of protection and a reference point for locating the well. Wells located in high traffic areas or road allowance right of ways are undesirable and should be avoided if possible. Low lying areas are also undesirable.

Field ties accurately identifying each well location must be taken as soon as each well is completed to insure that no confusion with other well installations occurs.

4.3.4.2 CONSTRUCTION TECHNIQUES

i) Well Installation

The borehole shall be drilled as close to vertical as possible. Slanted boreholes shall not be acceptable unless specified in the design. The well casings and the well screen shall be placed into the borehole and plumbed. Where critical, centralizers may be used to aid in the well installation. Another method of placing the casings and well screen into the borehole and plumbing it at the same time is to suspend the string of well casing and screen in the borehole by means of the wireline on the drill rig.

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

Before the casing and well screen are placed on the bottom of the borehole, at least 6 inches (15 cm) of filter material shall be placed at the bottom to serve as a footing (exception may occur if NAPL is being monitored). The well shall be placed into the borehole plumb. Centralizers may be used to plumb a well, but they shall be placed so that the placement of the filter pack, bentonite seal, and annular grout will not be hindered. Monitoring wells less than 50 feet (15 m) deep do not require centralizers. If centralizers are to be used, they shall be placed below the well screen and above the bentonite seal. When installing the monitoring well through hollow-stem augers, the augers shall be slowly pulled back as the filter pack, bentonite seal, and grout are tremied and/or poured into place. Once the monitoring well is in place, the filter pack shall be placed around the screen up to the designated depth. When the filter pack has been installed, the bentonite seal shall be placed directly on top of the filter pack up to the designated depth or a minimum of 2 feet (0.6 m) above the filter pack. The bentonite seal shall be allowed to hydrate for a reasonable amount of time. Usually, 30 minutes is sufficient. Once the bentonite seal has hydrated, the grout shall then be pumped by the tremie method into the annular space around the casing up to within 2 feet (0.6 m) of ground surface or below the frost line, whichever is greater [6 to 12 inches (0.16 to 0.3 m) in cases where concrete caps are not being used]. The end of the grout pipe should always be submerged in the grout to ensure positive displacement. The grout shall be allowed to set for a minimum of 24 hours before the concrete surface seal is installed. Check grout level and regrout, if necessary. After the wells have been installed, the protective casings shall be permanently marked with the well number on the cover or inside.

If the monitoring wells are installed in a traffic area (such as a parking lot), in a residential yard, or along a road, it may be required to install a flush-mounted protective casing that is watertight. Flush-mount casings are designed to extend from the ground surface down into the concrete plug around the well casing. The immediate areas around flush-mount well installations shall be elevated to the extent practicable above surrounding areas to minimize standing water and promote runoff. It is to be noted that the selection of well locations prior to drilling should always avoid low areas which are subject to surface water ponding.

ii) Double-Cased Wells

Double cased wells shall be constructed when there is reason to believe that interconnection of two aquifers by well construction may cause cross contamination. A pilot boring shall be bored through the overburden and/or the contaminated zone into a confining layer (clay) or bedrock. An outer casing (sometimes called surface casing) shall then be placed into the borehole and grouted. The borehole and outer casing shall extend into the upper layer of the confining layer. The depth of penetration will depend upon the thickness of the confining layer but usually only a few feet is needed. In the case of bedrock, drilling can stop at the top of competent bedrock. The size of the outer casing shall be of sufficient inside diameter (ID) to contain the inner casing and the 2-inch (5 cm) minimum annular space. The outer casing shall be grouted by either the tremie method or by pressure grouting to within 2 feet (0.6 m) of the ground surface. The grout shall be pumped into the annular space between the outer casing and the borehole wall. A minimum of 24 hours shall be allowed for the grout to "set" or cure before attempting to drill through it. The grout mixture used to seal the outer annular space may be either a neat cement or cement/bentonite. When drilling through the seal, care shall be taken to avoiding cracking, shattering, and/or washing out of the seal. The two most commonly used casing installation techniques are described in the following:

a) Immersion Method

- drill borehole;
- fill borehole with grout;
- insert casing that has bottom end plugged with grout (previously placed and set) into borehole (water may be added inside casing to overcome buoyancy); and
- tap casing into confining layer or bedrock.

b) Pumping Method

- drill borehole;
- insert casing into borehole;
- insert grout pumping tube and inflatable packer into casing;
- inflate packer (with grout pumping tube extending through center of packer);
- pump grout through packer until grout return is noted at surface from around outside of casing;
- tap casing into confining layer or bedrock; and
- remove packer and grout tube.

Typical casing installation details are presented on Figures 4.8 and 4.9.

iii) Bedrock Wells

The installation of monitoring wells into bedrock may be accomplished in two ways:

a) The first method is to drill a pilot borehole through the overburden into the bedrock. An outer casing is then installed into the borehole by setting it into the bedrock and grouting it into place as described in the previous section.

After the grout has set, the borehole may then be advanced through the grout seal into the bedrock. The borehole is typically advanced into the bedrock by the rock coring method. Rock coring makes a smooth, round hole through the seal and into the bedrock without cracking and/or shattering the seal. Roller cone bits are commonly used in soft bedrock, but caution shall be used when advancing through the grout seal due to excessive water and "down" pressure which may cause cracking and/or shattering of the seal. The advantages of the coring technique are that it provides a continuous core of the rock penetration, allowing for proper formation and fracture identification and providing a sample for the geologic record. When the drilling is complete, the finished well consists of an open borehole from the casing end to the bottom of the well. There is no inner casing. The open rock interval serves as the monitoring zone. The outer casing installed down into bedrock extends aboveground surface and can also serve as the protective casing. If the protective casing becomes cracked or is sheared off at the ground surface, the well is open to any contamination from the ground surface and will have to be repaired immediately or abandoned. It may be more desirable to install a protective casing over the outer casing as an extra precaution.

For wells installed to monitor bedrock units below the uppermost layers, a second casing would be installed to the top of the desired monitoring interval. Thereafter, the borehole would be extended through the casings into the bedrock interval selected to be monitored.

b) The second method of installing a monitoring well into bedrock is to install the outer casing and drill the borehole into the bedrock, and then install an inner casing and well screen and backfill with the filter pack, bentonite plug, and grout. This well installation method enables isolation of the monitoring zone after the hole has been drilled. This method may also be needed in cases where the bedrock continually collapses into the open corehole.

iv) <u>Well Development</u>

Prior to the collection of hydraulic or groundwater quality data, a monitoring well must be developed. The objective of the monitoring well development is to repair the damage done to the formation (unconsolidated or consolidated) by the drilling operation so that the natural hydraulic properties of the waterbearing formation are restored.

The three most suitable methods for well development are:

1. surge block surging;
2. pumping/overpumping/backwashing;
3. bailing; and
4. combinations of above three methods.

The Well Development and Stabilization Form (Form SP-09) is available to document this task, once completed.

Surge Block

Surge blocks can be used effectively to destroy the bridging of the fine formation particles and to create the agitation that is necessary to develop a monitoring well. A surge block is used alternatively with either a bailer or pump so that material that has been agitated and loosened by the surging action is removed. The surge block assembly must be of sufficient weight to free fall through the water in the well and create a vigorous outward surge. Surging begins at the top of the well intake so that sand or silt loosened by the initial surging action cannot cascade down on top of the surge block and prevent removal of the surge block from the well. Surging is initially gentle, and the energy of the action is increased during the development process. A combination of surging and pumping should continue until the water is free from suspended particulate matter.

Pumping/Overpumping/Backwashing

The easiest, least expensive, and most commonly employed technique of monitoring well development is some form of pumping. Overpumping causes an increase in the flow velocity of the water to the well intake and creates a rapid and effective migration of particulates toward the well.

Where there is no backflow prevention valve (check valve) installed, the pump can be alternately started and stopped. This backwashing produces a surging action in the well and tends to loosen the bridging of the fine particles in the formation. Backwashing can only be performed using dedicated pumps and hoses or those that have been cleaned prior to use at the well being developed. The types of pumps commonly used for well development are BK pump, Grundfos submersible pumps, Red-jacket submersible pump, etc.

All of the above techniques are designed to remove the drilling effects from the monitored zone, and insofar as possible, to restore the formations penetrated to indigenous conditions. The above development techniques avoid the use of introduced fluids, including air, into the monitored zone during the development process. This not only minimizes adverse impacts on the quality of water samples, but also restricts development options that would otherwise be available.

a) Development of Overburden Wells

Any of the development techniques described above can be used to develop monitoring wells installed in relatively permeable formations. However, in formations that have low hydraulic conductivity, none of the preceding well development methods are completely satisfactory.

b) Development of Bedrock Wells

All drilling methods produce some plugging of fractures. Any material that causes sealing of waterbearing fractures as a result of the drilling activities must be removed by a development procedure. Any of the development methods described above can be used to develop wells installed in bedrock. Surging is often needed to obtain maximum efficiency of bedrock wells.

Bailing

In relatively clean, permeable formations where water flows freely into the well, bailing is an effective development technique. The bailer is allowed to fall freely through the monitoring well until it strikes the surface of the water. The contact of the bailer produces a strong outward surge of water. This tends to break up bridging that has developed within the formation. As the bailer fills and is rapidly withdrawn, the drawdown created in the borehole causes the particulate matter outside the well intake to flow through the well intake and into the well. Subsequent bailing removes the sand and other particulate matter from the well. Bailing should be continued until the water is free from suspended particulate matter.

4.3.4.3 DESIGN CONSIDERATIONS

i) Well Diameter

The diameter of the well installed is primarily dictated by the purpose of the installation. In general, wells installed for groundwater monitoring purposes should be at least 2 inches (5 cm) in diameter. This allows small diameter bladder pumps to be installed for sampling as well as small diameter bailers and suction tubes. Wells of smaller diameter should be avoided unless they are solely used for hydraulic monitoring. (The materials cost saving between 1-inch and 2-inch (2.5 and 5 cm) diameter is negligible in comparison to the cost of the installation). For groundwater extraction wells, a 4-inch (10 cm) diameter well should be the minimum size considered. This will allow a reasonable sized submersible pump to be installed and operated.

ii) Screen Length and Placement

The screen length should be consistent with the desired monitored interval and geologic conditions encountered. A 5- to 10-foot (1.5 to 3 m) screen length is generally sufficient when the screen is completely submerged and monitoring of an isolated zone is desired, however, in some cases it is necessary to screen the entire monitored interval. In cases where the water table is being monitored (i.e., NAPL) a 15- to 20-foot (4.3 to 5.7 m) screen length is preferred to accommodate seasonal fluctuations of the water table. A 5- to 10-foot (1.5 to 3 m) screen length is adequate where the formation into which the well is being installed is of a low enough hydraulic conductivity to allow the water level to be drawn down during sampling through the filter pack and into the screened interval. This will allow any floating layer to be drawn into the well when the water level is depressed for sampling. Dense NAPL (DNAPL) , if present, should be easily detectable since the well screen may be set on the bottom of the borehole and should be located at the top of some form of confining layer. As long as the screen material is more permeable than the surrounding geologic strata, a 5- to 10-foot (1.5 to 3 m) filter pack length should suffice. If the formation is more permeable and the potential for Light NAPL (LNAPL) presence exists, a longer screen length may be necessary.

iii) Well Slot Size/Filter Pack Material

The slot size of the well screen must be sized to match the filter pack material. The filter pack material must be sized to match the geologic strata.

iv) Well Materials

The materials selected for the well construction must be compatible with the chemicals anticipated to be present in the groundwater and parameter groups selected for chemical analysis.

The following well materials are often used:

- stainless steel well screen and riser pipe;
- stainless steel well screen and black steel riser pipe; and
- PVC well screen and riser pipe.

Note: PVC should not be used where solvents are present, nor should solvent cement be used to join PVC sections of pipe together.

4.3.4.4 WELL INSTALLATION DOCUMENTATION

Details of each overburden well installation may be recorded on the Stratigraphy Log (Overburden) (Form SP-17) or recorded within a standard CRA field book. Overburden Instrumentation Log (Form SP-18) is provided for recording the overburden well instrumentation details, this figure must note:

- borehole depth;
- well screen depth;
- filter pack interval;
- seal/plug interval;
- grout interval;
- surface cap detail;
- well material;
- well instrumentation (i.e., riser and screen length);
- well diameter;
- filter pack material;
- type of seal;
- type of grout;
- stick-up/flush-mount detail;
- date installed; and
- development record.

The soil stratigraphy encountered at each well location must be recorded in accordance with CRA's standard borehole penetration methods (see Section 4.2).

Details of bedrock well installation are typically recorded and sketched within a CRA standard field book. Bedrock Drill and Stratigraphic Log (Form SP-19) and Bedrock Stratigraphic Core Log (Form SP-20) provide a bedrock drill and stratigraphic log for bedrock description, and bedrock stratigraphic core log, respectively.

The field book records and sketches of bedrock well installations must note:

- corehole diameter, depth, and lengths;
- casing diameter, depth, materials, and lengths;

- overburden depth;
- grout placement;
- surface cap details;
- date of installation; and
- development record.

Each well installed must have accurate field ties to the center of the well from three adjacent permanent features.

Development records may be documented on the Well Development and Stabilization Form (SP-09).

Each well must be permanently marked to identify the well number designation.

4.3.4.5 FOLLOWUP ACTIVITIES

Once the monitoring well(s) have been completed and developed, the following activities need to be done:

- all logs shall be submitted to CRA's hydrogeology department who will be responsible for the generation of the final well log;
- well/boring locations plotted onto site plan, since boring locations may be changed in the field due to underground/overhead interferences or other conditions;
- arrange surveyor to obtain accurate horizontal and vertical control;
- tabulate monitoring well details;
- a summary write-up on field activities including, but not necessarily limited to such items as drilling method(s), well construction material, site geology and well development;
- field book shall be kept at the appropriate CRA office; and
- collect a round of water level measurements (or several) once the monitoring well installation activities are complete.

4.3.5 CONTACT INFORMATION

The following CRA personnel may be contacted regarding monitoring well design and construction procedures or for additional information:

Contact	*Office*	*Phone Number*	*Fax Number*
Brian Carter	Baton Rouge	(225) 292-9007	(225) 292-3614
Walt Pochron	Chicago	(773) 299-9933	(773) 299-6421
Scott Green	Detroit	(734) 942-0909	(734) 942-1858
Peter Storlie	Minneapolis	(651) 639-0913	(651) 639-0923
Dave Hill	Nashville	(615) 315-9927	(615) 315-9934
Doug Oscar	Niagara Falls	(716) 297-2160	(716) 297-2265
Jim Hayman	Titusville	(407) 269-9891	(407) 269-9802
Jeff Ratliff	Titusville	(407) 269-9891	(407) 269-9872
Mike Mateyk	Waterloo	(519) 725-3313	(519) 725-1394

4.3.6 REFERENCES

Numerous publications are available describing current monitoring well design and construction procedures, three excellent references are:

i) Driscoll, F.G., 1986. Groundwater and Wells, 2nd Edition. Johnson Division.
ii) Freeze, R.A. and Cherry, J.A., 1979. Groundwater. Prentice Hall, Inc.
iii) ASTM D5092. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifer.

In addition, the following ASTM publications apply:

ASTM D5474	Guide for Selection of Data Elements for Ground-Water Investigations
ASTM D5787	Practice for Monitoring Well Protection
ASTM D5521	Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers
ASTM D5978	Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells

ASTM D5299 Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes and Other Devices for Environmental Activities

4.4 FLUID LEVEL MONITORING

4.4.1 GENERAL

The measurement of fluid levels (groundwater or phase-separated compounds) in monitoring wells, piezometers, extraction wells, and/or boreholes is required in geotechnical, hydrogeologic, and waste management investigations to determine the presence and condition of the groundwater, or the presence and thickness of phase-separated compounds. Water level measurements (hydraulic head) are used to determine: hydraulic gradients and the direction of groundwater flow; the effectiveness of groundwater extraction systems; and the volume of water required for well purging prior to groundwater sampling. The measurement of the thickness of phase-separated compounds provides a qualitative (not quantitative) monitoring of this severe form of contamination.

In order to provide reliable data, water levels must be collected over as short a period of time as possible. Barometric pressure can affect groundwater levels and, therefore, observation of significant weather changes during the period of water level measurements must be noted. Tidal fluctuations, navigation controls on rivers, rainfall events and groundwater pumping can also affect groundwater level measurements. Personnel collecting water level data must note if any of these controls are in effect during the groundwater level collection period. Due to possible changes during the groundwater level collection period, it is imperative that the time of data collection at each station be accurately recorded.

In conjunction with groundwater level measurements, surface water (e.g., ponds, lakes, rivers, and lagoons) must be monitored as well. This information is critical in understanding the hydrogeologic setting of the site and most importantly how contaminants may move beneath the site.

A number of devices are used by CRA to collect water level measurements. Typical devices used are:

- calibrated electronic water level indicators (e.g., Solinst or Slope Indicator);
- tape/ploppers;
- pressure transducers and dataloggers (generally for pumping tests and long-term monitoring); and
- Stevens™ recorders for long-term monitoring.

Devices typically used by CRA to measure phase-separated compounds are:

- interface probe;
- clear "bottom loading" bailers; and
- weighted cotton string or cord.

The pressure transducers, Stevens™ recorders, and oil/water interface probes have manuals which describe their use. This FMG will focus on an overview of this equipment use and other methods which have more widespread use in fluid level measurement.

Since many decisions concerning the distribution, transport, and remediation of groundwater contamination will be made on the basis of the fluid level monitoring, the accuracy of the measurements made at an appropriate level of precision is very important (see Section 3.8 - Accuracy, Precision, and Significant Figures). Typically, the precision required is +0.01 foot (+1 mm); the majority of CRA's measuring devices are graduated to this precision level. To ensure accuracy, double check all fluid level readings; it is very easy to misread a tape or transpose figures when recording the data.

4.4.2 PRIOR PLANNING AND PREPARATION

The following shall be taken into consideration prior to obtaining fluid levels:

i) Review with the Project Coordinator the Work program, project documents, and site-specific health and safety plan.
ii) Complete an equipment requisition form and assemble all equipment and supplies required per the Water Level Measurement Equipment and Supply Checklist (Form SP-12).
iii) Assemble the site plan, well depths, and previous measurements. Determine the exact number of points (wells and surface water levels to be measured).
iv) Obtain monitoring well and site access keys.
v) Determine measurement notification needs with the Project Coordinator. Have the Client, regulatory agency, landowner been notified?

4.4.3 FIELD PROCEDURES

Once the prior planning and preparation activities are completed, fluid level measurements can proceed. The typical series of events which will take place are:

- well identification/inspection;
- air monitoring;

- reference point determination;
- level measurements;
- equipment decontamination;
- field note completion, review. and checking;
- equipment return; and
- documentation submitted to appropriate staff and files.

Note: *Similar to sampling sequence, fluid level measurements should follow a logical order from the least known or suspected level of contamination to the greatest. This will minimize the potential for cross-contamination between wells/monitoring locations.*

i) Well Identification/Inspection

Once at the site and prior to fluid level measurements, it is a requirement to confirm that the well to be measured has been correctly identified and located. Frequently sites under evaluation have numerous wells, or wells located in clusters such that identification errors can easily occur. The monitoring personnel should be alert to potential cap switching, mislabeled locations or unlabeled wells.

Proper well locations can be determined by comparison of the well log details to measured well details (i.e., total well depth, casing diameter, casing stick-up or stick-down distances), field ties and site plans.

Once the correct monitoring well is identified, a thorough inspection shall be completed, and recorded in the field book. Determine if the cap and lock are secure or if they have been tampered with. If the well is unlocked, replace the lock. Any cracks in the protective casing and/or surface seal should be noted, as well as any subsidence or surface water ponding in the vicinity of the well.

Note the results of the well inspection (even if the well is in perfect condition) and inform the Project Coordinator of any well repairs required. Arrange to have any unmarked wells permanently stamped for proper identification. (A temporary marking at the time of monitoring should also be performed.)

ii) Air Monitoring

For environmental investigations, prior to opening the well cap, measure the breathing space above the well casing with a photoionization detector (PID) to establish baseline levels. Repeat this measurement once the well cap is opened. If either of these measurements exceeds any of the air quality criteria established in the HASP, then air purifying respirators (APRs) or supplied air systems will be required.

In addition to the measurement of breathing space air, obtain a measurement from inside the riser pipe. This measurement is a good indication of the presence of elevated chemical presence or non-aqueous phase liquids (NAPLs) that may be present in the water.

This may not be required at all sites. Confirm with the Project Coordinator.

iii) Reference Point

Fluid level measurements are made relative to a surveyed reference point. For groundwater level measurements, the reference point is usually the top of the well riser or casing. (The protective casing should not be used as a reference point.) The top of the well riser/casing is usually not level and/or square and, therefore, the reference point must be clearly marked on the riser and noted in the field book. Clearly marking the reference point will eliminate future measurement errors. Measure and record the distance from the reference point to the ground surface. The elevation of the reference point should be determined to the nearest 0.01 foot (or 1 mm).

Surface water reference points are established at some sites. These usually consist of t-bars or staff gages. The top of the t-bar should be surveyed. Bridge abutments, sewer outfalls, and other structures can be used as surface water reference points.

iv) Fluid Level Measurements

The following paragraphs describe the most common techniques used by CRA to measure fluid levels.

Helpful Hint! Beware of watertight caps which provide an airtight seal on the casing end and the water level is positioned within the casing area (i.e., not within the screened interval). Often if this condition exists, a vacuum or pressurized zone is created within the casing section which supports or depresses the water column within the well casing, creating an artificially high or low water column. This effect can cause a few inches or feet of error in the static water level. Two or three water level measurements will confirm water level stability or changing conditions. Once the water level has stabilized (i.e., static) the proper measurement may be taken.

A. Electrical Water Level Indicators

The most common method of obtaining water level measurements is the electronic water level indicator (e.g., Solinst meter or Slope Indicator). These meters consist of calibrated cable or tape with a weighted sensing tip at one end. When the tip contacts the water, an electric circuit is completed and the light and/or buzzer signals the contact. The following procedures shall be used with electrical water level meters:

1. Check the proper operation of the meter by inserting the tip into water and noting if the contact is registered clearly.

Deionized water cannot be used for this check, as it will not conduct an electrical current.

Always check to see if the tape has been previously repaired and if a correction of the measurement is required.

2. Dry the tip and then slowly lower the tip into the well until contact with the water is indicated.

3. Slowly raise the tip until the light and/or buzzer just begins to activate. This indicates the static water level.

4. Using the thumb and index finger, grasp the tape at the reference point, and note the reading (to the nearest hundredth of a foot or 1 mm).

5. The reading should be checked two times before removing the tape from the well.

6. Record the water level measurement in the field book and/or water level form. Compare to previous measurements to see if significant changes [i.e., greater than 2 feet (0.6 m)] have occurred. Recheck water level if a significant difference is measured.

7. Decontaminate the submerged end of the tape in accordance with the Work Plan protocols.

Helpful Hint: In cases where water levels will be measured on several occasions, it may be advantageous to set up a separate page within the field book for the water level measurements from each well. This will allow the measurements to be compared to the previous water level events and allow significant differences to be easily identified.

B. Tape/Plopper

A weighted standard surveying tape, typically graduated in increments of 0.01 foot (1 mm) weighted with a sounding device, was used for many years as the only means of measuring fluid levels in monitoring wells, boreholes, and pits. It should still be considered as a fail-safe backup method (there are no batteries or electrical circuits to fail), or alternative device if an electrical level indicator is not available.

Although the tape can be weighted with any heavy object (e.g., a nut, fishing sinker), the device commonly used by CRA is a hollow-pipe section described as a "plopper". The exact top of the fluid level will be determined by carefully listening for the sound the "plopper" makes when it contacts the fluid surface. The "plopper" is hung from the bottom of the tape such that the capped end is up and the open end is down. When the open end of the hollow pipe touches the fluid surface, a hollow "plopping" sound results. By moving the tape up and down ever so slightly, the fluid level can be determined very precisely.

Since the weight is hanging from the "zero" end of the tape, and since it is the weight touching the fluid level which allows detection of the fluid surface, the length of the weight must be ADDED to the tape reading. It is most convenient (and results in fewer errors) if the weight is purposely designed to be a standard, easily remembered length, say 0.50 foot (15 cm). Thorough field cleaning the hollow "water plopper" is very important due to its shape and the potential for contaminants lingering around the internal area.

C. Interface Probe

Electrical water level indicators are not reliable when phase-separated liquids are floating on the water surface.

Phase-separated liquids may consist of lighter-than-water materials (petroleum hydrocarbons) which float on the groundwater surface and are categorically referred to as Light Non-Aqueous Phase Liquids (LNAPL); or heavier-than-water materials (dense organic chemicals) which are denser than water and will sink until a confining layer or less permeable layer is encountered, and are categorically referred to as Dense Non-Aqueous Phase Liquids (DNAPL). Interface probes will detect the surface of LNAPL layers and the interface between LNAPL and groundwater or groundwater and DNAPL.

The interface probe uses an optical liquid sensor, in conjunction with an electric circuit to detect the top of a phase-separated liquid and the interface between the phase layer and water (water level). The procedure for use of this probe is:

1. Lower the probe tip into the well until discontinuous beeping is heard (this indicates the top of the oil has been detected). Grasp the calibrated tape at the reference point and note reading. Confirm the reading by slowly raising and lowering the probe to the level of the phase layer.
2. Once the top of the phase layer is confirmed, slowly lower the probe until a continuous sound is heard. This indicates that the water level has been encountered. Grasp the tape at the reference point and note the reading. Confirm this water level measurement.
3. Decontaminate the submerged end of the tape and probe prior to the next use in accordance with the Work Plan requirements.

D. Alternative NAPL Measurement Methods

Alternative NAPL measurement methods exist in the event an interface probe is unavailable or not functioning properly. These methods tend to be less accurate than the interface probe but may be used to establish an estimated NAPL measurement.

Clear Bailer – A clear bottom-loading bailer may be used to estimate NAPL thickness if floating or denser than water. If NAPL presence is suspected, the bailer is carefully lowered to the location of suspected NAPL presence (top of water column/base of water column), and slowly removed and examined for NAPL. If present, the column of NAPL within the clear bailer can be measured to estimate the NAPL thickness within the groundwater column.

Weighted Cord – Primarily used for DNAPL measurements, a weighted "cotton" string or cord may be lowered to the base of the well and inspected upon retrieval. Typically, the lower DNAPL layer will "coat" the string indicating the approximate thickness of this layer.

This method, if effective at a site, can be an economical and quick method to measure DNAPL layers.

v) Decontamination

Typically, all fluid level measuring equipment must be decontaminated between each well. (Note: this applies to hazardous waste sites and landfill investigations, not to water supply investigations.) If the site has a specific cleaning protocol, it must be followed. Section 4.10 of this manual outlines decontamination procedures in detail for sampling/ measurement equipment.

At a minimum, the following procedure shall be used:

- rinse the submerged portions of the equipment with deionized water; and
- dry with a paper towel.

> Note: *In addition to cleaning the probe and/or plopper and submerged tape components, it is also necessary to inspect the remaining tape sections for rust/crud or dirt and clean accordingly.*

If phase-separated liquids are encountered, the equipment must be cleaned with a non-phosphate detergent, and other oil/organic removal agents. Specific cleaning protocols may need to be established if unexpected phase-separated liquids are encountered.

Decontamination fluids must be contained and disposed in accordance with the Work Plan requirements. In cases where solvents or acids are used as part of the decontamination process, they must be contained separately from the water and each other. The spent solvents will often evaporate before the end of the day eliminating further handling concerns.

vi) Field Note Completion and Review

The fluid levels must be recorded in a standard bound "survey" type field book and/or appropriate site-specific forms. The logbook should identify the following:

- identification of measurement point;
- date and time of measurement;
- reference point and reference point elevation;
- measurement method;
- depth to water level;
- presence of phase-separated liquids; and
- odor (if noted).

The recorded fluid levels must be compared to previous results, if applicable. All elevation calculations must be checked and initialed by a co-worker who did not perform the original calculations. While seasonal variations in water levels occur, any major changes [greater than 2 feet (0.6 m)] should be noted, especially if the general water level trends are less than this. All wells which exhibit a significant change should be re-checked immediately prior to moving to the next well. The Project Coordinator must be advised on any significant changes in water levels before leaving the site.

vii) LNAPL Thickness/Displacement Correction

Historical studies and direct field observations have shown that there is no direct relationship between the thickness of LNAPL measured in a well and the thickness of LNAPL in the soil adjacent to the well. No quantitative relationship exists other than a general observation has been found that the more porous the soil, the more the NAPL thickness in the well seems to reflect the thickness in the soil.

The occurrence of LNAPL in a well is a positive indication that LNAPL is present in the subsurface in volumes exceeding that which is adsorbed by the soil. The repeated occurrence of LNAPL upon bailing is a positive indication that those adsorption volumes are still exceeded in the soil; a trend of decreasing LNAPL thickness with repeated bailing suggests that the volume is being reduced to the adsorption level. The occurrence of phase-separated material in a well indicates nothing more quantitative than these general relationships.

When compiling a groundwater contour plan or utilizing groundwater data for other compilations, it is necessary to calculate the elevation of the groundwater by eliminating the effects of the LNAPL layer. The displacement correction for an LNAPL layer is as follows:

(Measured elevation of groundwater surface) + (measured LNAPL thickness times the LNAPL specific gravity) = corrected groundwater elevation.

Generally, a specific gravity of 0.75 is a good average value for LNAPL layer displacement corrections.

4.4.4 FOLLOWUP ACTIVITIES

The following activities shall be performed at the completion of the field work.

i) Compare newly obtained water levels with historic data and recheck any which do not conform.
ii) Ensure wells are locked and return site/well keys to key box.
iii) The equipment shall be cleaned and returned to the equipment administrator and the requisition form shall be dated and signed. The equipment shall be decontaminated at the site. No cleaning shall be performed at any CRA office. Field decontamination procedures are discussed in Section 4.10.
iv) Water level monitoring forms and field notes shall be sent to the file. The field book will be stored at the CRA office.
v) Prepare and distribute a Water Level Measurement • Completion Checklist (Form SP-13). Water Level Records (Form SP-14) is available for summarizing the water level records for an entire site or repeated measurements at a single location.

4.4.5 COMPLETION CHECKLIST

At the completion of the water level monitoring program, a Water Level Measurement • Completion Checklist (Form SP-13) must be completed to document activities conducted and serve to remind personnel of the various tasks required. This form must be signed and filed at the respective field office, regional CRA office and issued to the Project Coordinator.

4.4.6 CONTACT INFORMATION

The following CRA personnel may be contacted regarding fluid level monitoring procedures or for additional information:

Contact	*Office*	*Phone Number*	*Fax Number*
Brian Carter	Baton Rouge	(225) 292-9007	(225) 292-3614
Walt Pochron	Chicago	(773) 380-9933	(773) 380-6421
Scott Green	Detroit	(734) 942-0909	(734) 942-1858
John Evanoff	Houston	(281) 492-8311	(281) 492-2340
Peter Storlie	Minneapolis	(651) 639-0913	(651) 639-0923
Dave Hill	Nashville	(615) 315-9934	(615) 315-9934
Doug Oscar	Niagara Falls	(716) 283-6720	(716) 283-6724
Jeff Ratliff	Titusville	(407) 269-9891	(407) 269-9872
Mike Mateyk	Waterloo	(519) 725-3313	(519) 725-1394

4.4.7 REFERENCES

For additional information pertaining to fluid level monitoring the user of this manual may reference the following:

ASTM 4750	Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
ASTM D6000	Guide for Presentation of Water-Level Information from Ground-Water Sites

4.5 GROUNDWATER SAMPLING

4.5.1 GENERAL

The objective of most groundwater quality monitoring programs is to obtain samples that are representative of existing groundwater conditions, or samples that retain the physical and chemical properties of the groundwater within an aquifer. Improper sampling and transport procedures may cause compounds of interest to be removed from or added to the sample prior to analysis. The importance of proper and consistent field sampling methods cannot be over emphasized; as well as the importance of proper documentation.

One of the most important aspects of groundwater sampling is acquiring samples that are <u>free of suspended silt, sediment, or other fine grained particulates</u>. Fine grain materials may often have a variety of chemical components sorbed to the particle or have the ability to sorb chemicals from the aqueous phase to the particle which will bias the subsequent analytical results. The additional field expense to extend purging requirements or modify sampling techniques to achieve sediment-free groundwater is minor when considering the implications of gathering data that are unfairly biased. Sound analytical data are considered invaluable to a groundwater monitoring program. CRA often successfully criticizes the work of others on the basis that turbid samples were submitted for analysis. Section 4.5.3 describes techniques that typically achieve sediment-free conditions. When sampling for natural attenuation parameters, more stringent measures are required in order to ensure sediment-free samples that represent the total mobile load (i.e., dissolved and naturally suspended particles). Low-flow purging (LFP) techniques are strongly recommended, if not mandated, when taking samples for natural attenuation parameters. The LFP techniques described in Section 4.5.3 are in accordance with USEPA low-flow procedures (Puls and Barcelona, 1996).

Groundwater sampling may be required for various reasons, such as investigating potable or industrial water supplies, checking for and/or tracking contaminant plume movement, or examining a site where groundwater is thought to be contaminated.

Groundwater is usually sampled through an in-place well, either temporarily or permanently installed; although municipal, industrial, or residential wells may be sampled during an investigation. The following FMG is specifically intended for monitoring well sampling. Alternate sampling procedures are used for municipal, industrial, and residential wells. These procedures are described in Section 4.6.

Note:	*It is common practice to pre-plan the schedule of sampling activities such that sample collection progresses from "clean" to "dirty" areas in an effort to eliminate the potential for cross-contamination. Review previous analytical data (if available) to determine the best sampling sequence.*

4.5.2 PRIOR PLANNING AND PREPARATION

The following shall be considered prior to groundwater sampling:

i) Review the work program, project documents, and the health and safety requirements with the Project Coordinator.

ii) Complete an equipment requisition form. Assemble all equipment and supplies per the groundwater sampling equipment and supply checklist (Form SP-07).

iii) Assemble site plan, well logs, and previous sampling/purging data that will be required for the planned sample event. Determine the exact number and locations of the wells to be sampled. Information from purging and sampling events may be recorded on Forms SP-09, SP-10, SP-11A, and SP-11B.

iv) Contact the CRA QA/QC analytical group to arrange:

- laboratory;
- glassware;
- preservatives;
- filtration information;
- coolers;
- shipping details;
- starting date; and
- expected duration.

v) If several sampling events are planned, evaluate with the Client for well-specific dedicated equipment to reduce the chances of cross-contamination and to minimize decontamination requirements.
At a minimum, sample tubing should be dedicated to each well and should be left securely hanging in the well casing for subsequent usage. For LFP, dedication of the pump is recommended.

vi) Evaluate sample notification needs with the Project Coordinator. Have the regulatory groups, Client personnel, landowner, CRA personnel, and laboratory been informed of pending sample events?

vii) Arrange access to the site. Assemble well keys and site keys. Also consider site conditions (e.g., is snow removal required?).

viii) Evaluate groundwater and spent fluid disposal requirements before sampling activities start.

ix) Pre-plan sampling sequence to insure that "clean" wells are sampled before "dirty" wells to reduce cross-contamination potential.

x) Pre-plan the sampling sequence to insure that "dry" wells fit into the overall sampling schedule to reduce the need for extension of the sampling period and to reduce the need for weekend purging/sampling.

4.5.3 FIELD PROCEDURES

Once the prior planning and preparation activities are completed, groundwater purging and sampling can proceed at the respective well sites. The typical series of events which will take place are:

- well identification/inspection;
- air monitoring;
- water level monitoring;
- well depth sounding;
- well volume calculation;
- pump/equipment installation;
- well purging and stabilization monitoring;
- sample collection, sample preparation, and sample packaging;
- final water level monitoring (if required), equipment removal, well securement;
- equipment decontamination;
- field note completion and review;
- sample shipment, chain-of-custody distribution;
- purged groundwater/decon fluid disposal;
- sample record documentation, equipment return; and
- documentation submitted to appropriate staff and files.

Whichever method is used for purging and sampling, new plastic sheeting shall be placed on the ground around the well casing to prevent contamination of the pumps, hoses, ropes, etc., in case they need to be placed on the ground during purging/sampling and to prevent contact with the ground during installation.

The following sub-sections provide additional information for field procedures:

i) Well Identification/Inspection

Once at the well location and prior to sample collection activities, it is a requirement to confirm that the well to be sampled has been correctly identified and located. Frequently, sites under evaluation have numerous wells, or wells located in clusters, such that misidentification can easily occur. The sampler should be alert to potential cap switching, mislabeled locations, or unlabeled well sites.

Proper well locations can be determined by comparison of the well log details to measured well details (i.e., total well depth, casing diameter, casing stick-up or stick-down distances), field ties, and site plans.

Once the correct monitoring well is identified, a thorough inspection shall be completed and recorded in the sampling field book, to determine if the well is suitable for sampling. Determine if the cap and lock are secure or if they have been tampered with. If the well is unlocked, replace the lock. Any cracks in the protective casing and/or surface seal should be noted, as well as any subsidence in the vicinity of the well.

Note the results of the well inspection (even if the well is in perfect condition) and inform the Project Coordinator of any well repairs required. Arrange to have any unmarked wells permanently stamped for proper identification. (A temporary marking at the time of sampling should also be performed.)

ii) Air Monitoring

Prior to opening the well cap, measure the breathing space above the well casing with a photoionization detector (PID) to establish baseline levels. Repeat this measurement once the well cap is opened. If either of these measurements exceed any of the air quality criteria established in the health and safety plan, then air purifying respirators (APRs) or supplied air systems will be required.

In addition to the measurement of breathing space air, obtain a measurement from inside the riser pipe. This measurement is a good indication of the presence of elevated chemical presence or non-aqueous phase liquids (NAPLs) that may be present in the water.

iii) Water Level Monitoring/Well Depth Sounding

Prior to commencing the groundwater purging/sampling tasks, a water level must be obtained to determine the well volume and for hydraulic purposes. Typically, a round of water levels of all site wells or select wells is collected to establish groundwater conditions site-wide before groundwater extraction occurs.

Helpful Hint! Beware of watertight caps which provide an airtight seal on the casing end and the water level is positioned within the casing area (i.e., not within the screened interval). Often if this condition exists, a vacuum or pressurized zone is created within the casing section which supports or depresses the water column within the well casing, creating an artificially high or low water column. This effect can cause a few inches or feet of error in the static water level. Two or three water level measurements will confirm water level stability or changing conditions. Once the water level has stabilized (i.e., static) the proper measurement may be taken.

A number of devices exist to collect groundwater level data. CRA typically utilizes:

- electronic water level gages (i.e., audible and/or visual identification of water level);
- electronic transducers (numerous manufacturers) and recording devices for long-term monitoring; and
- Stevens™ recorders (both float and electronic instrumentation) for long-term monitoring.

Section 4.4 fully describes the equipment and monitoring techniques for water level measurement.

Well depth sounding may be required to confirm a well identification or may be necessary to evaluate sediment presence in the well bottom. Sounding is typically performed with the water level gage or a weighted measuring tape lowered to the base of the well. A comparison is then made of the installed well depth vs. the measured depth. The presence of excess sediment or drill cuttings may warrant well redevelopment or flushing before groundwater samples are collected.

The total depth measurements shall be compared to the original total well depth. In general, if the well screen is more than 50 percent blocked, the well should be redeveloped prior to the next sampling event. Identify any monitoring wells requiring redevelopment to the Project Coordinator.

Total well depth should be measured on an annual basis or biannual basis if the well is equipped with a dedicated pump.

For LFP, well depth measurements are required to ensure proper placement of the pump intake. The use of a wide-based probe, such as a water level plopper, is necessary to minimize penetration and disturbance of the well bottom sediment. The measurement device must be lowered slowly to the well bottom to minimize mixing of the stagnant well casing water and to minimize sediment mobilization.

Reminder! Do not forget that decontamination procedures apply to the water level monitoring device as well as the groundwater sampling equipment. If well sounding is performed, the entire measuring device must be thoroughly cleaned before the next location is monitored. MEASURING THE WELL DEPTH WITH A SOLINIST-TYPE WATER LEVEL INDICATOR MAY DAMAGE THE PROBE SEAL. THEREFORE, A WEIGHTED TAPE SHOULD BE USED TO MEASURE WELL DEPTH.

iv) Well Volume Calculation

This calculation does not apply to LFP.

Prior to well purging, the volume of water in the well must be known to evaluate the number of well volumes to be removed. A well volume is defined as the volume of water contained within the well screen and casing (and in the case of bedrock wells, the volume of water within the open corehole). To determine the water volume in a well, the following method shall be used:

a) Calculate the distance from the bottom of the well to the static water level.

b) Measure the inside diameter of the well or casing. Obtain the volume of water within the well by utilizing the following formula:

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

where:

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

To convert gallons (U.S.) to liters, multiply by 3.785.

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

v) Well Purging and Stabilization Monitoring

a) Typical Method

Prior to groundwater sample collection, each well must be purged of the standing volume of stagnant water which is not representative of the formation groundwater. The objective of purging is to pump the well until water that is representative of the formation groundwater is obtained. This is usually achieved by removal of the three to five times the volume of standing water in the well (USEPA Convention). Purging is considered complete once sediment free groundwater is obtained and the specific conductance, temperature, and pH of the groundwater stabilizes. Groundwater stabilization has occurred if three consecutive well volume measurements of temperature and specific conductivity are approximately plus or minus 10 percent and if the pH values are within 1 pH unit of the last three value averages, and groundwater turbidity values are less than 5 NTU (Guidance Value Only). Once the required number of well volumes to reach stabilization is known for a particular well, the need to establish stabilization for future sample events is eliminated or at least reduced. Extended purging will usually result in achieving sediment-free groundwater.

If stabilization has not occurred within the first five well volumes removed, continue purging and monitoring until eight well volumes have been pumped. If stabilization has still not occurred, it may be dropped as a pre-condition to sampling.

For high yielding wells, the removal of three to five casing volumes is usually sufficient prior to sampling. For low yielding wells (i.e., well location pumps dry), it may be necessary to purge the well dry on 3 successive days, unless full recovery occurs within a shorter time period. If the recharge rate is sufficiently high, groundwater sample collection may commence after the well has fully recovered or once the well has recovered to sufficient height to collect the necessary samples.

Helpful Hint: Dry wells should be scheduled to begin purging on Monday or Tuesday, to reduce weekend requirements.

Groundwater turbidity may be evaluated by a visual examination for sediment/silt presence or use of a nephlometer which physically measures groundwater turbidity (Nephlometric Turbidity Units - NTU). In most cases a reading of 50 NTU or less is acceptable for groundwater sample collection, although some regulatory areas/districts have established a lower criteria (i.e., less than 5 NTU) before sampling proceeds or groundwater filtration is required. Low flow purging should result in turbidity less than 5 NTU.

Helpful Hints: Any 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).

Monitoring well purging is accomplished by using in-place pumps or by using either a peristaltic, bladder, or other appropriate pump, depending on depth. A bailer may be used for purging although bailing will stir up sediment in the well and likely increase the purging effort required before stabilization is achieved. Section vii) summarizes the equipment available to complete purging tasks.

Monitoring equipment used during purging includes water level indicator, pH meter, thermometer, conductivity meter, and nephlometer.

Purging Entire Water Column

The pump/hose assembly or bailer used for purging should be lowered into the top of the standing water column and not deep into the column . This is done so that the purging will move water from the formation into the screened interval of the well and up through the casing so that the entire static volume may be removed. If the pump inlet is set too deep into the water column, the water above the pump inlet may not be removed, and the samples collected may not be representative of the groundwater.

If the recovery rate of the well is faster than the pump rate, the pump may be left suspended until an adequate volume has been purged. If the pump rate exceeds the recovery rate of the well, the pump will have to be lowered.

b) Low-Flow Purging (LFP) Technique

Because LFP causes minimal drawdown, less purging is required before formation water is drawn. The amount of purging required is also reduced because LFP causes less agitation and mobilization of sediments compared to traditional techniques.

For LFP, a precleaned stainless steel bladder pump with a Teflon bladder is strongly recommended. The pump discharge line may be polyethylene tubing with an inside diameter of 1/4 or 3/8 inch (smaller diameter tubing ensures the discharge line remains water filled with no air bubbles at low-flow purging rates). The pump is secured to nylon rope and positioned in the well such that the pump intake corresponds to the mid-point of the well screen, or a minimum of 2 feet above the well bottom/sediment level (pre-measurement of the required rope length will help ensure accurate positioning of the pump intake). The pump must be lowered very slowly into position to minimize mixing of the stagnant well casing water and to minimize the agitation of any solids into suspension which will increase purging times. If feasible, the pump is placed in the well a few hours prior to purging to allow any disturbed sediment to settle. It is recommended that the pump be dedicated to the well if regular monitoring is planned.

Purging of the monitoring well is conducted using a pumping rate between 100 to 500 milliliters per minute (mL/min). Initial purging will begin using a pumping rate within the lower end of this range. The groundwater level is measured while purging to ensure that less than 0.3 feet (0.1 m)of drawdown occurs. The pumping rate may be gradually increased depending upon the amount of drawdown and the behavior of the stabilization parameters, discussed below. Pumping rate adjustments generally are made within 15 minutes from the start of purging and then should remain constant for the duration of purging. While purging, the pumping rate and groundwater level are measured and recorded every 10 minutes (or as appropriate).

Stabilization of the purged groundwater is necessary prior to sampling to ensure that the samples obtained are representative of groundwater in the subsurface only and are not influenced by stagnant groundwater stored in the well casing. The field parameters (pH, temperature, conductivity, oxidation-reduction (redox) reaction potential (ORP), dissolved oxygen (DO), and turbidity) are monitored while purging to evaluate the stabilization of the purged groundwater. The field parameters are measured and recorded every 10 minutes (or as appropriate). Stabilization is considered to be achieved when three consecutive readings for each parameter, 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; and
- turbidity — ±10 percent of the average value of the three readings, or a final value of less than 5 nephelometric turbidity units (NTU).

The field parameters are measured using a flow-through-cell apparatus. At the start of purging, the purge water is visually inspected for water clarity prior to connecting the flow-through-cell. If the purge water appears turbid, purging is continued until the purge water becomes visually less turbid before connecting the flow-through-cell. Measurement of the field parameters may be obtained using individual meters or a multiple meter unit. The meters are calibrated prior to use each day in accordance with the meter manufacturer's instructions. While purging, 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°Celsius] may indicate a DO meter malfunction;
- negative ORP and DO <1 to 2 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have positive ORP and DO <1 to 2 mg/L under oxidizing conditions); and
- positive ORP and DO less than 1 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have negative ORP and DO less than 1 mg/L under reducing conditions).

Meter calibration fluids are available for meter recalibration in the field, if necessary. Spare meters are available for meter replacement, if necessary.

Note: Dissolved oxygen (DO) levels exceeding the solubility of oxygen in water are erroneous, and are indicative of meter malfunction or poor sampling technique causing turbulence and aeration. DO concentrations cannot exceed: *9 mg/L at 20 °Celsius,* *10 mg/L at 15 °Celsius,* *11 mg/L at 10 °Celsius, and* *14 mg/L at 1 °Celsius.*

In general, stabilization of the individual field parameters is considered to occur in the order listed above. Should stabilization not be achieved for all field parameters, purging is continued until a maximum of 20 well screen volumes have been purged from the well. Since LFP likely will not draw groundwater from a significant distance above or below the pump intake, the screen volume is based upon a 5-foot (1.4 m) screen length. After purging 20 well screen volumes, purging is continued if the purge water remains visually turbid and appears to be clearing, or if stabilization parameters are varying slightly outside of the stabilization criteria listed above and appear to be approaching stabilization.

In the event that the groundwater recharge to the monitoring well is insufficient to conduct the LFP protocol, the well is pumped to dryness and allowed to sufficiently recharge prior to sampling. Wells which are purged to dryness will not be subject to the above purging criteria.

vi) Sampling Techniques

Once the purging activities are complete, and the groundwater stabilization/clarity is acceptable as per the applicable protocol described above, the collection of samples can proceed. Typically the field parameters of temperature, conductivity, and pH are monitored first, as well as any other analyte that is field measured.

The sampling may occur directly from the purging pump, when permissible, or an alternate device (i.e., pump or bailer) is installed to collect the samples. If a bailer or alternate pump is utilized, the first few bails or first pump discharge volumes should be discarded to allow the new equipment a period of "acclimation" to the groundwater.

Samples are typically collected directly from the pump or bailer with the groundwater being discharged directly into the appropriate sample container. Care must be taken to avoid handling the interior of the bottle or bottle cap. New gloves (i.e., disposable surgical gloves) must be worn for each well sampled. The bottle cap must not be placed on the ground or in a pocket to avoid contamination.

For LFP sampling, the flow-through-cell should be disconnected or bypassed prior to obtaining the sample. The discharge line is positioned at the base of the sample bottle. The sample bottle is filled from the bottom to the top and is allowed to overflow before sealing (overflow is not recommended if the sample bottles have been prepared with preservatives).

Section vii) - Purging/Sampling Equipment describes the various pumps/devices available for groundwater sampling.

The following describes the key activities involved in groundwater sample collection:

a) Order of Sample Collection

Samples should generally be collected and containerized in the order of the following volatilization sensitivity:

- volatile organic compounds (VOCs),
- semi-volatile organic compounds (SVOCs),
- total organic carbon,
- total organic halogens,
- extractable organics,
- total metals,
- dissolved metals,
- phenols,
- cyanide,
- sulfate and chloride,
- nitrate and ammonia, and
- radionuclides.

Section 3.9 describes the typical QA/QC requirements for groundwater sampling activities.

b) Sample Acquisition and Transfer

If using a pump, the pumping rate for VOC sample collection should not exceed 100 mL/min to avoid agitation of the sample and to reduce the loss of volatiles. In addition, transfer of the sample to its container or filtration device should be conducted in such a way as to minimize agitation and aeration of the sample. Samples should be transferred directly to the final container for laboratory submittal and not collected in a larger container with subsequent transfer to smaller containers. (Exceptions on occasion are required for filtration and/or sample compositing.) When sampling for VOCs, it is important that sample collection, handling, and containerization do not take place near a running motor or any type of exhaust system because discharging fumes may contaminant the samples.

Samples to be analyzed for VOCs should be contained in 40 mL glass vials filled to the top until a meniscus is formed and topped with a Teflon-lined cap. It is imperative that no air bubbles or headspace remain in containers containing water for volatile compounds analysis in order to prevent the loss of volatiles from the sample. Air bubbles can be checked for by inverting the vial and tapping. If any bubbles are present, the sample should be discarded and retaken. The container should not be "topped-off" to fill the additional head space.

Note: Gas bubbles may appear in the VOC container after collection due to degassing. If this occurs, note this occurrence on the chain of custody (COC); resampling is not required in most cases.

c) Sample Labels/Sample Identification

All samples must be labeled with:

- a unique sample number (never to be re-used, nor likely to be);
- date and time;
- parameters to be analyzed;
- job number; and
- sampler's initials.

Labels should be secured to the bottle and should be written in indelible inks. It is also desirable to place wide clear tape over the label before packing in a cooler for label protection during transport. Labels may be prepared in advance at a CRA office if the office has a label-generating program.

Section 3.9 describes sample labeling requirements in detail for environmental sample management programs.

vii) Purging/Sampling Equipment

CRA owns and maintains a variety of purging/sampling devices for groundwater removal and sample collection. The groundwater samplers must familiarize themselves with each type of pump/device available, and understand the pump/device limitations and use. Some devices are very useful for purging (i.e., high flow rates) but not permissible for LFP or for sampling sensitive parameters (i.e., volatiles cannot be collected with a turbine or suction type pump). Once the groundwater sampler understands the various equipment operation and limitations, the proper purging and sampling device can be selected to minimize sample duration and maximize productivity.

Caution: Gas powered equipment at sampling sites require special care to ensure that CRA staff hauling these units do not contaminate down-hole equipment. Frequent disposable glove changes are required; as well as, strict separation of sampling crew tasks (i.e., those handling pumps and hoses do not conduct generator/fueling activities).

The following subsections describe the equipment available, their appropriate use, approximate flow rates. and advantages/disadvantages.

a) Peristaltic Pumps

A peristaltic pump is acceptable for purging wells and for most analyte sample collection with the exception of VOCs/SVOCs. Like most suction pumps, the peristaltic pump is only capable of lifting water up to 25 feet below the pump. A peristaltic pump is a self-priming, low volume, suction pump which consists of a rotor with ball-bearing rollers. Flexible tubing (silicone) is inserted around the pump rotor and squeezed by the heads as they revolve in a circular pattern (The section of silicone tubing cannot exceed 36 inches in length). Additional rigid polyethylene or Teflon™ tubing (as required) is attached to the flexible tubing and placed into the well while the other end of the flexible tubing is used for sample collection. The flexible tubing and rigid tubing should be dedicated to that well location for future use. The tubing is typically tied and suspended within the well. The flexible or rigid tubing is not re-used at other well sites due to the cross-contamination that would occur if re-use was permitted.

> *Helpful Hint: Often a length of tubing is accidentally dropped into a well and can be very difficult to retrieve. Retrieval is easily accomplished by sending another piece of tubing down the well over lapping the lost section of tubing. Once inserted, rotate the tubing in hand, essentially wrapping, i.e., "cork-screwing" the lost tubing and new tubing together. After a number of "screw" turns are completed remove the tubing, hopefully with the lost section wound around the new piece. Repeat, if unsuccessful.*

The peristaltic pump moves the liquid within the sample tube by creating a vacuum as the rotor head turns. No part of the pump comes in contact with the liquid. A peristaltic pump provides a low sampling rate (i.e., typically less than 1 gallon per minute) with less agitation than other suction pumps as long as the tubing is secured to the well casing and not allowed to jiggle (Section b). The flow rate may be regulated by adjusting the rotor head speed.

Peristaltic pumps are easily transported, require minimal setup, do not require decontamination, and require minimal maintenance. Disadvantages with peristaltic pumps are the limited lift and flow capabilities and the sample limitations on the collection of VOCs/SVOCs.

If VOC/SVOC sampling is required but the groundwater sampler wishes to use the peristaltic pump for purging and other analyte sample collection, it is common practice to collect the initial VOC/SVOC analytes with a bottom loading bailer then utilizing the peristaltic pump for the remaining sample analytes.

Peristaltic pumps are not recommended for LFP because they may cause degassing, pH modification, and loss of VOCs.

b) <u>Suction Pumps</u>

A number of suction-type pumps (i.e., centrifugal) exist which are typically used for purging applications only. A suction-type pump draws water through the pump suction line by creating a vacuum within the suction tubing or hose. The groundwater comes in direct contact with the pump rotor/chamber area and as such, is undesirable for groundwater sampling as the water is highly agitated (i.e., aerated) and decon of this type of pump is difficult. Similar to the peristaltic pump, this type of pump is limited to a lift of 25 feet. Larger suction pumps, such as a 2-inch "trash pump" can achieve very high flow rates under low head conditions. Flow rates of 15 to 20 gallons per minute can be achieved, minimizing purging time. A new clean suction line is needed for each well.

Suction pumps are also useful for high rate well development, in conjunction with agitation/surging devices.

Suction pumps are not recommended for LFP because they may cause degassing, pH modification, and loss of VOCs.

Warning! 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 (i.e., moyno/progressive cavity pumps) can be used for purging/development but again must be deconned prior to leaving the site or commencing work at other well locations.

In summary, suction pumps are useful for high rate purging, require no equipment (other than a suction line) down the well, and are easily transported from site to site. Their use is limited to a lift of 25 feet, decontamination is difficult, and only limited sample analyses can be collected from a suction-type pump. Suction pumps are not suitable for LFP.

c) Submersible Pumps

Submersible pumps provide high discharge rates for water withdrawal at depths beyond the capability of suction pumps. Submersible pumps can pump water from substantial depths with pumping rates varying up to hundreds of gallons per minute or more depending on depth, size, and type of pump. A submersible pump can provide higher extraction rates than any other method. At high pumping rates, sample agitation and aeration does occur, eliminating the use of some submersible pumps for the collection of VOCs/SVOCs.

Adjustable rate submersible pumps, constructed of stainless steel or Teflon, are suitable for LFP applications (e.g., bladder pumps) provided that low flow rates are maintained.

Submersible pumps require decontamination before use elsewhere, including the electrical cable and lowering cable used to install the pump.

When installing a submersible pump in bedrock locations or within deeper well installations, it is advantageous to use rigid piping (i.e., 3/4-inch steel) as the pipe permits exact pump depth placement, allows pushing and pulling of the pump should a narrow or "tight" spot exist within the well, provides a solid/secure grip for holding the pump in place during installation and retrieval, and lastly, is used for affixing the electrical cable onto and lowering cable/safety line. If rigid piping is used, a safety line or cable affixed to the pump head should still be used in the event the piping unthreads or connection to the pump is lost.

In summary, submersible pumps can provide high flow rates and are useful in deep purging locations. Submersible pump use is labor intensive, poses decontamination problems, and has sample analyte limitations. Some submersible pumps (e.g., adjustable rate bladder pump) are suitable for LFP applications.

d) <u>Air Lift Pumps</u>

Air lift pumps utilize compressed air in direct contact with the groundwater to force the groundwater from the pump cylinder through a series of check balls into the discharge line. The pump operation is cyclic, having alternating pump filling and pump discharging cycles which are regulated by a control device at the ground surface. Air lifting is possible from deeper depths with moderate to low return flow rate achievable (2 to 3 gallons per minute) depending on depth of installation, static head, tubing size and the air pressure available.

As the air has direct contact with the groundwater, VOC/SVOC sampling is not permissible.

Generally air lift pumps are used for deep purging applications only. Sampling is typically accomplished with an alternate device (i.e., bailer or bladder pump).

e) <u>Bladder Pumps</u>

Bladder pumps are air driven but the air/groundwater contact is eliminated by the presence of a Teflon or natural rubber bladder. The pump operation is cyclic, controlled at the ground surface by a control device which alternates the pump filling and discharge cycles. VOCs/SVOCs can be collected from bladder-type pumps as can most other groundwater analytes.

The bladder pump operation is typically very "quiescent" imparting little formation/well disturbance. Consequently sediment-free groundwater is easily achieved using a bladder-type pump. Adjustable rate bladder pumps are ideal for LFP applications. The flow rates achievable from a bladder pump at best will approach 1.5 gallons per minute but are reduced for deeper sampling locations.

Both well purging and sampling can be performed with a bladder-type pump. Once sampling is complete, the pump must be disassembled and cleaned before sampling elsewhere occurs. The sample tubing including air line is typically suspended in the well for future use (well dedicated) or discarded.

In summary, bladder-type pumps provide excellent sample quality, can collect all groundwater analytes, and are useful for deeper sampling needs. Disadvantages include labor intensive setup, difficult decontamination, and low flow rates. Bladder pumps are strongly recommended for LFP applications.

f) <u>Inertia Pump</u>

The inertia pump or "Waterra™" pump is a manually operated or mechanically driven system which utilizes only a foot valve on the sample/purge tubing to lift the groundwater out of the well. The rapid raising and lowering action of the tubing imparts an inertia to the water column within the tubing, which causes the water column to rise to the ground surface and discharge out of the end of the tube. The foot valve holds the water column within the tubing on the up stroke and allows groundwater entry on the down stroke.

CRA owns both manual and mechanical gas-powered systems. Flow rates are variable depending on cycle speed, tubing size, and depth to groundwater. This type of pump is useful for purging and may be used for sample collection of most analytes. Acceptability of VOC and SVOC sampling is gaining approval in select areas when using an inertia type system. Prior to using the inertia pump as a sampling device check with the Project Coordinator for approval.

The inertia pump is very useful for extracting dense NAPLs, because none of the equipment except the foot valve is exposed to this type of gross contamination. Tubing is typically dedicated to the well, or discarded after each use.

Inertia pumps excessively disturb the water column in the well making it almost impossible to collect sediment-free samples. These pumps are not suitable for LFP.

g) <u>Bailers</u>

Bailers are manual sampling devices typically consisting of a hollow tube (i.e., Teflon, PVC, or stainless steel) with a lower check ball to permit water entry and prevent water loss. The bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon retrieval. A rope or cable is affixed to the bailer to permit lowering and retrieval of the bailer within the monitoring well. Bailing is generally very disruptive to the formation and well screen. Consequently, sediment-free samples are difficult, if not impossible, to achieve when using a bailer device. VOC/SVOC sampling, as well as all other groundwater analytes, can be collected using a bailer. Compatibility of the bailer material and the groundwater analytes must be reviewed and approved prior to bailer use. Teflon bailers are generally acceptable for all analyte needs.

Power winches to raise and lower the bailer in conjunction with an overhead tripod are available.

The flow rate attainable from a bailer is a function of the bailer size and frequency of retrieval.

Bailers can be useful for well development as their rapid placement and removal "surges" the well screen promoting sediment suspension for subsequent removal.

Bailers may provide representative samples once the well has been adequately developed and purged; however, bailers are not recommended for LFP sampling. Rope used for suspending the bailers must be kept off the ground and free of other contaminating material that could be carried into the well. Once used, the rope is either well dedicated or discarded.

Bailers are not practical for deep wells, for removal of large volumes of water, or for LFP.

viii) Field Notes

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

The field notes will be recorded in a standard bound 'survey' type field book issued for general note taking/field records and available from all CRA equipment administrators. All field book entries must be made in black ink and any changes/corrections shall be stroked out with a single line and initialed and dated to indicate who and when the correction was made. Section 3.4.1 describes the field log book requirements in detail.

The logbook should document the following for each well sampled:

- identification of well,
- well depth,
- static water level depth and measurement technique,
- sounded well depth,
- presence of immiscible layers and detection/collection method,
- well yield - high or low,
- purge volume and pumping rate,
- time well purged,
- measured field parameters,
- purge/sampling device used,
- well sampling sequence,
- sample appearance,
- sample odors (if respiratory protection is not required),
- sample volume,
- types of sample containers and sample identification numbers,
- preservative(s) used,
- parameters requested for analysis,
- field analysis data and method(s),
- sample distribution and transporter,
- laboratory shipped to,
- chain-of-custody number for shipment to laboratory,
- field observations on sampling event,
- name of collector(s),
- climatic conditions including air temperature, and
- problems encountered and any deviations made from the established sampling protocol.

Temperature, specific conductance, pH, and turbidity shall be measured each time a well is sampled. Stabilization of these parameters is measured during the purging process to insure that samples representative of the groundwater formation are being collected. The measurements for these parameters prior to sampling are recorded in the field records for the well. If these parameters were not performed during purging they shall be obtained prior to sampling.

ix) Groundwater/Decon Fluid Disposal

Prior to implementation of a groundwater sampling program, the method of groundwater and decon fluid disposal must be determined by the Project Manager/ sampling personnel.

Groundwater disposal methods will vary on a case-by-case basis, but may range from:

- off-site treatment at private treatment/disposal facilities or public owned treatment facilities (sanitary sewer);
- on-site treatment at Client operated facilities;
- direct discharge to the surrounding ground surface, allowing groundwater infiltration to the underlying subsurface regime; or
- direct discharge to impervious pavement surfaces, allowing evaporation to occur.

The last two options above should only be implemented after a careful review of these practices and the conditions anticipated. Under no circumstances should CRA personnel aggravate an existing condition or spread contamination into "clean" areas.

Decon fluids (specifically cleaning solvents/acids) should be segregated and collected separately from wash waters/groundwater containers. Often the small volumes of solvents used during the day can be allowed to evaporate if left in an open pail. In the event evaporation is not possible or practical, off-site disposal arrangements must be made.

4.5.4 FOLLOWUP ACTIVITIES

The following shall be performed once field activities are complete.

i) Double check Work Plan to ensure all samples have been collected and confirm this with Project Coordinator.
ii) Equipment shall be cleaned and returned to the equipment administrator and the appropriate form dated and signed.
iii) Complete purge water disposal, and cleaning fluid disposal requirements per the Work Plan.
iv) Notify the contract laboratory as to when to expect the samples. The chain-of-custody and covering letter, indicating the parameters and number of samples, shall be enclosed in the sample cooler.
v) Complete the appropriate forms and data sheets. A copy shall be sent to file, along with any field notes. Forms SP-10 (Field Information Form) and SP-11A (Sample Collection Data Sheet)/SP-11B (Monitoring Well Record for Low-Flow Purging) are available for reporting purposes, if required.
vi) Return site/well keys.
vii) Prepare and distribute the Program completion checklist described in Section 4.5.5.

4.5.5 COMPLETION CHECKLIST

At the completion of the groundwater sampling program, the Groundwater Sampling Checklist (Form SP-08) must be completed to document activities conducted and serves to remind personnel of the various tasks required. This form must be signed and filed at the respective field office, regional CRA office, and issued to the Project Coordinator.

4.5.6 CONTACT INFORMATION

The following CRA personnel may be contacted regarding groundwater sampling procedures or for additional information:

Contact	*Office*	*Phone Number*	*Fax Number*
Brian Carter	Baton Rouge	(225) 292-9007	(225) 292-3614
Linda McConnell	Baton Rouge	(225) 292-9007	(225) 292-3614
Jerry Eplin	Charlotte	(704) 676-0502	(704) 676-0704
Walt Pochron	Chicago	(773) 380-9933	(773) 380-6421
Scott Green	Detroit	(734) 942-0909	(734) 942-1858
Peter Storlie	Minneapolis	(651) 639-0913	(651) 639-0923
Brian Webster	Nashville	(615) 315-9927	(615) 315-9934
Doug Oscar	Niagara Falls	(716) 297-6150	(716) 297-2265
Jeff Ratliff	Titusville	(407) 269-9891	(407) 269-9872
Mike Mateyk	Waterloo	(519) 725-3313	(519) 725-1394

4.5.7 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

4.9 SINGLE-WELL RESPONSE TESTS

4.9.1 GENERAL

The purpose of the single-well response test is to obtain an estimate of a formation's hydraulic properties (i.e., hydraulic conductivity and transmissivity). The data available from a single-well response test is insufficient to obtain the well property of specific capacity and the formation property of storage coefficient. Longer-term pumping tests, described in Section 4.7, are required to estimate these two properties.

Permeability (k) is a function only of the formation properties and has the dimensions L^2 (e.g., cm^2).

Hydraulic Conductivity (K) is a function of both the formation and the fluid properties described by:

$$K = \frac{k\rho g}{\mu}$$

where:

ρ	=	*fluid density (M/L^3)*
g	=	*gravitational constant (L/t^2)*
μ	=	*fluid dynamic viscosity (M/Lt).*

Note: by convention M/Lt = 1 Pa•sec = 1,000 centipoise.
K has the dimensions L/t (e.g., cm/sec). Typically, $\rho = 1\ gm/cm^3$ and μ = 1 centipoise for water. Thus the terms permeability and hydraulic conductivity are often interchanged when referenced to water.

Transmissivity (T) - The rate at which water is transmitted through a unit width of formation under a unit hydraulic gradient. Typically expressed as: gallons per minute, through a vertical section of aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 1; or cubic meters per day through a vertical section of 1 meter width, extending the full saturated height of the aquifer under a hydraulic gradient of 1.

There are two types of single-well response tests; the slug test and the recovery test.

The slug test involves causing a sudden change in water level in a well and measuring the water level response within that well. Water level change may be induced by suddenly injecting or removing a known quantity or "slug" of water into or out of the well, emplacement or removal of a solid slug (i.e., stainless steel, PVC) into the water column, or a release of pressure in a tightly capped well.

The slug test is advantageous over a pumping test in that it does not require the disposal of large quantities of water that may be produced. This is of special importance when testing a potentially contaminated formation. However, a disadvantage of the slug test is that typically the slug is of small volume and only provides an estimate of the formation hydraulic properties immediately adjacent to the well. In addition, if the static water level is located within the screened interval and surrounding sandpack, the data may be useless, depending on the size of the slug, since the "data" will represent either the saturation or dewatering of the sandpack (which should be more permeable than the formation) and not of the formation.

An alternate single-well response test, which provides estimates of the hydraulic properties of a larger portion of the formation surrounding the monitored interval and which is not as sensitive to impacts from a partially saturated sandpack, is recovery monitoring after the completion of either well development or after sampling. After sample collection, if the well has recovered to a significant extent, it may be necessary to pump some additional water from the well prior to performing the recovery monitoring.

It is common practice to pre-plan the schedule of single-well response tests such that the tests progress from "clean" to "dirty" areas in an effort to eliminate the potential for cross-contamination. Review previous analytical data (if available) to determine best testing sequence.

Historically, single-well response test water levels have been measured using the manual methods (i.e., electronic water level indicator). Manual methods have generally been replaced with the use of pressure transducers and electronic data recorders which provide the following two advantages:

- the water levels can be recorded at selected short time intervals (e.g., 0.5 sec) to allow evaluation of quickly recovering wells which previously could not be evaluated since the well recovered too quickly to obtain the necessary data by the manual method; and
- the data from the data recorders can be transferred directly to computer programs which calculate the formation properties, without the time consuming manual transposition and evaluation of data.

The use of pressure transducers and recorders is the method preferred by CRA.

In order to provide reliable data, the tests must be performed over as short a period of time as possible. Barometric pressure can affect groundwater levels and therefore, observation of significant weather changes during the period of the tests must be noted. Tidal fluctuations, navigation controls on rivers, rainfall events, and groundwater pumping can also affect groundwater level measurements. Personnel performing the tests must note if any of these controls are in effect during the testing period. Due to possible changes during the testing period, it is imperative that the time of data collection at each location be accurately recorded.

4.9.2 PRIOR PLANNING AND PREPARATION

The following shall be considered prior to conducting a single-well response test.

i) Review the Work Plan and HASP with the Project Coordinator.

ii) Complete an equipment requisition form. Assemble all equipment and supplies per the Slug and Aquifer Test Equipment and Supply Checklist (Form SP-23). If a recovery test is to be performed after well development or sampling, it is expected that the equipment and supplies obtained pursuant to the Groundwater Sampling Equipment and Supply Checklist (Form SP-07) will be sufficient with the addition of pressure transducers, electronic data recorders, and portable computers. Ensure that the psi range of the pressure transducer is sufficient.

iii) Obtain information on each monitoring well to be tested. Information shall consist of inside diameter of the well screen and well casing, borehole diameter, depth of well, static water level, and the length and depth setting of the screen. For slug tests, this information will be used to calculate the volume of the "slug" required. The volume of the slug should be sufficient to affect a minimum change of 6 inches in the well's water level. If the static water level is within the screened portion of the well, the volume calculation must account for the porosity of the sandpack (a value of 0.3 is generally assumed). For well recovery tests, the volume of water removed during development/purging/sampling must be recorded on the Well Development and Stabilization Form (Form SP-09) or Well Purging Field Information Form (Form SP-10).

iv) Arrange access to the site. Assemble well keys and site keys. Also consider site conditions (e.g., is snow removal required?).

v) Establish groundwater and spent decontamination fluid handling and disposal methods before testing activities start.

vi) Pre-plan the testing sequence to insure "clean" wells are tested before "dirty" wells to reduce the potential for cross-contamination.

vii) Determine testing notification requirements with the Project Coordinator. Have the Client, landowner, and appropriate regulatory agencies been notified?

4.9.3 FIELD PROCEDURE

The following outlines the steps required to be performed for a single-well response test:

1. Recovery Test

   a) After Well Development

      i) Prepare the area around the well, performing well identification/inspection, air monitoring, and static water level measurements as outlined in Section 4.4 prior to development.

      ii) Prior to development, calibrate the pressure transducer/datalogger to static conditions by inserting the pressure transducer to within 6± inches of the bottom of the well, record its depth, mark a reference point on the cable using masking tape, connect the electronic data recorder, and check the operation of the system (i.e., water levels are being recorded correctly).

      iii) Remove the transducer and develop the well as described in Section 4.3.4.2. Since the purpose of well development is to remove any sediment within the well casing and to develop the sandpack by the removal of fine grained material from the sandpack, aggressive procedures (i.e., surging with bailers or solid slugs) throughout the depth of the water column are used. These procedures could damage the pressure transducer and electrical cable. Thus, it is not recommended that the pressure transducer be in the well during well development to prevent potential damage to the transducer.

      iv) Once development is complete, quickly insert the pressure transducer to the previously established reference point, connect the data recorder, and commence to record water levels immediately after completing well development. Typically the data recorder is set to record water levels at 1-second intervals. However, for coarse materials (e.g., gravel, coarse sand) and bedrock with frequent and/or large fractures, a shorter time interval may be required (e.g., 0.1 or 0.5 seconds). The water levels should also be checked manually to ensure that the well has recovered to 90± percent of the induced change prior to stopping water level recording. If water level measurements are made using either electrical water level indicators or a measuring tape with a plopper, follow the procedures for water level monitoring presented in Section 4.4.3.

v) Prior to removing the pressure transducer from the well, the data should be field checked by transferring the data from the data recorder to a disk and reviewing the data on the PC. The disk is a backup to ensure the data are not lost. Review of the data may indicate that sufficient data (i.e., 6 or more data points before 90± percent recovery) were not obtained (e.g., the well recovered completely or to a large extent while installing the pressure transducer).

vi) For those instances where the data recorded are insufficient, the recovery test must be redone, typically using a shorter time interval for water level recording. The transducer should be reinserted to the same reference point and a volume of water (50± percent of well volume) rapidly removed using a method which will not damage the pressure transducer or electrical cable (e.g., high rate submersible pump).

vii) Should the well recover to static within 20 minutes, consideration should be given to performing two tests to provide confirmatory data.

viii) At the completion of the test, the non-dedicated equipment shall be properly decontaminated per the Work Plan or see Section 4.10.

b) After Well Purging/Sampling

i) Prepare the area around the well, performing well identification/ inspection, air monitoring, and static water level monitoring as per Section 4.4 prior to well purging.

ii) Well purging/sampling methods are non-aggressive methods designed to remove the existing water column and sediment within the well without inducing additional sediment migration into the well from the surrounding sandpack and formation. Thus, it is recommended that the pressure transducer be inserted into the well prior to the start of well purging unless the equipment used for well purging/sampling (e.g., bailer, inertia pump) has a high potential to damage the transducer or electrical cable.

iii) Perform the appropriate steps outlined in 1.a) (After Well Development) above. Note that additional water removal may be required if the well has recovered to a significant degree during sample collection.

2. Slug Test

The following steps need to be performed for a slug test, assuming that the well has been previously developed:

i) Prepare the area around the well, performing well identification/inspection, air monitoring, and static water level monitoring pursuant to Section 4.4.

ii) Insert the pressure transducer at a sufficient depth below the water table so that upon insertion of a slug into the water column, the slug will not strike the pressure transducer. Check the operation of the transducer and data recorder.

iii) Set the slug just above the static level.

iv) Release the slug instantaneously. It is important that the slug is completely submerged in the water column.

This is called a "falling-head" test.

v) Upon 90 percent recovery of the induced change, remove the slug rapidly and completely from the water column being careful not to inadvertently raise the pressure transducer.

This is called a "rising-head" test.

vi) Confirm the well has again recovered to 90 percent of the induced change and complete the test by performing steps v) through viii) outlined in 1.a) (After Well Development) above.

Water levels along with the well data and time shall be recorded on the Single-Well Response Test - Data form (Form SP-24) and in the site field book. Figure 4.15 provides definitions for the parameters listed on Form SP-24.

Under some conditions (i.e., very permeable formations) the slug test can best be conducted by simulating the withdrawal/injection of a slug of water by the release of pressure in a tightly capped well. The following steps need to be performed:

i) Prepare the area around the well, performing well identification/inspection, air monitoring, and static water level monitoring pursuant to Section 4.4.

ii) Insert the pressure transducer at a sufficient depth below the water table. Check the operation of the transducer and data recorder.

iii) Install sealed well cap with a pressure cap.

iv) Increase the pressure in the well to lower the water level (usually a bicycle pump is a sufficient source of compressed air).

v) Release the pressure by opening a valve on the well cap and allow well to recover.

vi) Repeat the test three or four times.

4.9.4 FOLLOWUP ACTIVITIES

The following activities shall be completed after the field program:

i) The equipment shall be cleaned and returned to the equipment administrator and the appropriate form dated and signed. Note any equipment which requires maintenance or service.

ii) Make sure that completed copies of the field notes and Form SP-24, and the disk with the documented transducer are sent to the Project Coordinator and to file. The field book shall be stored at the CRA office.

iii) If groundwater has been removed, handle appropriately, including the collection of any samples to determine treatment/disposal options.

iv) Return keys to the key box.

4.9.5 CONTACT INFORMATION

The following CRA personnel may be contacted regarding single-well response tests for additional information:

Contact	*Office*	*Phone Number*	*Fax Number*
Brian Carter	Baton Rouge	(225) 292-9007	(225) 292-3614
Walt Pochron	Chicago	(773) 299-9933	(773) 299-6421
Scott Green	Detroit	(734) 942-0909	(734) 942-1858
Peter Storlie	Minneapolis	(651) 639-0913	(651) 639-0923
Doug Oscar	Niagara Falls	(716) 297-6150	(716) 297-2265
Jeff Ratliff	Titusville	(407) 269-9891	(407) 269-9872
Mike Mateyk	Waterloo	(519) 725-3313	(519) 725-1394

4.9.6 REFERENCES

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

ASTM D4043 Standard Guide for Selection of Aquifer-Test Method in Determining of Hydraulic Properties by Well Techniques

4.10 DECONTAMINATION OF FIELD EQUIPMENT

4.10.1 GENERAL

The following guideline presents decontamination procedures for field equipment used in the sampling of soils, soil gas, sludges, sediment, surface water, and groundwater which are to undergo either physical or chemical analyses.

Equipment decontamination is critical for all environmental investigations. Without effective decontamination procedures, any chemical data generated are subject to disqualification. Therefore, effective decontamination procedures must be incorporated into every aspect of the field investigations, from preliminary soil sampling to groundwater sampling. Wherever possible, an attempt should be made to use dedicated equipment at individual sampling locations rather than to reuse equipment that will require decontamination prior to use at the next sampling location.

Note: *Dedicated equipment at individual sample locations will minimize the potential for cross-contamination and eliminate most decontamination activities. The determination to provide a site with dedicated equipment is made after careful review of future monitoring requirements and evaluation of equipment purchase costs vs. reusable equipment decontamination costs.*

The purposes of decontamination are as follows:

- to prevent cross-contamination of individual sites and specific sampling locations;
- to ensure that representative samples are collected for analysis;
- to ensure proper operation of equipment and instrumentation; and
- to reduce exposure hazards to workers involved in handling potentially contaminated materials.

The primary focus of this section will be field equipment decontamination procedures used in groundwater and soil sampling investigations.

4.10.2 PRIOR PLANNING AND PREPARATION

Prior to undergoing a field program that involves equipment decontamination, a site-specific equipment decontamination protocol shall be prepared for distribution to the individuals involved with the particular sampling program. In most cases, the decontamination procedures will be specified in the site-specific Work Plan.

The following shall be considered prior to implementation of the decontamination procedures:

i) Assembly of and inventory of necessary equipment and supplies.
ii) Review Work Plan and HASP.
iii) Acquisition, storage and transportation of solvents (solvents should be procured preferably by the Client or contractor on an as-needed basis). Most solvents require special shipping procedures to comply with DOT CFR 49.
iv) Determination of where equipment decontamination activities will be performed.
v) Disposition of cleaning fluids upon completion of work.

Advance Preparation: Depending on the program duration, complexity, and the types of equipment decontamination required, it is necessary for the CRA sampler to determine the cleaning area requirements. In some instances, it may be necessary to prepare a decontamination area for washwater fluid capture. Most sampling programs can be conducted using plastic/polyethylene sheets lying on the ground to provide spill control (see Figure 3.2 *- Typical Decontamination Area). More elaborate areas for longer-term activities are shown on* Figures 3.3, 3.4, 3.5, *and* 3.6 *and require pre-planning and construction in advance of field activities.*

4.10.3 FIELD PROCEDURE

The decontamination procedures for field equipment can be subdivided into two categories of cleaning:

i) Those pieces of equipment that will come in direct contact with samples that are to be submitted for chemical analysis (i.e., pumps, stainless steel trowels, etc.).
ii) Those pieces of equipment that perform field measurements (i.e., pH meters, temperature probes) or are used to collect samples that are not to be submitted for chemical analyses (i.e., split spoons that are use to collect geologic record samples).

The first category of equipment requires extensive, documented and defensible procedures. The second category is less intensive. Both categories of decontamination procedures are described in the following:

i) Equipment Which Contacts Samples to be Chemically Analyzed

The following cleaning procedures are applicable for some programs requiring decontamination to prepare equipment for sampling where a chemical analysis is to be performed.

- if a Work Plan has been developed for the site, it is imperative that the decontamination procedure outlined in the Work Plan be used. If no Work Plan is available, verify with the CRA Chemist that the following decontamination procedures are appropriate;
- wash with clean potable water and laboratory detergent (Alconox or Liquinox or similar solution) using a brush if necessary to remove any particles or surface films. For equipment that cannot be adequately cleaned with a brush such as internal mechanisms or piping, the decontamination solutions shall be circulated through the equipment;
- rinse thoroughly with potable water;
- rinse thoroughly with deionized water;
- if analyses for metal compounds is required it may be appropriate to rinse thoroughly with 10 percent nitric acid (HNO_3) ultrapure solution (or 1 percent HNO_3 ultrapure solution for carbon steel equipment). Use appropriate precautions when handling nitric acid;
- rinse twice with solvent (i.e., isopropanol, acetone, hexane, or methanol - ACS reagent grade; more pure grades are available at significant cost increase). Note that isopropanol is not cold weather friendly;
- rinse thoroughly with deionized water and allow to air dry; and
- wrap equipment with aluminum foil (shiny side out), if applicable, to prevent contamination if equipment is going to be stored or transported.

It is important to document the effectiveness of the decontamination procedure. The project's QA/QC program typically includes provisions for the collection of samples to evaluate the adequacy of a specific decontamination procedure. QA/QC samples could include:

- collection of a rinse or wipe sample prior to equipment decontamination to establish a base line of contaminants residing on or in the equipment; and
- collection of final rinse or wipe samples after equipment decontamination following its use.

Section 3.9 describes the typical QA/QC samples collected for evaluating decontamination procedures.

The frequency of sampling to demonstrate the completeness of equipment decontamination is dependent upon the objectives of the project (as a minimum, if not specified in the project plans, it is recommended to be done after every ten decontamination washings).

ii) Equipment Which Does Not Contact Samples Requiring Chemical Analysis

This category of cleaning includes sampling equipment used for collecting samples for physical analysis (i.e., inspection, grain-size distribution, etc.) and also those pieces of equipment that actually perform in field testing where no subsequent analyses of that portion of the samples is to be analyzed any further (i.e., pH meter, temperature probes, etc.). It is to be noted that water level measuring devices for groundwater programs are not included in this category as they potentially contact water that could be analyzed at a later date. Therefore water level measuring devices must be decontaminated in accordance with the first category of equipment.

For all field testing equipment, it is imperative that the cleaning procedures be completed in compliance with the manufacturer's specifications. Other cleaning methods may impact the instruments operating functions.

For all other sampling equipment that does not contact a sample requiring chemical analysis, a simple cleaning with potable water is typically sufficient between uses. Before leaving the site, the sampling equipment shall be decontaminated in a manner consistent with that described in the first category to ensure that site contaminants are not transferred to another site.

Note: Decontamination procedures must occur in the field, not at a CRA office. CRA is not a waste generator and does not wish to become one.

Spent Decontamination Fluids

All used cleaning fluids are to be placed into appropriate secure containers (i.e., drums), labeled as to contents and left at the site for the owner/Client to properly dispose of. To the extent practicable, different cleaning fluids should be kept segregated to minimize the costs for treatment or disposal.

Site/Sample Location-Specific Dedicated Equipment

Whenever dedicated sampling equipment is available at a site, it is to be used to the maximum extent practicable. Prior to use of dedicated equipment, it is necessary to at least inspect the equipment to insure that it is still clean and operable (often times insects nest inside monitoring wells and can clog tubing, etc.).

Prior to any sampling, the site-dedicated equipment should be purged several times to acclimate the equipment to fresh conditions. The purge volume shall be in accordance with the project-specific sampling protocols.

It is recommended that whenever possible, sample tubing for use in monitoring well programs be left inside the well for reuse at later dates. Sample tubing shall not be decontaminated. If the tubing becomes soiled or damaged, it should be discarded and replaced with new tubing.

4.10.4 FOLLOWUP ACTIVITIES

The activities completed for each equipment decontamination shall be documented in writing in the field book. Included in the field book shall be the following information:

- site location, date, time, and weather;
- sample location where equipment was employed;
- location where decontamination was performed;
- personnel performing decontamination;
- decontamination procedures;
- sources of materials (solutions) used for decontamination;
- volume of decontamination fluids generated;
- location where decontamination fluids have been stored; and
- QA/QC sampling performed.

The field book shall be stored in the CRA office.

At the conclusion of the site program, it is imperative that the Client receive written notification documenting that decontamination fluids have been left at the site and they are to be properly managed by the Client. CRA is available to assist the Client with this waste management.

4.10.5 REFERENCES

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

ASTM D5088 Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites

4.13 SURFICIAL SOIL SAMPLING

4.13.1 GENERAL

The following guideline focuses on ways to obtain surficial soil samples for chemical analyses. 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 that the sampling team is preparing to mobilize to the field. However, in order to successfully complete a soil sampling program, the sampling team members must have a basic understanding of the various considerations for the design of the soil sampling program. Section 4.13.2 is intended to provide information required for developing this basic understanding.

Soil sampling procedures may 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 requirements. The primary goal of surface soil sampling is to collect representative samples for examination and chemical analysis (if required).

Preparation activities, sampling procedures, and followup activities are discussed in further detail in Sections 4.13.3, 4.13.4, and 4.13.5, respectively.

4.13.2 SOIL SAMPLING CONSIDERATIONS

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

General

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

Random, Biased, and Grid-Based Sampling

Unless there is a strong indication of contaminant presence, such as staining, then soil sample locations may be randomly selected from several areas within the site.

If any areas show evidence of contamination, such as staining or vegetative stress, biased samples shall be collected from each area to characterize the contamination present in each area. Background and control samples are also biased, since they are collected in locations typical of non-site-impacted conditions.

When soil sampling investigations involve large areas, a grid-based soil sampling program is used. There is no single grid size that is appropriate for all sites. Common grid sizes are developed on 50-foot and 100-foot centers. It is acceptable to integrate several different grid sizes in a single investigation.

For surficial soil sampling programs, 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 was a concern).

Grab Versus Composite Samples

A grab sample is collected to identify and quantify compounds at a specific location or interval. The sample shall be 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 subsamples and are collected to characterize the average composition in a given surface area.

Sample Interval

Surficial soils are generally considered to be soil between ground surface and 6 to 12 inches below ground surface. However, for risk assessment purposes, regulatory authorities often consider soil from ground surface to 2 feet below ground surface to be surficial soil. 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 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.

4.13.3 PRIOR PLANNING AND PREPARATION

The following activities must be completed prior to undertaking a surficial soil sampling program:

i) Review the work program, project documents and the health and safety requirements with the Project Coordinator.

ii) Complete an equipment requisition form and assemble all equipment, materials, log books and forms required. Form SP-16 - BOREHOLE INSTALLATION/SOIL SAMPLING EQUIPMENT AND SUPPLY CHECKLIST provides a summary of the typical equipment/materials required for a soil sampling activity.

iii) Obtain a site plan and any previous stratigraphic logs. Determine the exact number and location of samples to be collected and the depths of samples for chemical analysis.

iv) Contact CRA's analytical group to arrange/determine:
- laboratory;
- glassware/sample jars;
- cooler;
- shipping details;
- start date; and
- expected duration.

v) Complete property access/utility clearance data sheet. In most instances, surface sampling activities will not require utility clearances.

vi) Determine notification needs with the Project Coordinator. Have the regulatory groups, Client, landowner, CRA personnel, and laboratory been informed of the sampling event?

vii) Determine the methods for handling and disposal of washwaters and spent decontamination fluids.

4.13.4 PROCEDURE

Soil sampling techniques 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 involves the use of a stainless steel trowel. Soil samples may also be collected with spoons and push tubes. In each case, the sampling device must be constructed of an inert material with smooth surfaces which can be readily cleaned. The cleaning protocol involves the use of a sequence of cleaning agents and water designed to remove surface contaminants. The sampling equipment is cleaned between sample locations. A typical surficial soil sampling protocol is outlined below:

i) Surficial soil samples will be collected using a precleaned stainless steel trowel or other appropriate tool. Each sample will consist of soil from the surface to the depth specified within the Work Plan. Sampling in ditches will be done only when there is no water present.

ii) A new pair of disposable gloves will be used at each sample location;

iii) Prior to use, at each sample location, all sampling tools will be decontaminated in accordance with the Work Plan.

iv) A precleaned sampling tool will be used to remove the sample from the layer of exposed soil. The collected soil will be placed directly in a clean, prelabeled sample jar and sealed with a Teflon-lined cap. Samples to be split for duplicate analyses will first be homogenized in a precleaned stainless steel bowl; and

v) Samples will be placed in ice or cooler packs in laboratory supplied coolers after collection.

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

In the event that the soil conditions are not as the sampler was led to believe by 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), then the sampling personnel should report the conditions to the Project Coordinator immediately for resolution. Similarly, if a sampling location is in a gravel or paved area, the 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, the 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.

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

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

With the exception of VOC analyses, soil samples should be placed in a stainless steel bowl to be homogenized 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 as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. When round bowls are used for sample mixing, mixing is achieved by stirring the material in a circular motion and occasionally turning the material over. Soil samples collected for volatile organic compounds analyses shall not be mixed. The sample container should be filled completely; no space should remain in the sample containers.

In 1997, EPA adopted new methods for sampling soils for volatile organic compound (VOC) analysis. Method 5035 calls for collecting soil using a coring device. 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.

During the sampling program, the sampling team leader should stay in contact with the CRA chemist assigned to the project such that the CRA chemist can properly inform the contract laboratory with 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.

4.13.5 FOLLOWUP ACTIVITIES

The following activities shall be completed at the conclusion of the field work:

i) Ensure that all sample locations are surveyed such that the sample location could be readily re-established.
ii) Equipment shall be cleaned and returned to the equipment administrator and the appropriate form dated and signed.
iii) Prepare and distribute the completion checklist (Form SP-16).
iv) Submit a memo to the Project Coordinator indicating sampling procedures and observations (such as surface staining) and grid layout and all QA/QC documentation.
v) Ensure that the CRA chemist has all relevant information required to track the progress of the sample analysis.

4.13.6 COMPLETION CHECKLIST

At the completion of the soil sampling program, Borehole Installation and Subsurface Soil Sampling • Completion Checklist (Form SP-16) must be completed to document activities conducted and serves to remind personnel of the various tasks required. This form must be signed and filed at the respective field office, regional CRA office, and issued to the Project Coordinator.

4.13.7 CONTACT INFORMATION

The following CRA personnel may be contacted regarding borehole installation and soil sampling procedures or for additional information:

Contact	*Office*	*Phone Number*	*Fax Number*
Bruce Monteith	Atlanta	(770) 441-0027	(770) 441-2050
Linda McConnell	Baton Rouge	(225) 292-9007	(225) 292-3614
Walt Pochron	Chicago	(773) 380-9933	(773) 380-6421
John Evanoff	Houston	(281) 492-8311	(281) 492-2340
Peter Storlie	Minneapolis	(651) 639-0913	(651) 639-0923
Doug Oscar	Niagara Falls	(716) 297-6150	(716) 297-2265
Mike Mateyk	Waterloo	(519) 725-3313	(519) 725-1394

4.13.8 REFERENCES

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

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

4.14 SURFACE WATER, LAGOON, AND SEDIMENT SAMPLING

4.14.1 GENERAL

The objective of surface water, lagoon, and sediment sampling is to obtain samples that are representative of existing water and sediment conditions.

Surface water sampling locations for water quality studies may be selected based on many factors, including: study objectives; the location of point source discharges, non-point source discharges and tributaries; the presence of structures (bridges, dams, etc.), and accessibility.

Sediment and sludge samples are collected to determine the nature of discharge impacts on sediment quality. Contaminants may become sediment bound through either deposition of contaminated suspended sediments or by adsorption of soluble surface water constituents to sediments. Organic chemicals are generally adsorbed to a greater degree as the fraction of organic carbon (foc) in the sediments increases.

It should be noted that sediment and sludge quality can vary substantially with depth depending on flow rates and depositional history. It is critical that sediment and sludge samples be collected from the sampling horizon identified in the Work Plan. If there is an ambiguity regarding the sediment sampling rationale, all concerns must be discussed with the Project Coordinator.

Note: *It is important to obtain surface water samples that are unimpacted by the re-suspension of sediment caused by sampling activities!*

4.14.2 PRIOR PLANNING AND PREPARATION

The following shall be considered prior to surface water, lagoon, and sediment/sludge sampling.

i) Review the Work Plan and HASP.
ii) Sampling locations may, at times, be located on private lands. Coordination of property access should always be discussed with the Project Coordinator in advance of field activities. Have all parties been notified that sampling is scheduled? Has a PA/UC Form been completed for this field activity?
iii) Make proper arrangements with the laboratory with regard to sample containers and the sampling date. Evaluate QA/QC requirements per the Work Plan.
iv) Assemble equipment and supplies using the Equipment and Supply Checklist (Form SP-21).
v) Consider in advance of sampling whether a hazard exists due to deep/fast moving water, difficult access, and if more than two people are required.
vi) Pre-plan the sampling sequence such that sampling commences at the furthest downstream sampling location and proceeds upstream.

4.14.3 SAMPLE SITE SELECTION

Before any sampling is conducted, the first requirement is to consider suitable sampling locations. Bridges and piers are normally good choices for surface water sampling since they provide access and permit water sampling at any point across the width of the water body. Sampling locations should be selected in accordance with the Work Plan and discussed with the Project Coordinator. Wading for water samples in lakes, ponds, and slow-moving rivers and streams must be done with caution since bottom deposits are easily disturbed. Samples must be collected without entrained suspended sediments. All surface water samples are to be collected commencing with the most downstream sample to avoid sediment interference with other downstream samples. A life vest and safety line will be worn in all cases where footing is unstable or where water is fast moving or over 3 feet (0.85 m) in depth. A second person may also be required for most of the sampling scenarios.

i) Rivers, Streams, and Creeks

Surface water samples should usually be collected in areas of the surface water body that are representative of the surface water body conditions. Representative samples can usually be collected in portions of the surface water body that have a uniform cross section and flow rate. Since mixing is influenced by turbulence and water velocity, the selection of a site immediately downstream of a riffle area (e.g., fast flow zone) will ensure good vertical mixing. These locations are also likely areas for deposition of sediment since the greatest deposition occurs where stream velocity slows.

A site that is clear of immediate point sources (e.g., tributaries and industrial and municipal effluents) is preferred for the collection of surface water samples unless the sampling is being performed to assess these sources.

Tributaries should be sampled as near the mouth as is feasible. However, it is important to select the sample location taking into consideration the impact that the downstream receiving water body has on the tributary flow and sediments. The downstream water body may change the water quality (salinity), temperature, or turbidity in the tributary near its mouth.

Sediment samples shall be collected along a cross-section of a river or stream in order to adequately characterize the bed material or as described in the Work Plan. A common procedure is to sample at quarter points along the cross-section of the sampling site selected. Samples may be composited as described in the Work Plan. Samples of dissimilar composition should not be combined.

ii) Lakes, Ponds, and Impoundments

The water in lakes, ponds, and impoundments has a much greater tendency to stratify than water in rivers and streams. The lack of mixing may require that more samples be obtained. An extreme turbidity difference may occur where a highly turbid river enters a lake. Therefore, each layer of the stratified water column may need to be considered separately. Stratification is caused by water temperature differences; the cooler, heavier water is beneath the warmer water.

Sample selection also should adequately represent the conditions of the lagoon or settling pond. Attention must be given to identify intakes and outflows within the lagoon or settling pond which may provide biased sample representation. Sample locations with adjacent structures (i.e., banks, piers, etc.) may also provide biased samples within active lagoons or settling ponds, as the potential for boundary flow and eddies exist.

The number of water sampling sites on a lake, pond, or impoundment will vary with the purpose of the investigation, as well as the size and shape of the basin. In ponds and small impoundments, a single sample should be collected at the deepest point. In naturally formed ponds, the deepest point is usually near the center. In impoundments the deepest point is usually near the dam.

In lakes and larger impoundments, several subsamples may be composited to form a single sample. These vertical sampling locations are often taken along a grid.

In lakes with irregular shape, with several bays and coves that are protected from the wind, additional samples may be needed to represent water quality at various points in the lake. Additional samples may be taken where discharges, tributaries, and other such factors are suspected of influencing water quality.

When collecting sediment samples in lakes, ponds, and reservoirs, samples should be collected at approximately the center of the water body or as directed by the Work Plan. This is also the case for reservoirs that are formed by the impoundment of rivers or streams. The coarse grained sediments are deposited near the headwaters of the reservoir, and the fine grained sediments near the center. The shape, inflow pattern, and circulation must be considered when selecting sediment sampling sites in lakes and reservoirs.

In all instances, the sampling locations should be properly documented with field notes and photographs, as appropriate.

4.14.4 SAMPLING EQUIPMENT AND TECHNIQUES

4.14.4.1 GENERAL

Any equipment or sampling technique(s) (e.g., stainless steel, PVC, etc.) used to collect a sample is acceptable as long as it provides a sample which is representative of the stream being sampled and is consistent with the Work Plan. Lagoons and/or settling ponds typically contain both liquids and solids, which may vary with depth. In addition to the water/sediment samples required, project-specific QA/QC samples are typically required to assess field techniques/laboratory performance. Section 3.9 outlines field derived QA/QC samples commonly required within a sampling program.

4.14.4.2 SURFACE WATER SAMPLING EQUIPMENT/TECHNIQUES

When collecting surface water samples, direct dipping of the sample container into the stream is acceptable unless the sample bottles contain preservatives. If the bottles are preserved, then precleaned unpreserved bottles should be used to collect the sample. The water sample should then be transferred to the appropriate preserved bottles. When collecting samples, submerse the inverted bottle to the desired sample depth and then tilt the opening of the bottle upstream to fill. Wading may cause bottom sediment deposits to be re-suspended and therefore could result in a biased sample. Wading is acceptable if the stream has a noticeable current and the samples are collected directly into the bottle while pointed upstream. If the stream is too deep to wade or if the sample must be collected from more than one water depth, additional sampling equipment will be required. Samples should be collected approximately 6 inches (15 cm) below the surface with the sample bottles completely submerged. This will keep floating debris from entering the sample bottles. Floating debris could result in unrepresentative analytical data.

Sample collection when the flow depth is minimal (i.e., <1 inch (<2.5 cm)) will require special consideration to prevent sediment disturbance. Sampling might be conducted with a container then transferred to the appropriate glassware, or collection may be permissible with a peristaltic pump using a 'fixed' suction line, secured to prevent sediment collection. A small excavation in the stream bed to create a 'sump' for sample collection may be permissible but should be prepared well in advance of the sample collection event to allow sediment settlement.

Teflon bailers may be used for surface water sampling if it is not necessary to collect a sample at a specified interval. A top-loading bailer with a bottom check-valve is sufficient for many studies. As the bailer is lowered through the water, water is continually displaced through the bailer until a desired depth is reached, at which point the bailer is removed. This technique is not suitable where strong currents are encountered (because the ball may not seat effectively), or where a discrete sample at a specific depth is required.

If discrete samples are required from a specific depth, and the parameters to be measured do not require a Teflon-coated sampler, a standard Kemmerer, or Van Dorn sampler may be used. The

Kemmerer sampler is a brass cylinder with rubber stoppers that leave the ends of the sampler open while being lowered in a vertical position to allow for passage of water through the cylinder. The Van Dorn sampler is plastic and is lowered in a horizontal position. In each case, a messenger is sent down a rope when the sampler is at the required depth to cause the stoppers to close the cylinder. The sampler is then raised to the surface. Water is removed through a valve to fill respective sample bottles. Dissolved oxygen (DO) sample bottles can be properly filled by allowing overflow using a rubber tube attached to the valve. When performing multiple depth sampling, care should be taken not to stir up the bottom sediment.

A glass beaker or stainless steel scoop may be used to collect samples if the parameters to be analyzed are not interfered with. The beaker or scoop should be rinsed three times with the sample water prior to collection of the sample. All field equipment should follow standard cleaning procedures.

4.14.4.3 WASTEWATER/WATER SAMPLING EQUIPMENT/TECHNIQUES

The preservation of wastewater/water column for sampling can be accomplished by inserting a tube or pipe (i.e., Teflon, PVC, or stainless steel) of sufficient length and diameter within the lagoon/settling pond wastewater/water matrix. The tube or pipe should be inserted firmly into the base of the lagoon/settling pond to prevent and/or minimize seepage into the sample core.

Following the insertion of the tube or pipe, the wastewater/water column sample is collected similarly to a groundwater sample (i.e., using a pump or bailer), as detailed in Section 4.5 for Groundwater Sampling. The use of a release bottle or Kemmerer sampler provides a means to collect discrete interval grab samples. Physical properties (i.e., suspended sediments, viscosity, specific gravity) of the wastewater/water matrix should be known to better evaluate which method of sample collection is preferable. Should select samples be collected at depth utilizing a pump, attention must be given to lower the pump gradually and collect the desired sample.

Sampling within a lagoon/settling pond typically necessitates a flotation vessel (i.e., barge, boat, raft, canoe) and special safety equipment (i.e., life vest, safety line), should access to a stable structure not be available. A second and/or third person will probably be necessary for safety reasons depending on the complexity of the sampling program.

The use of dedicated sampling equipment for each sampling location is recommended given the wastewater/water characteristics.

4.14.4.4 SLUDGE/SEDIMENT SAMPLING EQUIPMENT/TECHNIQUES

A variety of methods may be used to collect sediment samples from a stream, river, or lake bed. Dredging (Peterson and Ponar), coring and scooping are acceptable sediment sample collection techniques. Precautions shall be taken to ensure that a representative sample of the stream bed is collected. Caution should be exercised when wading in shallow water so as not to disturb the area to be sampled. The following describes some of these methods.

i) Dredging

The Peterson dredge is best used for rocky bottoms, in very deep water, or when the stream velocity is rapid. The dredge should be lowered slowly as it approaches the bottom, so as to not disturb the lighter sediments.

The Ponar dredge is similar to the Peterson dredge in size and weight. The Ponar dredge is a "clam-shell" type unit which closes on contact with the river/lake bottom. Depending on the size of the unit, a winch is required for larger units, whereas, smaller units are available for lowering by a hand line. Once retrieved, the unit is opened and the sample extracted using a sample scoop or spoon. The unit has been modified by the addition of side plates and a screen on top of the sample compartment. This permits water to pass through the sampler as it descends.

The Ponar grab sampler functions by the use of a spring-latch-messenger arrangement. The sampler is lowered to the bottom of the stream, lake, pond, etc. by way of a rope, then the messenger is sent down to trip the latch causing the sampler to close on the sediments. The sampler is then raised slowly to minimize the disturbance of the lighter sediments. Sediment is then placed into a stainless steel bowl, homogenized, and placed into the appropriate sample container (if collecting for VOC parameters, fill the VOC jars before homogenization).

ii) Corers

Core samplers are used to obtain vertical columns of sediment. Many types of coring devices are available, depending on the depth of water from which the sample is to be collected, the type of bottom material, and the length of core to be obtained. They vary from hand-push tubes to weight or gravity-driven devices to vibrating penetration devices.

Coring devices are useful in contaminant monitoring due to the minimal disturbance created during descent. The sample is withdrawn intact, allowing the removal of only those layers of interest. Core liners consisting of plastic or Teflon may also be added, thereby reducing the potential for sample contamination and maintaining a stratified sample. The samples may be shipped to the lab in the tubes in which they were collected. The disadvantage of coring devices is that only a small sampling surface area and sample size is obtained, often necessitating repetitive sampling in order to collect the required amount of sediment for analysis. It is often also difficult to extract the sediment sample back out through the water column without losing the sample.

The core tube is pushed/driven into the sediment until only 4 inches (10 cm) or less of tube is above the sediment-water interface. When sampling hard or coarse sediments, a slight rotation of the tube while it is pushed will create greater penetration and reduce compaction. Cap the tube with a Teflon plug or a sheet of Teflon. The tube is then slowly withdrawn, keeping the sample in the tube. Before pulling the bottom part of the core above the water surface, it must be capped.

iii) Scooping

If the water is wadeable, the easiest way to collect a sediment sample is to scoop the sediment using a stainless steel spoon or scoop. This may be done by wading into the stream or pond and, while facing upstream (into the current), scooping the sample from along the bottom in an upstream direction. This method is only practical in very shallow water.

iv) Mixing

Sediment samples collected for chemical analysis should be thoroughly mixed (except for volatile organic compounds) in a stainless steel bowl prior to placement in the appropriate sample container. Standard procedures exist for preparation of sediment samples (ASTM D3976). These should be followed or the laboratory informed of applicable procedures.

v) Air Monitoring

Prior to wastewater/sludge sampling, measure the breathing space above the sample location with a photoionization detector (PID), should the potential for volatiles be present, and use a hydrogen sulfide meter should hydrogen sulfide be present. Repeat these measurements during sampling. If either of these measurements exceed any of the air quality criteria established in the HASP, the air purifying respirators (APRs), or supplied air systems will be required.

Hydrogen sulfide odors are typical in lagoons and settling ponds where decomposition with depth occur over time.

vi) Sample Location Tie-In/Surveying

The recording of the sample locations and depth on the site plan is extremely important. This may be accomplished by manual measurement (i.e., swing ties) or stadia methods. Manual measurements for each sample location should be tied into three permanent features (e.g., buildings, utility poles, hydrants, etc.). Diagrams with measurements should be included in the field book.

> Note: *Manual field measurements are always necessary regardless of whether a survey is completed!*
> *Manual measurements allow future identification of the sample location without the need of a survey crew to locate positions using a grid system.*

4.14.5 FIELD NOTES

A bound field book will be used to record daily activities, describe sampling locations and techniques and describe photographs (if taken). Visual observations are important as they may prove invaluable in interpreting water or sediment quality results. Observations shall include (as applicable) weather, stream flow conditions, stream physical conditions (width, depth, etc.), tributaries, effluent discharges, impoundments, bridges, RR trestles, oil sheens, odors, buried debris, vegetation, algae, fish or other aquatic life, and surrounding industrial areas. The Stratigraphic Log Form should be utilized for lagoon sampling. The following observations should be considered for surface water studies:

- **Predominant Surrounding Land Use**: Observe the prevalent land use type in the vicinity (noting any other land uses in the area which, although not predominant, may potentially affect water quality).
- **Local Watershed Erosion**: The existing or potential erosion of soil within the local watershed (the portion of the watershed that drains directly into the stream) and its movement into a stream is noted. Erosion can be rated through visual observation of watershed and stream characteristics. (Note any turbidity observed during water quality assessment.)
- **Local Watershed Nonpoint-Source Pollution**: This item refers to problems and potential problems other than siltation. Nonpoint-source pollution is defined as diffuse agricultural and urban runoff (e.g., stormwater runoff). Other compromising factors in a watershed that may affect water quality are feedlots, wetlands, septic systems, dams and impoundments, and/or mine seepage.
- **Estimated Stream Width**: Estimate the distance from shore at a transect representative of the stream width in the area.
- **Estimated Stream Depth**: Riffle (rocky area), run (steady flow area), and pool (still area). Estimate the vertical distance from water surface to stream bottom at a representative depth at each of the three locations.
- **High Water Mark**: Estimate the vertical distance from the stream bank to the peak overflow level, as indicated by debris hanging in bank or floodplain vegetation, and deposition of silt or soil. In instances where bank overflow is rare, a high water mark may not be evident.
- **Velocity**: Record an estimate of stream velocity in a representative run area (see Section 4.15).
- **Dam Present**: Indicate the presence or absence of a dam upstream or downstream of the sampling station. If a dam is present, include specific information relating to alteration of flow.
- **Channelized**: Indicate whether the area around the sampling station is channelized.
- **Canopy Cover**: Note the general proportion of open to shaded area which best describes the amount of cover at the sampling station.
- **Sediment Odors**: Disturb sediment and note any odors described (or include any other odors not listed) which are associated with sediment in the area of the sampling station.
- **Sediment Oils**: Note the term which best describes the relative amount of any sediment oils observed in the sampling area.
- **Sediment Deposits**: Note those deposits described (or include any other deposits not listed) which are present in the sampling area. Also indicate whether the undersides of rocks not deeply embedded are black (which generally indicates low dissolved oxygen or anaerobic conditions).

4.14.6 FOLLOWUP ACTIVITIES

The following shall be performed once field activities are complete.

i) Equipment shall be cleaned and returned to the equipment administrator and the appropriate form dated and signed.

ii) The contracted laboratory shall be notified as to when to expect sample arrival. The sample cooler shall contain the chain-of-custody form.

iii) Field notes shall be sent to file and the field book stored at the CRA office.

iv) Prepare and distribute the completion checklist described in Section 4.14.7.

4.14.7 COMPLETION CHECKLIST

At the completion of the surface water/sediment sampling program, Surface Water/Sediment Sampling • Completion Checklist (Form SP-22) must be completed to document activities conducted and serves to remind personnel of the various tasks required. This form must be signed and filed at the respective field office, regional CRA office and issued to the Project Coordinator.

4.14.8 CONTACT INFORMATION

The following CRA personnel may be contacted regarding surface water or sediment sampling procedures or for additional information:

Contact	*Office*	*Phone Number*	*Fax Number*
Linda McConnell	Baton Rouge	(225) 292-9007	(225) 292-3614
John Evanoff	Houston	(281) 492-8311	(281) 492-2340
Carol Dunnigan	Niagara Falls	(716) 297-6150	(716) 297-2265
Jeff Ratliff	Titusville	(407) 269-9891	(407) 269-9872
Dave Millard	Waterloo	(519) 884-0510	(519) 884-0525
John Sinnige	Waterloo	(519) 884-0510	(519) 884-0525
Glenn Turchan	Waterloo	(519) 725-3313	(519) 725-1394
Tom Emenhiser	West Palm Beach	(561) 688-9008	(561) 688-9005

4.14.9 REFERENCES

For additional information pertaining to this topic, 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

4.28 SITE SURVEYING

4.28.1 GENERAL

Surveying to establish the location of natural and man-made features is an important part of many projects. The Project Coordinator must determine if a licensed surveyor is required or if CRA staff may perform the survey. In some jurisdictions, or for some purposes such as wellhead elevations or property limits, a licensed Land Surveyor must perform the survey.

Staff operating survey equipment must have appropriate training in its' use to meet CRA's Quality System requirements.

Differential leveling is used to determine differences in elevation between points that are remote from each other.

Topographic or pre-engineering surveys are made to collect data that can be drawn to scale on a plan or map. These plans show the location of natural features such as trees, rivers, hills, valleys, and the like, and the location of man-made features such as roads, structures, pipelines, etc., and usually illustrate site relief via the use of contour lines.

Construction surveys provide layout for construction projects. This layout marks the horizontal location (line) as well as vertical location or elevation (grade) of the proposed works.

4.28.2 PRIOR PLANNING AND PREPARATION

The following shall be considered prior to performing a site survey:

i) Review the work program, project documents, and health and safety requirements.

ii) Confirm that permission for site access has been arranged.

iii) Arrange utility locates as required.

iv) Assemble necessary equipment and supplies:

a) For Determining Elevations:

- survey level and tripod;
- leveling rod;
- rod level (optional);
- copy of site plan and benchmark information;
- field book; and
- requisite QS field data forms.

b) For Detail Pickup/Point Layout:

- transit/theodolite and tripod (stadia, polar tie-ins);
- leveling rod (stadia);
- rod level (optional);
- right-angle prism (right angle tie-ins);

- measuring tape and plumb bobs (right angle tie-ins, swing ties);
- eye level;
- copy of site plan and horizontal control information;
- field book; and
- requisite QS field data forms.

c) Miscellaneous Equipment and Supplies:

- stakes and sledge hammer;
- indelible marker or paint pen;
- paint/flagging;
- two-way radios;
- bar finder;
- atv/snowmobile;
- traffic cones; and
- safety vests.

4.28.3 FIELD PROCEDURES

4.28.3.1 VERTICAL CONTROL POINTS (BENCHMARKS)

SURVEY CONTROL

Geodetic benchmark elevations are established relative to Mean Sea Level. Benchmarks (BM), at the national level, are precisely established by federal agencies utilizing first-order survey methods and first order instruments. The same high requirements are also specified for state and provincial networks. Wherever possible, the use of geodetic benchmarks is recommended.

Agencies that typically administer benchmark databases include:

- US Geological Survey (USGS);
- US Coast and Geodetic Survey (USC&GS);
- National Oceanographic and Atmospheric Administration (NOAA);
- Army Corps of Engineers (COE);
- Soil Conservation Service (SCS);
- Natural Resources Canada;
- Ministry of Natural Resources;
- Ministry of Transportation; and
- Local Municipalities.

A temporary benchmark (TBM) is a semi-permanent reference elevation established to provide elevation control convenient to a specific engineering project and should be determined from the geodetic network, if available.

A TBM may be an "X" chiseled into concrete, the edge of a manhole lid, the top spindle of a hydrant, a spike in a pole, the top of a building foundation, or other stable and accessible point.

It is customary in benchmark leveling at all orders of accuracy to first verify that the starting benchmark's elevation is correct by leveling to the closest adjacent BM. This check is particularly important when the survey loops back to close on the starting BM and no other verification is planned.

If a benchmark is not available for the site a convenient, semi-permanent, stable point or feature is selected as an arbitrary TBM, with an assumed elevation. The assumed elevation should be carefully selected with the following criteria in mind:

- assumed elevations should be even, order of magnitude values, such as 10.00 or 100.00;
- the assumed TBM elevation should not be similar to the geodetic elevations in the area to avoid confusion; and
- select an assumed TBM elevation that will not result in a negative value for elevations elsewhere on the site.

4.28.3.2 HORIZONTAL CONTROL POINTS

Horizontal control points can be tied in to provincial or state coordinate grid monuments, property lines, roadway centrelines, or site-specific baselines or grids.

Control stations must be permanent or readily replaceable, and must be established at a relatively high level of accuracy. If the control is inaccurate, the survey and any resultant design will also be inaccurate. If the control is not well referenced, it will be costly if not impossible to precisely relocate the control points in the field if they are lost. In addition to providing control for the original survey, the control will be used for any additional pre-engineering surveys and construction layout. It is not unusual to have one or more years pass between the preliminary survey and the subsequent construction layout. To ensure that construction layout will be accurate, the control points must be set to a high level of accuracy. In addition, precise setting of the control points requires that strong geometric shapes be used in designing the control network. Control points should be positioned on the following criteria:

i) Good visibility to other control points and an optimal number of layout points are required, not only for existing site conditions, but also during all stages of construction.

ii) Control points should be placed in locations that will not be affected by primary or secondary construction activity. Temporary disruptions to the terrain resulting from access roads, materials stockpiles, and so on must be anticipated. Try to locate control points adjacent to features that will not be moved (power towers, concrete walls, large valuable trees).

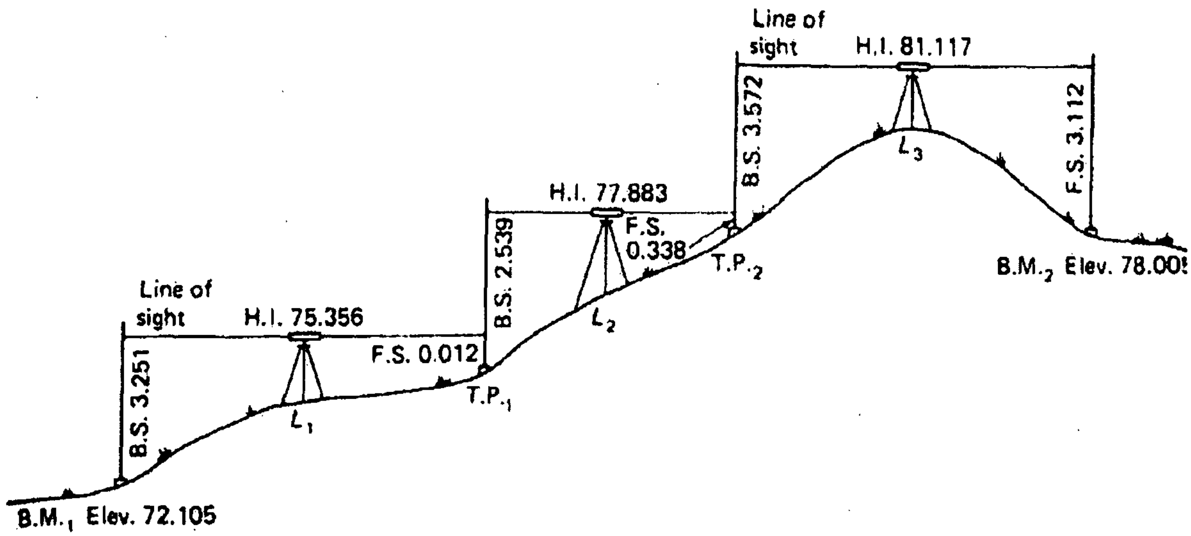
iii) Control points must be established on solid ground, preferably encompassing the work area, and forming triangular networks if possible.

4.28.3.3 DIFFERENTIAL LEVELING

The procedure for differential leveling is completely described by only two basic steps, which are repeated as often as necessary. From your setup location:

i) Take a backsight (BS) to a point of known elevation (BM, TBM, TP) and add the rod reading to the known elevation to determine the height of instrument (HI).

ii) Take a foresight (FS) to a point with unknown elevation and subtract the rod reading from the HI to determine the elevation of the point.



Key stations such as well risers, manholes, or culverts should have the elevation established by making it a turning point to include it in the loop. This procedure mathematically confirms the elevation. When the elevation of the desired point has been determined, it can be used as a turning point (TP) to continue the survey when a new instrument setup is necessary.

Intermediate sights (IS) are taken from an instrument setup after the HI has been established. Subtract the rod reading from the HI to determine the elevation of the unknown point. IS' are generally taken to non-key points as the calculated elevations are not mathematically confirmed as part of the loop.

Good field procedures include the following:

- Complete the activities and calibration detailed on Sheet 1 of the "Field Equipment Record Form".
- For a level with a magnification of 22X , the maximum length of sight should be limited to approximately 70 metres/230 feet.
- Foresight and backsight lengths should be kept approximately equal (within 10 metres/30 feet).
- On shots to key points (part of the loop), hold the rod plumb side to side, and rock it slowly toward and away from the instrument. The lowest rod reading is correct. Alternatively, use a bulls eye rod level.
- Consistency in wellhead elevations can be attained by always measuring to the highest point on the well casing.
- Close all level loops, preferably between two different BM's.

Quality System Form QSF-264D is provided when a level is signed out. The field notes for leveling follow the format defined on Sheet 2 of the record form.

FIELD DATA: (QSF-264D)

Field Book No.: 99-W-1234 **Page No.:** 23

Close all leveling loops, and ensure that closure is appropriate for the purpose of the data.

STA.	*B.S.*	*H.I.*	*I.S.*	*F.S.*	*ELEV.*	
TBM 1	3.251	75.356			72.105	TBM Concrete Monument # 1
			1.358		73.998	Gnd @ TP18-99
TP #1	2.539	77.883		0.012	75.344	T/riser – MW6-99
			2.107		75.776	Gnd at MW7-99
			1.220		76.663	T/riser – MW7-99
TP #2	3.572	81.117		0.338	77.545	NW Corner of wood retaining wall
TBM 2				3.112	78.005	TBM Concrete Monument # 2 Check (78.010)

Filing: Field File

Project No: 01001-17 **Name (please print):** Jack Ferenczy

Date: February 17, 1999 **Signature:** *Jack Ferenczy*

Section 4.0 - Revision No. 0
May 26, 1998

The level loop must be closed into a point of known elevation so that the accuracy and acceptability of the survey can be determined. Following is the recommended tolerance for closures based upon the length of the level loop.

8 mm times the square root of the total loop distance in kilometres
or
0.035 ft times the square root of the total loop distance in miles

For example, if the level loop was 2 km long then the closure should be:

8 mm x square root of 2 = 8 mm x 1.4 = 11 mm

The survey should be repeated if the closure is not within the allowable limits. Data should be reduced and checked in the field to confirm elevations prior to returning to the office.

4.28.3.4 TOPOGRAPHIC SURVEY

The ultimate purpose of the topographic data must be understood when determining the precision required for a topographic survey. Since most natural features cannot be precisely defined, topographic surveys in areas having only natural features can be accomplished by using relatively less precise survey methods. Some surveys though, provide the designer with field dimensions that must be considered for related construction design. These values are more precisely determined to meet design requirements.

Considerations with respect to levels of precision, that:

i) Some detail cannot be precisely defined or located (1 ft/0.3 m) – for example, stream banks, limits of wooded areas, rock outcrops, top/bottom of slope, etc.
ii) Some detail can be located with only moderate precision, with normal techniques (0.1 ft/0.01 m) – for example, large single trees, manhole covers, walkways, etc.
iii) Some detail can be precisely defined and located (0.01 ft/0.005 m) – for example, well risers, building corners, bridge abutments, sewer and culvert inverts, etc.

When a topographic survey requires all three of the above levels of precision, the items in 3) are located at a precision dictated by the design requirements; the items in 1) and 2) are usually located at the higher level of precision (0.1 ft/0.01 m).

Measurements can be taken by rectangular tie-ins (right-angle offset), polar tie-ins (angle and distance), intersecting tie-ins (swing ties), stadia [manual and electronic (Total Station)], or GPS (satellite Global Positioning System).

Tie-ins at Right Angles to a Baseline

This technique provides the location of plan detail by measuring the distance perpendicular from a baseline to an object, and in addition, measuring along the baseline to the point of perpendicularity. The baseline is laid out in the field with stations marked at appropriate intervals. A sketch of the features to be measured is entered in the field book before measuring commences. Using a right angle prism, walk up the baseline noting and booking the stations of the features on both sides of the baseline. Once the stations have been booked for the interval, measure the offsets to the details left and right of the baseline and include these dimensions in the field notes.

Intersecting Ties

Intersecting ties (swing ties) are used to locate features relative to points of known location. These points of known location could be existing control points or any feature that can be identified on existing mapping. By measuring the distance from at least two known points, the feature to be mapped can be located at the intersection of the arcs. If possible, two ties should be close to 90 degrees apart to yield more accurate results, and at least three swing ties should be taken to the feature.

Polar Tie-ins

Polar tie-ins (angle/distance) locate a new point from known points by angle and distance. With a transit or a level set up on a known point or feature, backsight another known point or feature. Record the horizontal angle read from the instrument (or set angle to zero), then rotate the instrument so the horizontal angle can be measured to the new point. Record the horizontal angle reading, and measure the distance from the instrument to the new point.

Stadia (Using Transit and Rod)

Stadia is useful in areas of rugged terrain or large variations in elevation. Stadia is similar to polar tie-ins in that points are located by angle and distance.

To determine the distance, the transit (and some levels) has two additional horizontal cross hairs on the scope, one above and the other below the main middle hair. These hairs are positioned so that the distance to the rod is 100 times the difference between the lower and upper rod readings [rod interval (S)].

For example, if the lower hair crosses the rod at 1.00 foot, and the upper hair crosses the rod at 1.86 feet, then the slope distance is approximately 86 feet. The true horizontal distance varies depending on how far the transit scope is tilted off horizontal.

By recording the vertical angle and the middle rod reading, the elevation of the point can be calculated.

To begin a stadia survey, the transit is set on a known control point and the HI is measured and recorded. The horizontal circle is zeroed and referenced to another known control point. The zero setting should be checked prior to leaving the station and periodically during the setup by sighting back on the original backsight to ensure that the setting has not been inadvertently moved from zero.

To observe a point, the rod is sighted approximately horizontally, and then the scope is tilted up or down until the lower stadia hair is on the closest major graduation of the rod. The value at the lower, middle, and upper stadia hairs are read and recorded. If it happens that the entire rod interval cannot be seen on the rod, the middle and one other hair can be read and the remaining reading can be calculated (the interval from lower to middle hair should be the same as from the middle to upper hair). This reduces precision considerably, so extra care should be taken when taking readings for the half interval.

After the rod interval readings are booked, the main cross hair reading is booked and the rod person is waved off to the next point. The instrument person then records the vertical and horizontal angle readings, after which the procedure is repeated for the next point.

Usually the calculations of horizontal distances and elevations are performed after field hours. These calculations can be completed manually using equations or stadia tables and the points are manually plotted using a scale and protractor. Alternately, data may be entered into a spread sheet developed by CRA which converts field book data into X,Y,Z coordinate values for automated insertion into an AutoCAD drawing. A spreadsheet example is presented on 4.28-11.

Calculation of distance and elevation require that:

i) the sloped sight distance from the instrument to the rod must be reduced to a horizontal distance (HD); and
ii) the rod interval of a sloped sighting (S') when the line of sight is inclined by an angle (θ) from zenith (straight up) is used to calculate the difference in elevation(V) from the HI to the middle rod reading (RR).

The horizontal distance can be calculated by:

$$HD = 100S' \sin^2\theta$$

The difference in elevation is calculated by:

$$V = 100S' \cos\theta \sin\theta$$

The elevation of the surveyed point is calculated by:

Elevation @ Rod Location = Instrument Station Elevation + HI + V – RR

An example of typical stadia field notes is shown on example QSF-266D. Field notes may be recorded in a field book or on form QSF-266D.

FIELD DATA: (QSF-266D)

Field Book No.: 99-W-1234 **Page No.:** 16

	HOR			*VERT*		*ROD*	*DESCRIPTION*
Deg	Min	Sec	Deg	Min	Sec	L M U	
						Set up on control Pt. 5, IH=1.425m, BS Pt 8.	
0	0	0	90	10	20	1.00 1.26 1.52	Control Pt 8
31	26	50	90	20	00	2.00 2.17 2.34	T/B of exc'n
33	56	20	92	34	10	3.00 3.20 3.40	B/B of exc'n
47	18	30	89	11	40	1.00 1.36 1.73	Corner Bldg 4
128	32	30	88	57	20	1.00 1.57 2.14	500mm decid tree
257	29	10	90	02	50	2.00 2.68 3.36	T/riser MW7-99
345	42	40	89	51	00	1.00 1.09 1.18	MH29A
0	0	0	90	10	20	1.00 1.26 1.52	Control Pt 8 (check)

Filing: Field File

Project No: 01001-17 **Name (please print):** Jack Ferenczy

Date: February 17, 1999 **Signature:** *JACK FERENCZY*

4.28.3.5 CONSTRUCTION LAYOUT

The Contractor's surveyor or CRA's dedicated survey crew generally undertakes precise construction layout based on alignments designed from the original control network. Layout requirements vary widely based upon the type of construction, site characteristics, design details, and Contractor preference, and are therefore, not included in CRA's Training Program.

For small-scale layouts such as a few boreholes or monitoring wells, techniques such as swing ties or baseline and offset may be appropriate.

4.28.4 FOLLOW-UP ACTIVITIES

Once the surveying activities are complete and prior to returning to the office:

i) data reductions and closures shall be checked; and
ii) the equipment shall be cleaned and decontaminated, as necessary.

After returning to the office:

i) the equipment is returned to the equipment administrator;
ii) red tag any equipment that is damaged or out of calibration;
iii) the appropriately completed Quality System forms are signed, dated, and filed; and
iv) file the field book in the appropriate CRA office.

4.28.5 CONTACT INFORMATION

Contact	*Office*	*Phone Number*	*Fax Number*
Dan Salter	Waterloo	(519) 884-0510	(519) 884-5256
Dave Kramp	Waterloo	(519) 884-0510	(519) 884-5256
Sunil Agrawal (Nova Surveying and Mapping Services)	Detroit	(248) 347-3512	(248) 347-4152
Linda McConnell	Baton Rouge	(225) 292-9007	(225) 292-3614

As well, there are dedicated survey crews operating out of the Waterloo office and the CRA family company Nova Surveying and Mapping Services, Detroit office that are available to perform conventional, Total Station, and GPS surveys for CRA projects.

STRATIGRAPHY LOG (OVERBURDEN)

PAGE 1 OF 1

PROJECT NAME Hydrogeologic Eval
PROJECT NUMBER F490-81
CLIENT CRA
LOCATION As per plan, (100' N, 175' E of NE building corner)

DRILLING CONTRACTOR Deep Drilling
DRILLER Doug Soil
SURFACE ELEVATION 1262.4 Ft AMSL
WEATHER (AM) -
(PM) Sunny, 14°F

HOLE DESIGNATION BH-1-98
DATE/TIME STARTED January 11, 98
DATE/TIME COMPLETED 11
DRILLING METHOD 4¼" ID HSA
CRA SUPERVISOR Sandy Brown

STRATIGRAPHIC INTERVALS (DEPTHS IN ft/m BGS) FROM	AT	TO	SAMPLE DESCRIPTION — ORDER OF DESCRIPTORS: PRIMARY COMPONENT/SECONDARY COMPONENTS, RELATIVE DENSITY/CONSISTENCY (POCKET PENETROMETER), GRADATION/STRUCTURE, COLOUR MOISTURE CONTENT, SUPPLEMENTARY DESCRIPTORS	SAMPLE #	SAMPLING METHOD	PENETRATION RECORD SPLIT SPOON BLOWS 6"	6"	6"	6"	RECOVERY	PID (ppm)	CHEMICAL ANALYSIS	GRAIN SIZE
0		2'	upper 6" Topsoil 6" to 21" - ML-SILT (Fill), with clay, trace sand, soft, low plasticity, brown, very moist, brick fragments (occasional) up to ½" Ø, low dry strength, rapid dilatancy	1	SS	2	2	1	1	21"	0		
2'		4'	CL- CLAY (Till) with silt, trace fine sand, trace fine gravel, stiff, low plasticity, brown, mottled, moist, diagonal fissures (oxidized & calcite infilling), medium dry strength, no dilatancy, medium toughness	2	SS	3	5	5	6	19"	0		
			drill to 6', hit boulder at 5', push aside										
6'		8'	SP - SAND, trace silt, compact, poorly graded, brown, saturated, slight chemical odor	3	SS	8	9	10	7	22'	50	✓	✓
			End of hole at 8' BGS										

NOTES AND COMMENTS

DEPTH OF BOREHOLE CAVING 5.5 Ft DEPTH OF FIRST GROUNDWATER ENCOUNTER 5.5 Ft TOPSOIL THICKNESS 6"
WATER LEVEL IN OPEN BOREHOLE ON COMPLETION 5.0 Ft, AFTER 2 HOURS 4.3 Ft
COMPLETION DETAILS: Grouted to 2' BGS. Backfilled with cuttings 0-2' BGS

CRA

figure 4.1

TYPICAL OVERBURDEN LOG

BEDROCK CORING AND DRILLING STRATIGRAPHIC LOG

PROJECT NAME Hydrogeologic Inc.
PROJECT NUMBER 1490-81
CLIENT CRA
LOCATION As per Plan

DRILLING CONTRACTOR Deep Drilling
DRILLER Doug Sail
SURFACE ELEVATION NA
WEATHER (A.M.) sunny +60°F
(P.M.) cloudy, showers +75°F

HOLE DESIGNATION MW1-02
DATE/TIME STARTED Aug 29/02 9AM
DATE/TIME COMPLETED Aug 30/02 4PM
DRILLING METHOD HQ wet coring
CRA SUPERVISOR Sandy Brown

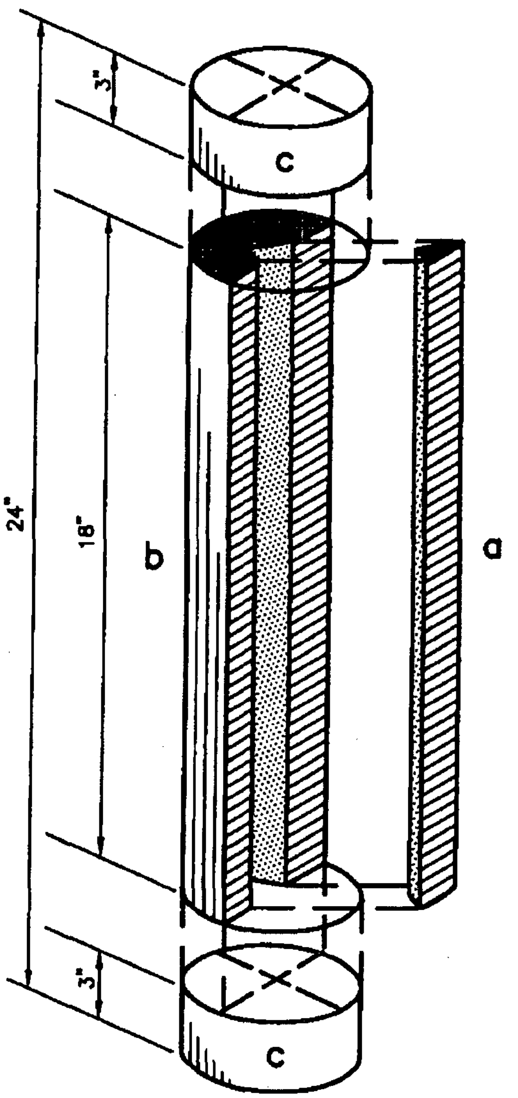
STRATIGRAPHIC INTERVALS DEPTHS IN FEET/METRES BGS			SAMPLE DESCRIPTION	NOTE: USE THESE COLUMNS FOR RECORDING DRILLING RATE AND CORE RECORD (IF CORING) DRILLING RATE/CORE DRILLING RECORD						WATER USAGE
FROM	AT	TO	BEDROCK DESCRIPTION: FORMATION NAME, ROCK TYPE, COLOUR, BEDDING, GRAIN SIZE, TEXTURE, WEATHERING, CEMENTATION, POROSITY, FOSSILS, SUPPL. DESCR. FRACTURE DESCRIPTION: TYPE, ORIENTATION, SPACING, ROUGHNESS, APERTURE, WEATHERING, INFILLING, SUPPLEMENTARY DESCRIPTION	RUN NO.	DEPTH FROM / START TIME	DEPTH TO / END TIME	CORE REC'Y / DRILL RATE	RQD %	FRACTURE INDEX	VOL. WATER LOST PER RUN
25		90	Guelph Fm. dolostone, light to medium grey, massive,	3	35	40	60"/60"	60"/60"	1/60"	~15gal
			fine to medium crystalline, saccharoidal, unweathered,		11:30	12:15	~7'/hr			
			1-3mm vugs, occasional fossil molds to 1" (brachiopod)							
				4	40	45	54"/60"	52"/60"	6/60"	~50gal
	39		horizontal fracture, rough, open, slightly weathered,		12:15	13:00	~7'/hr			
			brown silty clay filled							
				5	45	50	60"/60"	52"/60"	6/60"	~50gal
	41		41, 41.3, 41.7, 41.8, 41.9, 42.1, closely spaced horizontal fractures,		13:00	13:45	~7'/hr			
			smooth, tight, unweathered, minor crystalline filling							
	43		43, 43.6, 44.2, 45.4 stylolites							
	44		12" long, near vertical fracture, smooth, open,							
			slightly weathered, partially white crystal filled 1-2mm ø							
	46		becomes mottled texture, occasional sulphide mineral [illegible]							

NOTES AND COMMENTS 1-2mm ø

CRA

figure 4.1a

TYPICAL BEDROCK LOG



TYPICAL SOIL CORE

a

PORTION OF SAMPLE FOR CHEMICAL ANALYSIS

-CONTACT WITH UNSTERILIZED MATERIALS IS NOT ACCEPTABLE

-STORAGE – REFRIGERATED (4°C)

-SHIPPING – ON ICE BY COURIER TO DESIGNATED LAB

b

PORTION OF SAMPLE TO BE RETAINED FOR GEOLOGIC RECORDS

-CONTACT WITH UNSTERILIZED MATERIALS IS NOT A PROBLEM

-CONTAINER: – CLEAN GLASS JAR
– CLEAR GLASS IS SUITABLE

-STORAGE – IN STANDARD SHIPPING CARTON
– NO REFRIGERATION REQUIRED

c

PORTION OF SAMPLE TO BE DISCARDED

-DISCARDED WITHIN 55 GALLON DRUM MAINTAINED ON-SITE

figure 4.2

SPLIT SPOON SAMPLE SELECTION DETAILS

CRA

01001-00(029)GN-WA007 SEP 13/1999 REVISION 5

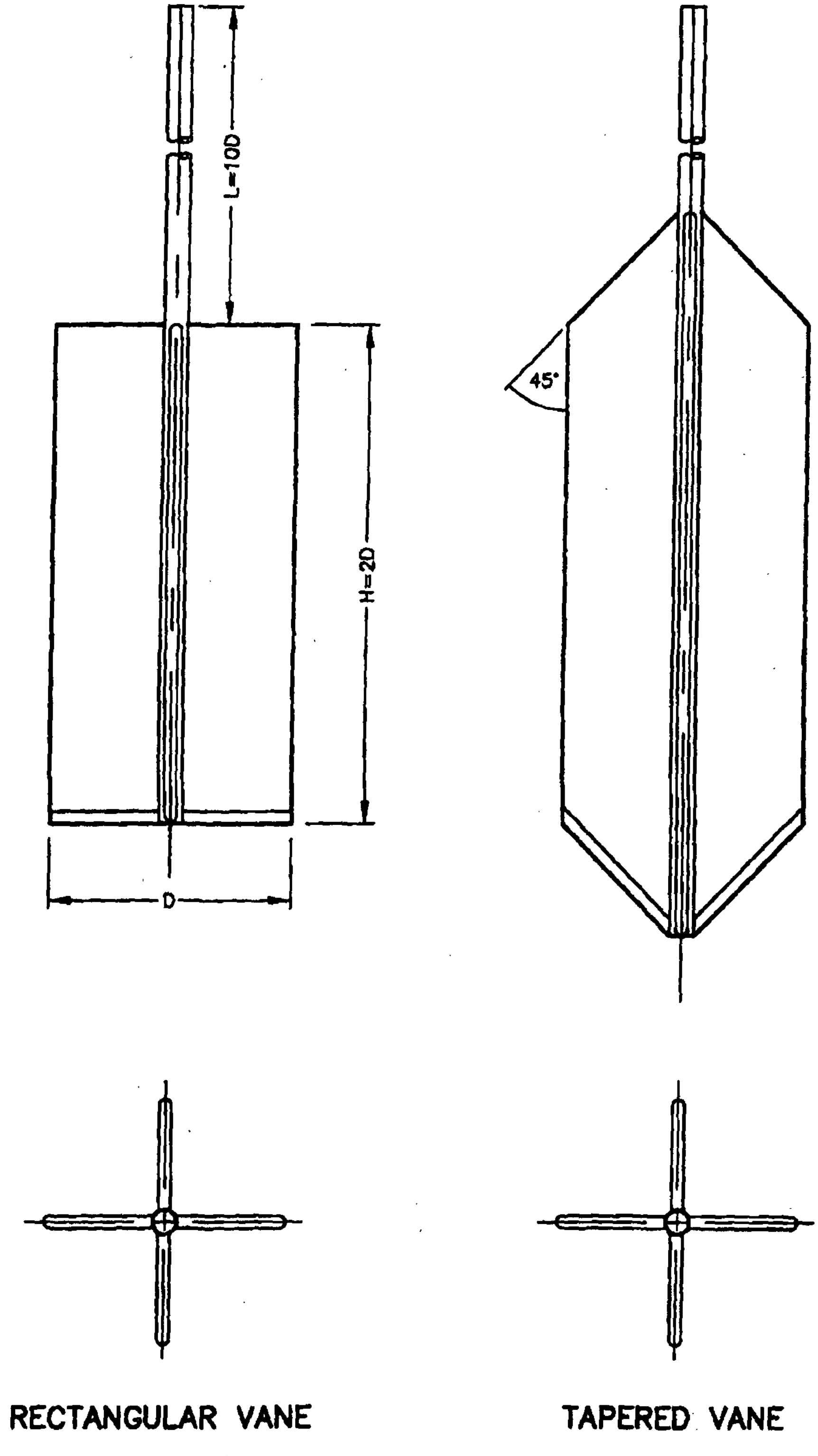


figure 4.3

GEOMETRY OF STANDARD FIELD VANE

CRA

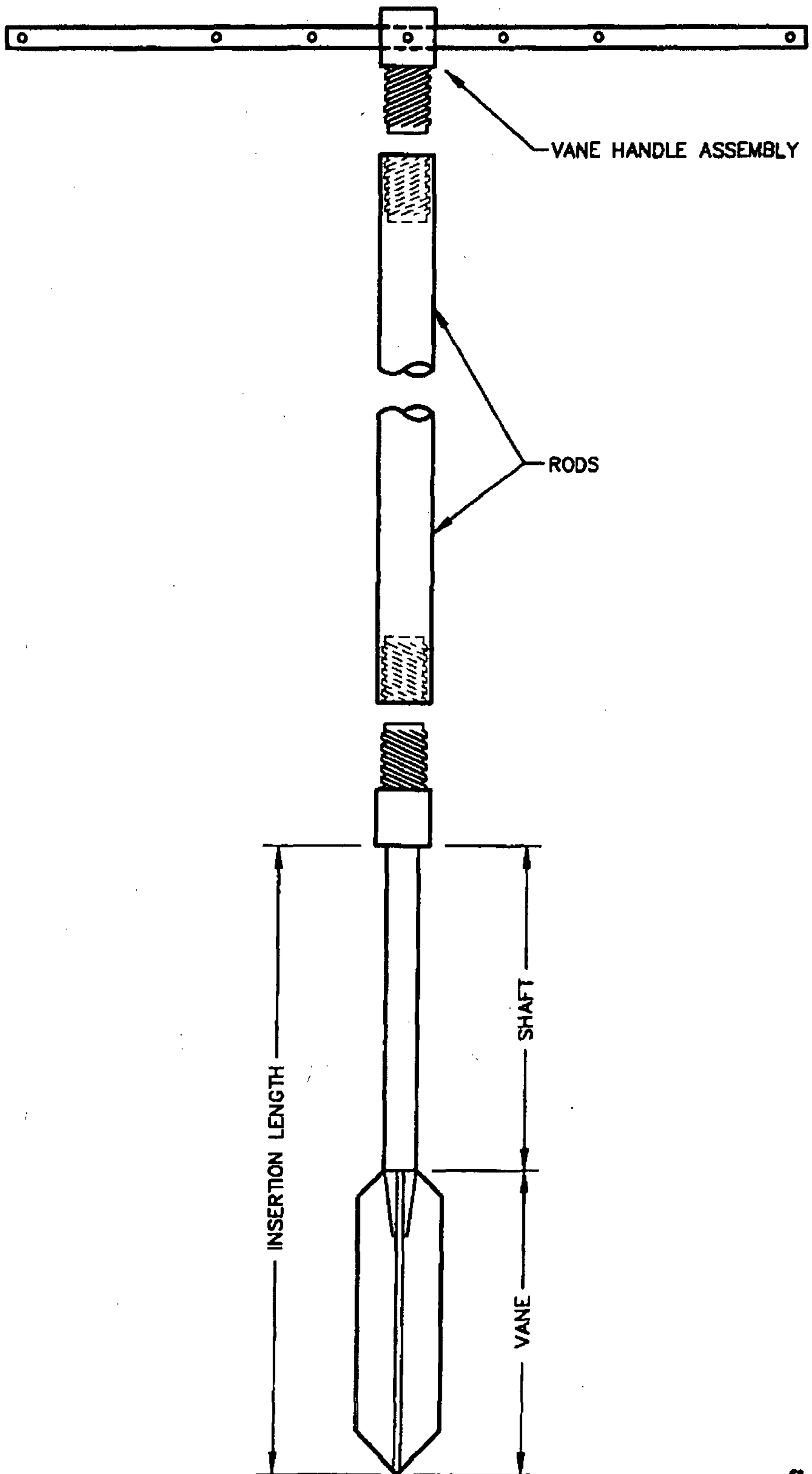


figure 4.4
FIELD VANE COMPONENTS

CRA

01001-00(029)GN-WA024 SEP 13/1999 REVISION 5

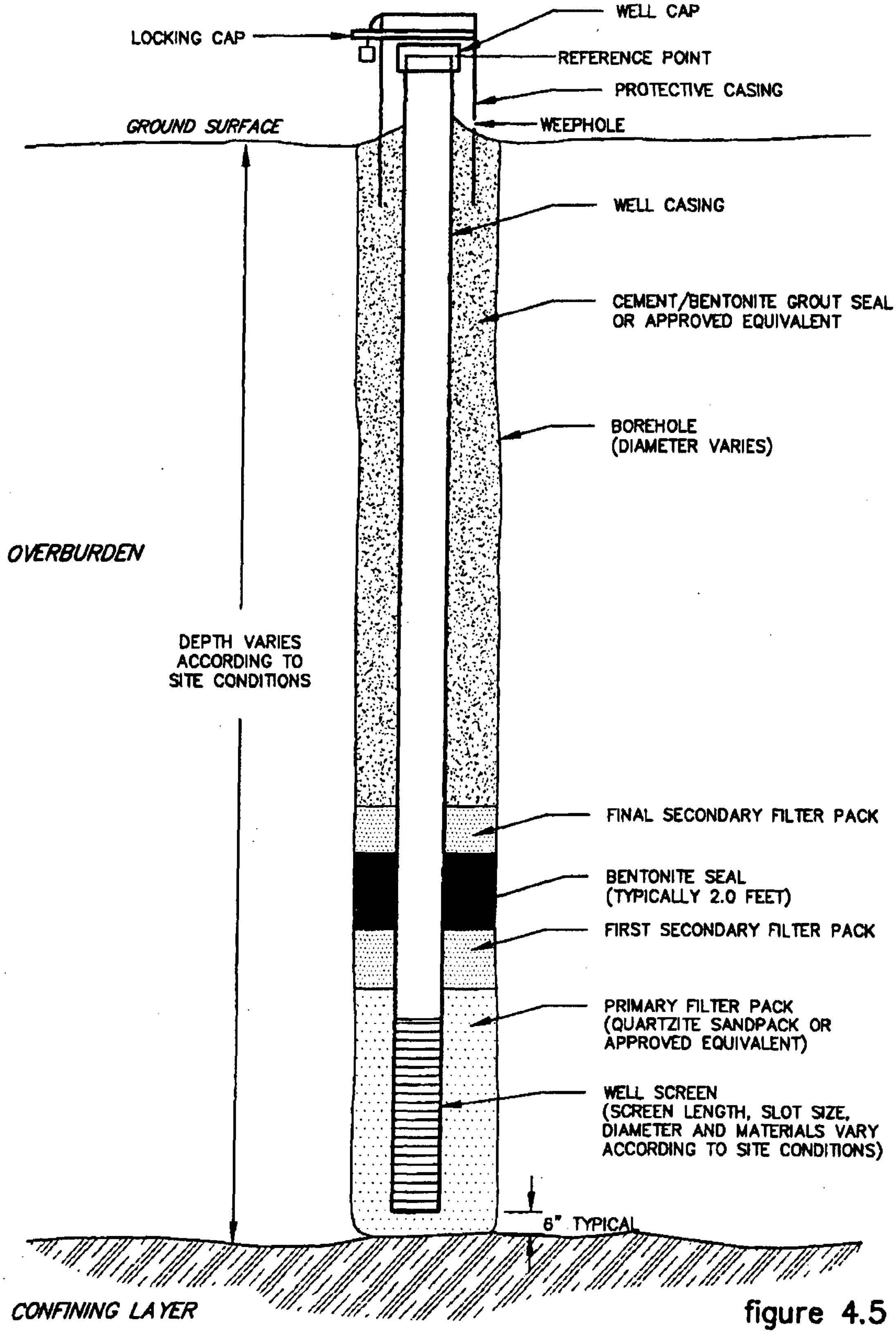


figure 4.5

TYPICAL OVERBURDEN WELL INSTALLATION

CRA

01001-00(029)GN-WA008 SEP 13/1999 REVISION 3

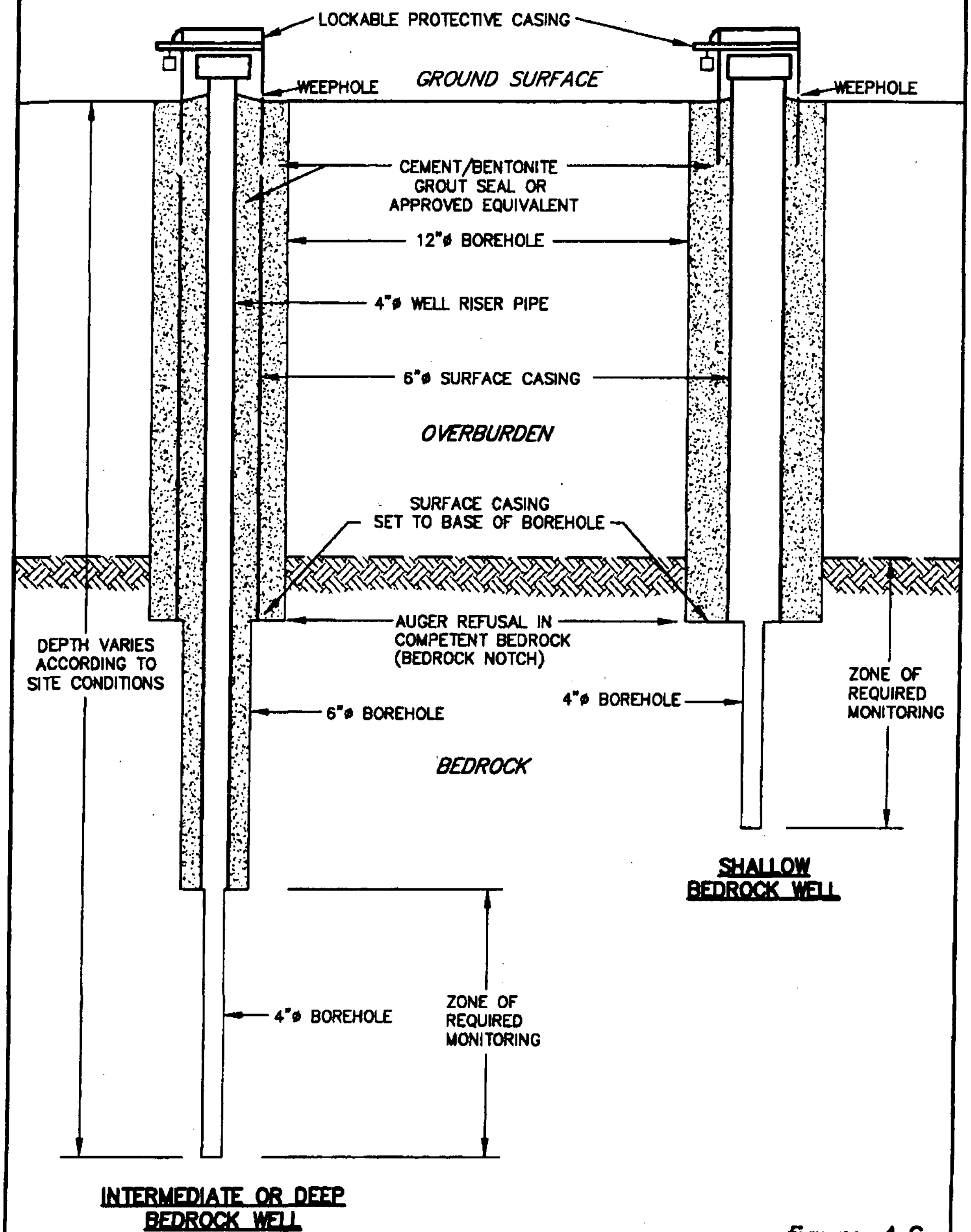


figure 4.6

TYPICAL BEDROCK WELL INSTALLATION

CRA

01001-00(029)GN-WA019 SEP 13/1999 REVISION 3

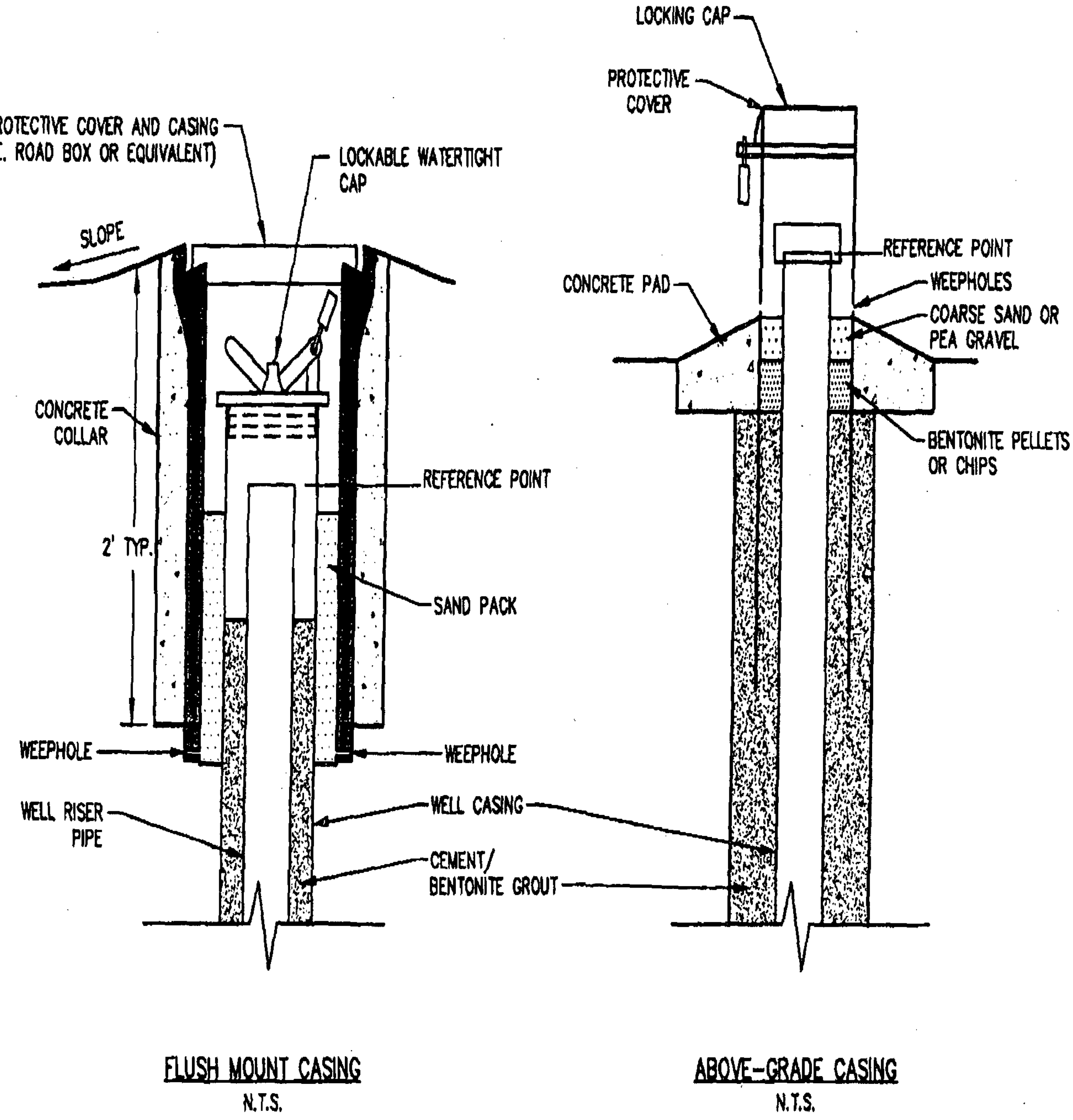
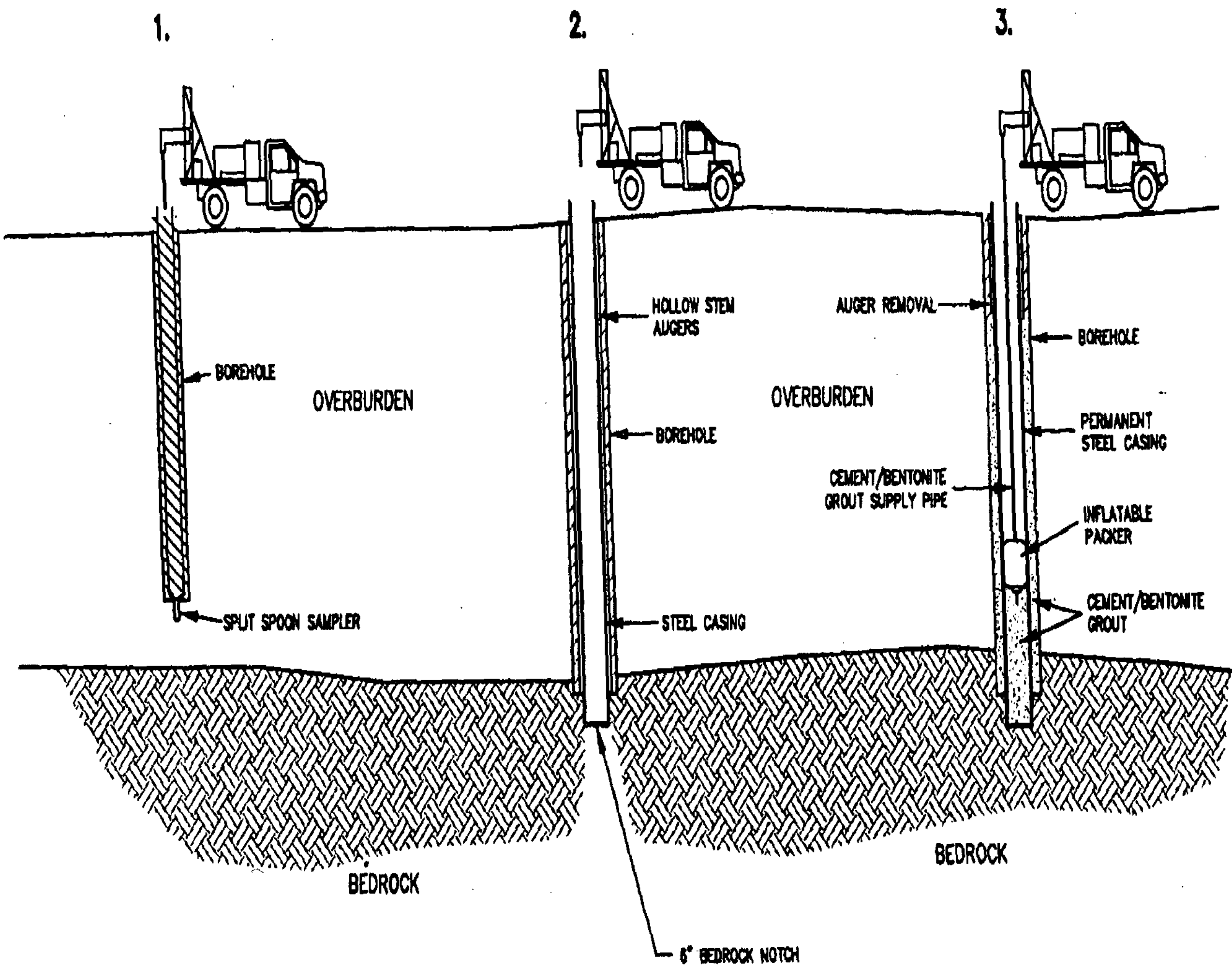


figure 4.7

PROTECTIVE CASING INSTALLATION

CRA

01001-00(029)GN-WA009 SEP 13/1999 REVISION 3



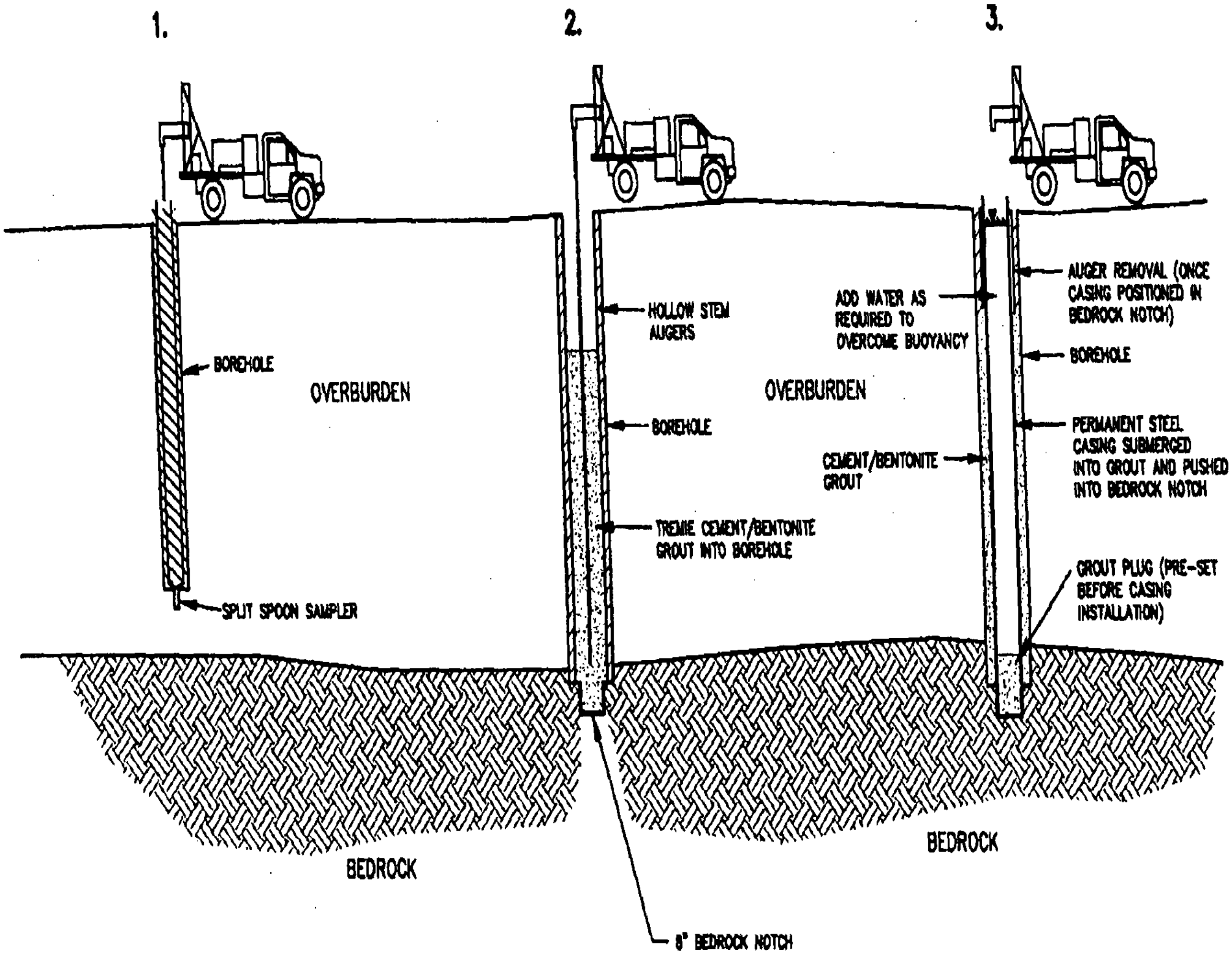
1. AUGER AND SPLIT SPOON TO TOP OF COMPETENT BEDROCK.
2. ONCE TO TOP OF COMPETENT BEDROCK, INSTALL STEEL CASING INSIDE AUGERS TO TOP OF BEDROCK.
3. INSTALL INFLATABLE PACKER INSIDE STEEL CASING (WITHIN 12" OF BOTTOM OF HOLE), INFLATE & COMMENCE PUMPING GROUT THROUGH PACKER, FORCING GROUT TO GROUND SURFACE. (GROUTING PRESSURE NOT TO EXCEED 0.7 P.S.I. PER FOOT OF OVERLYING MATERIAL). ONCE GROUT IS OBSERVED AT GROUND SURFACE, REMOVE AUGERS ADDING GROUT AS REQUIRED TO MAINTAIN CONTINUOUS GROUT ENVELOPE. ONCE ALL AUGERS HAVE BEEN REMOVED, IMMEDIATELY SEAT CASING INTO ROCK BY DRIVING WITH 140lb. HAMMER UNTIL REFUSAL.
4. TOP-OFF GROUT LEVEL ON EXTERIOR OF CASING, AS REQUIRED.

figure 4.8

TYPICAL CASING INSTALLATION – PACKER METHOD

CRA

01001-00(029)GN-WA020 SEP 13/1999 REVISION 3



1. AUGER AND CONTINUOUS SPLIT SPOON TO TOP OF COMPETENT BEDROCK.

2. ONCE TO TOP OF COMPETENT BEDROCK, TREMIE ESTIMATED VOLUME OF GROUT REQUIRED INTO BOREHOLE.

3. IN ADVANCE OF CASING PLACEMENT (IE 48 HOURS), PLACE GROUT PLUG IN CASING END (12 INCHES) AND ALLOW TO SET. SUBMERGE CASING INTO BOREHOLE GROUT AND PUSH INTO PLACE, SEATING WITHIN BEDROCK NOTCH. DRIVE CASING WITH RIG HAMMER IF REQUIRED. DURING CASING PLACEMENT, ADD POTABLE WATER TO OVERCOME BUOYANCY OF EMPTY CASING. TOP OFF GROUT LEVEL AS REQUIRED, DURING AUGER REMOVAL.

figure 4.9

TYPICAL CASING INSTALLATION
- PLUGGED PIPE METHOD

CRA

01001-00(029)GN-WA010 SEP 13/1999 REVISION 3

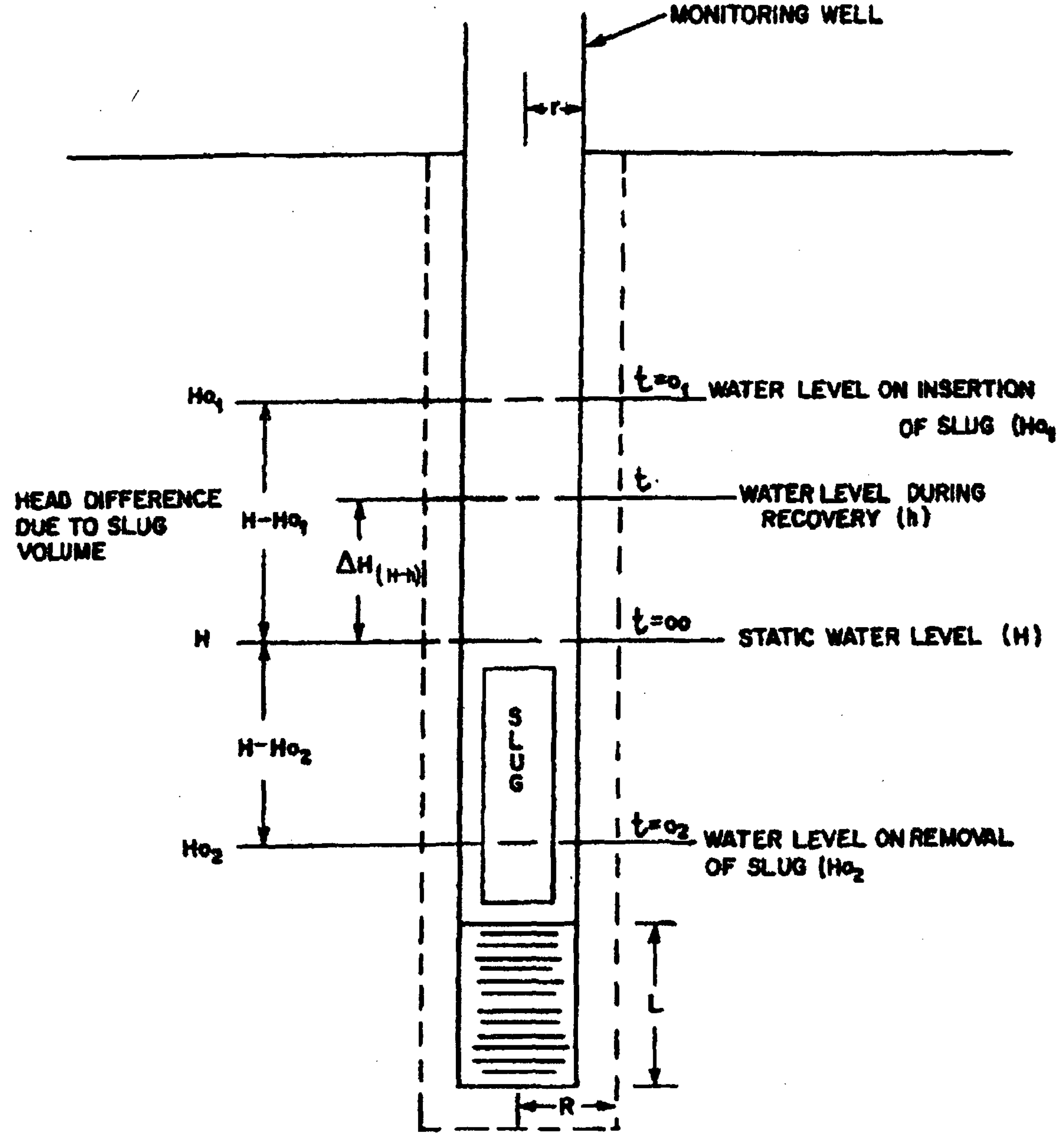


figure 4.15

SINGLE WELL RESPONSE TEST PARAMETERS

CRA

01001-00(029)GN-WA036 SEP 13/1999 REVSION 3

Date: ______________________ *Reference No.* ______________________

GROUNDWATER SAMPLING EQUIPMENT AND SUPPLY CHECKLIST

EQUIPMENT:

- ❑ Well pump/power cable (spare)
- ❑ Generator
- ❑ Bailer(s)
- ❑ Tubing
- ❑ Container for purge water
- ❑ Sample Filtration Equipment

SUPPLIES

- ❑ Gasoline can/gas
- ❑ Polypropylene rope
- ❑ Aluminum foil
- ❑ Paper towels
- ❑ pH buffer solution(s)
- ❑ Conductivity standard solution(s)
- ❑ Decontamination Fluids
  - ❑ 2 - Propanol
  - ❑ Deionized water
  - ❑ Hexane (pesticide grade)
  - ❑ Methanol (pesticide grade)
  - ❑ Acid Rinse for metals
  - ❑ Other
- ❑ Sample jars (extra)
- ❑ Sample jar labels (CRA) materials
- ❑ Cooler(s)/ice packs/packing materials
- ❑ Paper cups
- ❑ Trash bags
- ❑ Bailer brush
- ❑ Sample preservatives
- ❑ Disposable droppers
- ❑ Plastic spray bottles
- ❑ Plastic basin or pan
- ❑ Sample filter (On line or External Filter)
- ❑ Polyethylene sheeting

INSTRUMENTS:

- ❑ Water level indicator
- ❑ Thermometer *
- ❑ pH meter *
- ❑ Conductivity probe *
- ❑ Turbidity meter
- ❑ HNu/OVA/Microtip
- ❑ Air Monitoring Equipment
- ❑ Other ______________________

* - or combination pH/cond/temp meter

PERSONAL PROTECTIVE EQUIPMENT:

- ❑ Tyveks (assorted sizes and types)
- ❑ Latex gloves
- ❑ Hard hats/liner(s)
- ❑ Field overboots
- ❑ Work gloves (cotton and chemical resistant)
- ❑ Safety glasses/or side shields on OSHA-approved prescription lenses
- ❑ First Aid Kit
- ❑ Respirators
- ❑ Check Health and Safety Plan

DOCUMENTATION

- ❑ Chain of Custody Forms
- ❑ Well logs
- ❑ Notebook/Field book
- ❑ Photolog
- ❑ Site pass/badge
- ❑ Federal Express manifests
- ❑ Previous well logs/previous historical well data
- ❑ Site map
- ❑ Blank well data forms

MISCELLANEOUS:

- ❑ Well Cap Keys
- ❑ Bolt cutters
- ❑ Camera/film
- ❑ Knife
- ❑ Spare batteries for instruments
- ❑ Lock Deicer (winter)
- ❑ Reinforced packing tape
- ❑ Pen/pencil/indelible marking pen
- ❑ Tool box
- ❑ Spare locks/keys
- ❑ On Site Transportation (all Terrain Vehicle/Snowmobiles)

Completed by: ______________________ *Date:* ______________________

CRA

CRA 1001/29/FORM SP-07

CRA 1001 (29) Rev. 6, September 13, 1999, Form SP-07

Date ______________________ *Reference No.* ______________

GROUNDWATER SAMPLING • COMPLETION CHECKLIST

PRIOR PLANNING AND COORDINATION:

- ☐ Confirm well numbers, location and accessibility.
- ☐ Review of project documents, sampling Quality Assurance/Quality Control (QA/QC) and site-specific sampling requirements.
- ☐ Historical well data; depth, pH, performance and disposition of purge water.
- ☐ Site access notification and coordination.
- ☐ Coordination with laboratory.
- ☐ Procurement, inventory and inspection of all equipment and supplies.
- ☐ Prior equipment preparation, calibration or maintenance.

FIELD PROCEDURE:

- ☐ Instruments calibrated daily.
- ☐ Sampling equipment decontaminated in accordance with the QAPP.
- ☐ Initial well measurements logged.
- ☐ Well volume calculated and specified volumes removed.
- ☐ Purged water collected if required.
- ☐ Specified samples, and QA/QC samples taken per Quality Assurance Project Plan (QAPP).
- ☐ Samples properly labeled, preserved and packed.
- ☐ Well was secured after completion of sampling.
- ☐ Sample date times, locations and sample numbers have all been recorded in applicable log(s).
- ☐ Samples have been properly stored if not shipped/delivered to lab same day.
- ☐ Samples were shipped with complete and accurate Chain of Custody Record.

FOLLOW-UP ACTIVITIES:

- ☐ All equipment has been maintained and returned.
- ☐ Sampling information reduced and required sample keys and field data distributed.
- ☐ Chain of Custody Records filed.
- ☐ Expendable stock supplies replaced.
- ☐ CRA and client-controlled items returned.
- ☐ Arrange disposal/treatment for purged water and decontamination fluids.
- ☐ Confirm all samples collected.

Completed by: ______________________ *Date:* ______________

CRA

WELL DEVELOPMENT AND STABILIZATION FORM

PROJECT NAME: ______________________ PROJECT NO.: __________

DATE OF WELL DEVELOPMENT: ______________________

DEVELOPMENT CREW MEMBERS: ______________________

PURGING METHOD: ______________________

SAMPLE NO.: ______________________

SAMPLE TIME: ______________________

WELL INFORMATION

WELL NUMBER: ______________________

WELL TYPE (diameter/material) ______________________

MEASURING POINT ELEVATION: ______________________

STATIC WATER DEPTH: ______________________ ELEVATION: __________

BOTTOM DEPTH: ______________________ ELEVATION: __________

WATER COLUMN LENGTH: ______________________

SCREENED INTERVAL: ______________________

WELL VOLUME: ______________________

Note: For 2-inch diameter well: 1 foot = 0.14 gallons (imp) or 0.16 gallons (us)
1 meter = 2 liters

	UNITS	1	2	3	4	5	*TOTAL/ AVERAGE*
VOLUME PURGED (volume/total volume):							
FIELD pH:							
FIELD TEMPERATURE:							
FIELD CONDUCTIVITY:							
CLARITY/TURBIDITY VALUES:							
COLOR:							
ODOR:							
COMMENTS:							

COPIES TO: ____

WELL PURGING FIELD INFORMATION FORM

JOB# ______ - ___

SITE/PROJECT NAME: ____________________

WELL# ______

WELL PURGING INFORMATION

PURGE DATE (MM DD YY)	SAMPLE DATE (MM DD YY)	WATER VOL. IN CASING (LITRES/GALLONS)	ACTUAL VOLUME PURGED (LITRES/GALLONS)

PURGING AND SAMPLING EQUIPMENT

PURGING EQUIPMENT.........DEDICATED Y N (CIRCLE ONE)

SAMPLING EQIPMENT.........DEDICATED Y N (CIRCLE ONE)

PURGING DEVICE [ ] A - SUBMERSIBLE PUMP D - GAS LIFT PUMP G - BAILER X- ________ PURGING OTHER (SPECIFY)

B - PERISTALTIC PUMP E - PURGE PUMP H - WATERRA®

SAMPLING DEVICE [ ] C - BLADDER PUMP F - DIPPER BOTTLE X- ________ SAMPLING OTHER (SPECIFY)

PURGING DEVICE [ ] A - TEFLON D - PVC X- ________ PURGING OTHER (SPECIFY)

B - STAINLESS STEEL E - POLYETHYLENE

SAMPLING DEVICE [ ] C - POLYPROPYLENE X- ________ SAMPLING OTHER (SPECIFY)

PURGING DEVICE [ ] A - TEFLON D - POLYPROPYLENE F - SILICONE X- ________ PURGING OTHER (SPECIFY)

B - TYGON E - POLYETHYLENE G - COMBINATION TEFLON/POLYPROPYLENE

SAMPLING DEVICE [ ] C - ROPE X- ________ (SPECIFY) X- ________ SAMPLING OTHER (SPECIFY)

FILTERING DEVICES 0.45 [ ] A - IN-LINE DISPOSABLE B - PRESSURE C - VACUUM

FIELD MEASUREMENTS

WELL ELEVATION	(m/ft)	GROUNDWATER ELEVATION	(m/ft)
DEPTH TO WATER	(m/ft)	WELL DEPTH	(m/ft)

pH	TURBIDITY	CONDUCTIVITY	SAMPLE TEMPERATURE
(std)	(ntu)	(µm/cm) AT 25°C	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(°C)
(std)	(ntu)	(µm/cm) AT 25°C	(°C)

FIELD COMMENTS

SAMPLE APPEARANCE: ________ ODOR: ________ COLOR: ________ TURBIDITY: ________

WEATHER CONDITIONS: WIND SPEED ________ DIRECTION ________ PRECIPITATION Y/N OUTLOOK ________

SPECIFIC COMMENTS ________

I CERTIFY THAT SAMPLING PROCEDURES WERE IN ACCORDANCE WITH APPLICABLE CRA PROTOCOLS

CRA

DATE PRINT SIGNATURE

CRA 1001 (29) Rev. 6, September 13, 1999, Form SP-10

SAMPLE COLLECTION DATA SHEET - GROUNDWATER SAMPLING PROGRAM

PROJECT NAME ______________________ PROJECT NO. __________

SAMPLING CREW MEMBERS ______________________ SUPERVISOR __________

DATE OF SAMPLE COLLECTION ______________________

[Note: For 2" dia. well, 1 ft. = 0.14 gal (imp) or 0.16 gal (us)]

Sample I.D. Number	Well Number	Measuring Point Elev. (ft. AMSL)	Bottom Depth (ft. btoc)	Water Depth (ft. btoc)	Water Elevation (ft. AMSL)	Well Volume (gallons)	Bailer Volume No. Bails	Volume Purged (gallons)	Field pH	Field Temp.	Field Cond.	Time	Sample Description & Analysis

Additional Comments: ______________________

Copies to: ______________________

CRA

MONITORING WELL RECORD FOR LOW-FLOW PURGING

Project Data:

Project Name: ______________ Date: ______________

Ref. No.: ______________ Personnel: ______________

____

Monitoring Well Data:

Well No.: ______________ Screen Length (ft): ______________

Measurement Point: ______________ Depth to Pump Intake (ft)[1]: ______________

Constructed Well Depth (ft): ______________ Well Diameter, D (in): ______________

Measured Well Depth (ft): ______________ Well Screen Volume, V_s (mL)[2]: ______________

Depth of Sediment (ft): ______________ Initial Depth to Water (ft): ______________

Time	*Pumping Rate (mL/min)*	*Depth to Water (ft)*	*Drawdown from Initial Water Level[3] (ft)*	*pH*	*Temperature °C*	*Conductivity (mS/cm)*	*ORP (mV)*	*DO (mg/L)*	*Turbidity (NTU)*	*Volume Purged, V_p (mL)*	*No. of Well Screen Volumes Purged[4]*

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 2 ft above any sediment accumulated at the well bottom.

(2) The well screen volume will be based on a 5-foot screen length, $V_s=p*(D/2)^2*(5*12)*(2.54)^3$

(3) The drawdown from the initial water level should not exceed 0.3 ft.

(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stablization criteria and appear to be stablizing), No. of Well Screen Volumes Purged= Vp/Vs.

Date: ______________________ *Reference No.* ______________________

WATER LEVEL MEASUREMENT EQUIPMENT AND SUPPLY CHECKLIST

INSTRUMENTS:

- ❑ Water level indicator
- ❑ Steel Tape
- ❑ Oil/Water Interface Probe
- ❑ Air Monitoring Equipment

SUPPLIES

- ❑ Foil
- ❑ Tyveks (assorted sizes and types)
- ❑ Paper towels
- ❑ Decontamination Fluids
  - ❑ 2 - Propanol
  - ❑ Deionized water
  - ❑ Hexane (pesticide grade)
  - ❑ Methanol (pesticide grade)
  - ❑ Other
- ❑ Trash bags
- ❑ Plastic spray bottles

PERSONAL PROTECTIVE EQUIPMENT:

- ❑ Latex gloves
- ❑ Hard hats/liner(s)
- ❑ Field overboots
- ❑ Work gloves (cotton and chemical resistant) Safety glasses/or side shields on OSHA-approved prescription lenses
- ❑ First Aid Kit
- ❑ Respirators
- ❑ Check Health and Safety Plan

DOCUMENTATION

- ❑ Well logs
- ❑ Notebook/Field book
- ❑ Photolog
- ❑ Site pass/badge
- ❑ Previous well logs/previous historical well data
- ❑ Site map
- ❑ Blank well data forms

MISCELLANEOUS:

- ❑ Well Cap Keys
- ❑ Bolt cutters
- ❑ Camera/film
- ❑ Knife
- ❑ Spare batteries for instruments
- ❑ Lock deicer (winter)
- ❑ Pen/pencil/indelible marking pen
- ❑ Tool box
- ❑ Spare locks/keys
- ❑ On Site Transportation (all Terrain Vehicle/Snowmobiles)

Completed by: ______________________ *Date:* ______________________

CRA

Date: ______________________ *Reference No.* ______________

WATER LEVEL MEASUREMENT • COMPLETION CHECKLIST

PRIOR PLANNING AND COORDINATION:

- ❑ Confirm well numbers, location and accessibility.
- ❑ Review of project documents and site-specific Health and Safety Plan.
- ❑ Historical well data; depth, water level measurements.
- ❑ Site access notification and coordination.
- ❑ Procurement, inventory and inspection of all equipment and supplies.
- ❑ Prior equipment preparation, calibration or maintenance.

FIELD PROCEDURE:

- ❑ Instruments calibrated daily.
- ❑ Equipment decontaminated in accordance with the QAPP.
- ❑ Initial well measurements logged.
- ❑ Well was secured after measurements.
- ❑ Measurement date times, locations and results have all been recorded on applicable log(s) or in Field Book.

FOLLOW-UP ACTIVITIES:

- ❑ Questionable measurements field verified.
- ❑ All equipment has been maintained and returned.
- ❑ Water elevation data is reduced and checked.
- ❑ Expendable stock supplies replaced.
- ❑ Confirm all measurements taken.
- ❑ Well keys returned.
- ❑ Field data distributed.

Completed by: ______________________ *Date:* ______________

CRA

WATER LEVEL RECORDS

PROJECT NAME: ______________________ LOCATION: ______________

JOB NO. : ______________________ DATE: ______________

CLIENT: ______________________ ENGINEER/GEOLOGIST: ______________

OBSERVATION WELL	TOP OF CASING ELEVATION A		DEPTH TO WATER B		WATER LEVEL ELEVATION A-B	
	feet	metres	feet	metres	feet	metres

CRA

*Date:*____________________ *Reference No.* ______________

BOREHOLE INSTALLATION/SOIL SAMPLING EQUIPMENT AND SUPPLY CHECKLIST

INSTRUMENTS:

- ❑ Steel Tape (50 foot)
- ❑ Air Monitoring Equipment
- ❑ Water Level Meter
- ❑ Pocket Penetrometer

SUPPLIES

- ❑ Foil
- ❑ Plastic Sample Bags
- ❑ Paper towels
- ❑ Decontamination Fluids (as required by QAPP)
- ❑ Deionized water resistant)
- ❑ Labels
- ❑ Sample knives
- ❑ Trash bags
- ❑ Plastic spray bottles
- ❑ Sampling Glassware
- ❑ Coolers

PERSONAL PROTECTIVE EQUIPMENT:

- ❑ Tyveks (assorted sizes and types)
- ❑ Protective gloves
- ❑ Hard hats/liner(s)
- ❑ Field overboots
- ❑ Work gloves (cotton and chemical
- ❑ Safety glasses or OSHA-approved prescription lenses
- ❑ First Aid Kit
- ❑ Respirators and Cartridges
- ❑ Check Health and Safety Plan

DOCUMENTATION

- ❑ Notebook/Field book
- ❑ Photolog
- ❑ Site pass/badge
- ❑ Previous well logs/previous historical well data
- ❑ Site map
- ❑ Access Agreement Documentation
- ❑ Utility Clearance Documentation
- ❑ Stratigraphic Log (Overburden) - at least one for each 20 feet of drilling
- ❑ Chain-of-Custody Forms

MISCELLANEOUS:

- ❑ Camera/film pen
- ❑ Spare batteries for instruments
- ❑ Carpenters Rule (6 foot)
- ❑ Clipboard
- ❑ Indelible Pen/pencil/indelible marking
- ❑ Tool box
- ❑ Spare locks/keys
- ❑ On Site Transportation (all Terrain Vehicle/Snowmobiles)

* Do not use pen with water soluble ink

*Completed by:*____________________ *Date:* ______________

CRA

Date: ______________________ *Reference No.* ______________

DRILLING/WELL CONSTRUCTION CHECKLIST

PRE-DRILLING SITE REVIEW

Private Property:
- ❑ Access permission
- ❑ Underground utilities located
- ❑ Boring locations clearly marked

Public Right-of-Way:
- ❑ Copies of permits
- ❑ Boring locations clearly marked
- ❑ Utility services notified
- ❑ Underground utilities marked/drilling locations cleared
- ❑ Documentation of utility clearance or clearance number
- ❑ Prepared for traffic control requirements

General:
- ❑ Well permits or construction permits required
- ❑ Site personnel notified

DRILL CREW AND EQUIPMENT

- ❑ Job requirements reviewed with the drill crew
- ❑ Job safety requirements reviewed with drill crew

FIELD CLEANING

- ❑ Cleaning station selected
- ❑ Onsite water and power
- ❑ Casing, well screen, etc. field cleaned

DRILLING

- ❑ Driller checked for utility clearance
- ❑ Borehole at the EXACT location cleared for utilities
- ❑ First four feet hand-augered
- ❑ Drilling procedure in accordance with work plan
- ❑ Measured first water level
- ❑ Drilling returns (cuttings or mud) properly contained
- ❑ Soil sampling tools field cleaned between samples
- ❑ Measured length of augers, rods, casing, etc.
- ❑ Sampled any added fluids

WELL CONSTRUCTION

- ❑ Recorded type of and quantity of materials used
- ❑ Measured the depths (top of filter pack, top of seal, etc.)
- ❑ Measured casing/screen lengths and diameters
- ❑ Surface completion neat and professional

GENERAL

- ❑ All boring log entries completed before moving to next hole
- ❑ Well completion detail completed
- ❑ Survey and plot borehole location
- ❑ Survey elevation of top-of-casing
- ❑ Site policed, trash removed, pavement swept, etc.
- ❑ Drums in inconspicuous area

Completed by: ______________________ *Date:* ______________

CRA

Date: ______________________ *Reference No.* ______________________

BOREHOLE INSTALLATION AND SUBSURFACE SOIL SAMPLING • COMPLETION CHECKLIST

PRIOR PLANNING AND COORDINATION:

- ☐ Confirm borehole/sample locations and numbers.
- ☐ Review of project documents and site-specific Health and Safety Plan.
- ☐ Site access notification and coordination.
- ☐ Prior equipment preparation, calibration or maintenance.

FIELD PROCEDURE:

- ☐ Instruments calibrated daily.
- ☐ Equipment decontaminated in accordance with QAPP.
- ☐ Borehole/sampling details logged in appropriate field book or on field form.
- ☐ Borehole locations field measured.
- ☐ Borehole survey scheduled/completed (if required).
- ☐ Borehole backfill completed in accordance with Work Plan.
- ☐ Utility locates/approvals completed.

FOLLOW-UP ACTIVITES:

- ☐ Confirm all samples/boreholes required were completed.
- ☐ Field notes reviewed, checked, and distributed.
- ☐ All equipment has been maintained and returned.
- ☐ Expendable stock supplies replaced.
- ☐ Site keys returned.

Completed by: ______________________ *Date:* ______________________

CRA

STRATIGRAPHY LOG (OVERBURDEN)

PAGE ___ OF ___

PROJECT NAME ______________________
PROJECT NUMBER ______________________
CLIENT ______________________
LOCATION ______________________

DRILLING CONTRACTOR ______________________
DRILLER ______________________
SURFACE ELEVATION ______________________
WEATHER (A.M.) ______________________
(P.M.) ______________________

HOLE DESIGNATION ______________________
DATE/TIME STARTED ______________________
DATE/TIME COMPLETED ______________________
DRILLING METHOD ______________________
CRA SUPERVISOR ______________________

STRATIGRAPHIC INTERVALS (DEPTHS IN ft/m BGS)			SAMPLE DESCRIPTION	SAMPLE DETAILS							PID / FID (ppm)	CHEMICAL ANALYSIS	GRAIN SIZE
FROM	AT	TO	ORDER OF DESCRIPTORS: SOIL TYPE SYMBOL(S) - MAIN COMPONENT(S), (NATURE OF DEPOSIT), SECONDARY COMPONENTS, RELATIVE DENSITY/CONSISTENCY, GRAIN SIZE/PLASTICITY, GRADATION/STRUCTURE, COLOUR, MOISTURE CONTENT, SUPPLEMENTARY DESCRIPTORS NOTE: PLASTICITY DETERMINATION REQUIRES THE ADDITION OF MOISTURE IF THE SAMPLE IS TOO DRY TO ROLL (INDICATE IF MOISTURE WAS ADDED OR NOT).	SAMPLE #	SAMPLING METHOD	PENETRATION RECORD SPLIT SPOON BLOWS (RECORD N-VALUES & RECOVERIES) 6"	6"	6"	6"	SAMPLE INTERVAL			

NOTES AND COMMENTS

DEPTH OF BOREHOLE CAVING ________ DEPTH OF FIRST GROUNDWATER ENCOUNTER ________ TOPSOIL THICKNESS ________
WATER LEVEL IN OPEN BOREHOLE ON COMPLETION ________, AFTER ____ HOURS ____
COMPLETION DETAILS: ______________________

NOTE: FOR EACH SPLIT-SPOON SAMPLE, RECORD BLOW COUNTS, N-VALUE, SAMPLE RECOVERY LENGTH, AND SAMPLE INTERVAL.

CRA

SOIL CLASSIFICATION SYSTEM (MODIFIED U.S.C.S.)

MAJOR DIVISIONS			GROUP SYMBOL	TYPICAL DESCRIPTION
HIGHLY ORGANIC SOILS			PT	PEAT AND OTHER HIGHLY ORGANIC SOILS
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN NO. 200 SIEVE SIZE)	GRAVELS MORE THAN HALF OF COARSE FRACTION LARGER THAN NO. 4 SIEVE SIZE	CLEAN GRAVELS	GW	WELL GRADED GRAVEL, GRAVEL-SAND MIXTURES, < 5% FINES
			GP	POORLY GRADED GRAVELS AND GRAVEL-SAND MIXTURES, < 5% FINES
		DIRTY GRAVELS	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES, > 12% FINES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES, > 12% FINES
	SANDS MORE THAN HALF OF COARSE FRACTION SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS	SW	WELL GRADED SANDS, GRAVELLY SANDS, < 5% FINES
			SP	POORLY GRADED SANDS, OR GRAVELLY SAND, < 5% FINES
		DIRTY SANDS	SM	SILTY SANDS, SAND-SILT MIXTURES > 12% FINES
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES > 12% FINES
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES NO. 200 SIEVE SIZE)	SILTS BELOW "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT		ML	INORGANIC SILTS AND VERY FINE SAND, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY
			MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT		CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS
			CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
	ORGANIC SILTS & ORGANIC CLAYS BELOW "A" LINE ON PLASTICITY CHART		OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
			OH	ORGANIC CLAYS OF HIGH PLASTICITY

CONVENTIONAL SOIL DESCRIPTIONS

NON-COHESIVE (GRANULAR) SOIL

RELATIVE DENSITY	BLOWS PER FOOT (N-VALUE)
Very loose	less than 5
Loose	5 to 9
Compact	10 to 29
Dense	30 to 50
Very Dense	greater than 50

COHESIVE (CLAYEY) SOIL

CONSISTENCY	BLOWS PER FOOT (N-VALUE)
Very Soft	0 to 2
Soft	3 to 4
Firm	5 to 8
Stiff	9 to 15
Very Stiff	16 to 30
Hard	greater than 30

GRAIN SIZE CLASSIFICATION

COBBLES	Greater than 3 inches (76 mm)
GRAVEL	3 in. to No. 4 (4.76 mm)
Coarse Gravel	3 in. to 3/4 in.
Fine Gravel	3/4 in. to No. 4 (4.76 mm)
SAND	No. 4 (4.76 mm) to No. 200 (0.074 mm)
Coarse Sand	No. 4 (4.76 mm) to No. 10 (2.0 mm)
Medium Sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine Sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
SILT	No. 200 (0.074 mm) to 0.002 mm
CLAY	Less than 0.002 mm

NOTE: The "No. __ " refers to the standard sieve sizes.

COMPONENT PERCENTAGE DESCRIPTORS

Noun(s) (e.g. SAND and GRAVEL)	35 to 50%
Adjective (e.g. SANDY)	20 to 35%
With	10 to 20%
Trace	Less than 10%

SOIL STRUCTURE TERMS

Stratified	Blocky
Laminated	Lenses/Seams
Fissured	Homogeneous

CRA

01001-00(029)GN-WA23A SEP 13/99 (SP-17) REVISION 3

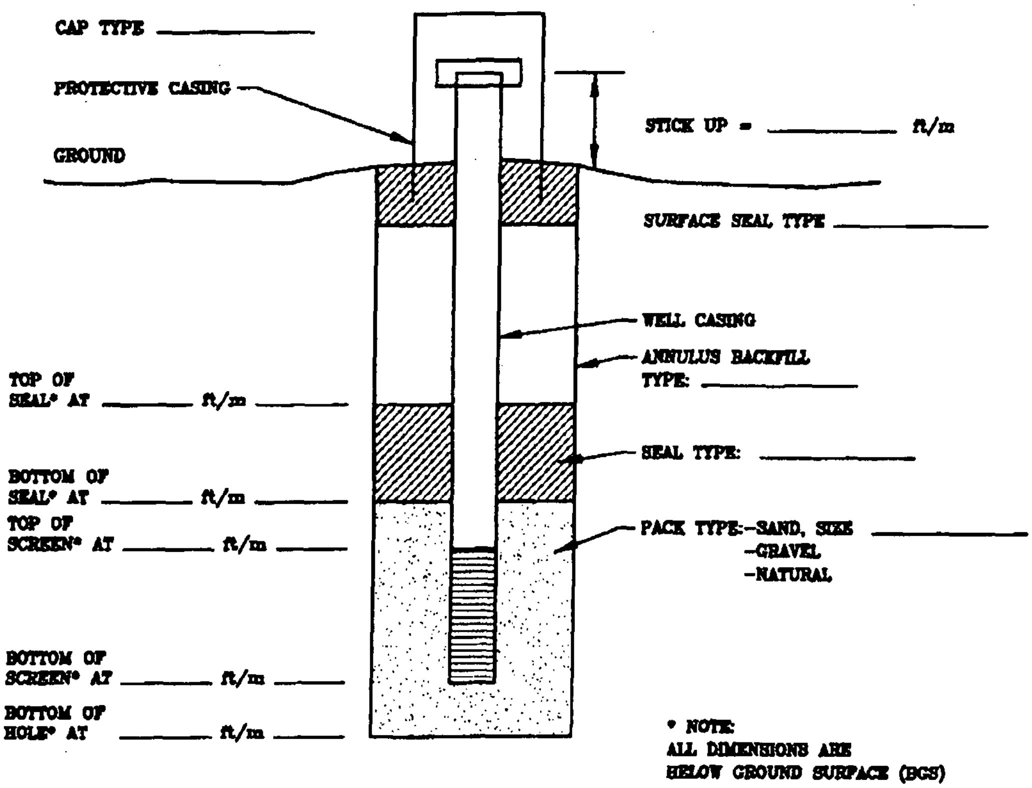
OVERBURDEN INSTRUMENTATION LOG

PROJECT NAME ____________________ HOLE DESIGNATION ____________________

PROJECT NUMBER ____________________ DATE COMPLETED ____________________

CLIENT ____________________ DRILLING METHOD ____________________

LOCATION ____________________ CRA SUPERVISOR ____________________



SCREEN TYPE: ☐ continuous slot ☐ perforated ☐ louvre ☐ other: ____________

SCREEN MATERIAL: ☐ stainless steel ☐ plastic ☐ other: ____________

SCREEN LENGTH: ________ ft/m SCREEN DIAMETER: ________ in/cm SCREEN SLOT SIZE: ________

WELL CASING MATERIAL: ____________ WELL CASING DIAMETER: ____________ in/cm

HOLE DIAMETER: ____________

DEVELOPMENT: METHOD: ____________ DURATION: ____________

CRA

BEDROCK DRILL AND STRATIGRAPHIC LOG

PROJECT NAME ____________ HOLE DESIGNATION ____________ PAGE ____ OF ____
PROJECT NUMBER ____________ DATE COMPLETED ____________ ELEVATIONS:
CLIENT ____________ DRILLING METHOD ____________ TOP OF CASING: ________
LOCATION ____________ SUPERVISOR ____________ GROUND ________

SAMPLE DESCRIPTION	STRAT CHANGE DEPTH	RUN NO.	SAMPLE INTERVAL		% RECOV	RQD%	% WATER RETURN	LAB	TEST INTERVAL	
			FROM	TO					FROM	TO
CRA										

BEDROCK CORING AND DRILLING STRATIGRAPHIC LOG

PAGE ______ OF ______

PROJECT NAME ____________ DRILLING CONTRACTOR ____________ HOLE DESIGNATION ____________

PROJECT NUMBER ____________ DRILLER ____________ DATE/TIME STARTED ____________

CLIENT ____________ SURFACE ELEVATION ____________ DATE/TIME COMPLETED ____________

LOCATION ____________ WEATHER (A.M.) ____________ DRILLING METHOD ____________

(P.M.) ____________ CRA SUPERVISOR ____________

STRATIGRAPHIC INTERVALS			SAMPLE DESCRIPTION	NOTE: USE THESE COLUMNS FOR RECORDING DRILLING RATE AND CORE RECORD (IF CORING)						WATER USAGE
DEPTHS IN FEET/METRES BGS			BEDROCK DESCRIPTION: FORMATION NAME, ROCK TYPE, COLOUR, BEDDING, GRAIN SIZE, TEXTURE, WEATHERING, CEMENTATION, POROSITY, FOSSILS, SUPPL. DESCR.	DRILLING RATE/CORE DRILLING RECORD						
FROM	AT	TO	FRACTURE DESCRIPTION: TYPE, ORIENTATION, SPACING, ROUGHNESS, APERTURE, WEATHERING, INFILLING, SUPPLEMENTARY DESCRIPTORS	RUN NO.	DEPTH FROM START TIME	DEPTH TO END TIME	CORE REC% DRILL RATE	RQD %	FRACTURE INDEX	VOL. WATER LOST PER RUN

NOTES AND COMMENTS ____________

CRA 1490 (12) - Rev. 4 - 09/11/2002, Form SP-20

ROCK DESCRIPTION

DRILLING METHOD: TYPE AND DIAMETER; CORING (NQ, HQ, PQ, ETC), AIR, WATER OR MUD (AND TYPE OF MUD) ROTARY.

DRILLING RATE/CORE RUN: DRILLED RATE FOR EACH DRILLED INTERVAL OR CORE RETRIEVED. LIST START/END TIMES FOR EACH DRILLED INTERVAL OR CORE RUN. DETERMINE RQD AND FRACTURE INDEX FOR CORE. A NEW RQD/FRACTURE INDEX SHOULD BE LISTED IF THE ROCK TYPE CHANGES WITHIN A SINGLE RETRIEVED CORE RUN.

WATER USAGE: RECORD VOLUME OF WATER LOST TO THE FORMATION DURING EACH DRILLED INTERVAL OR CORE RUN. IF DRILLING WITH AIR, RECORD VOLUME OF WATER RETURNED IN EACH DRILLED INTERVAL.

FORMATION NAME: TYPICALLY UNIQUE TO AREA AND AGE OF THE ROCK UNIT. SEE LOCAL BEDROCK GEOLOGY MAPS FOR FORMATION NAMES.

ROCK TYPE: SUCH AS DOLOMITE, LIMESTONE, SANDSTONE, SILTSTONE, MUDSTONE, SHALE, PHYLLITE, SCHIST, GABBRO, ETC (THERE ARE MANY OTHER ROCK TYPE NAMES).

BEDDING:

THICK BEDDED	>60 cm (>2 feet)	THICK LAMINATED	0.5 to 1 cm (1/4 to 1/2 inch)
THIN BEDDED	1 cm to 60 cm (0.5 inches to 2 feet)	THIN LAMINATED	<0.5 cm (<1/4 inch)

GRAIN SIZE: SIZE AND SHAPE OF GRAINS AND CRYSTALS, SUCH AS COARSE, MEDIUM, FINE, MICROCRYSTALLINE, AMORPHOUS

TEXTURE/FABRIC: ARENACEOUS, ARGILLACEOUS, FISSILE, INTERBEDDED, MICACEOUS, EQUIGRANULAR, SACCHAROIDAL, NODULAR, CROSS-BEDDED, LAMINATED, BIOCLASTIC, BURROWED, OOLITIC, FOLIATION, CLEAVAGE, ETC

CEMENTATION: TYPE (SUCH AS SILICA, CALCITE, ETC) AND DEGREE OF CEMENTATION.

FOSSILS: TYPE OF FOSSIL PRESENT, SUCH AS HORN CORAL, COLONIAL CORAL, BRACHIOPOD, GASTROPOD, BRYOZOAN, CRINOID, ETC.

POROSITY: SUCH AS INTERGRANULAR, INTERCRYSTALLINE, INTERFRAGMENTAL, VUGS/VOIDS (SIZE), FOSSIL MOLDS, ETC.

SUPPLEMENTARY DESCRIPTORS: PARTINGS, CRYSTAL VOID INFILLINGS (SIZE OF CRYSTALS AND TYPE, IF KNOWN), STYLOLITES, STRINGERS, MICROFRACTURES (SHORT LENGTH CLOSED FRACTURES), ETC.

THE FOLLOWING ONLY APPLIES TO NATURAL FRACTURES. MECHANICAL FRACTURES CAUSED BY THE DRILLING METHOD ARE COMMON AND CAN BE DETECTED AS THE MECHANICALLY FRACTURED SURFACE WILL BE CLEAN AND THE TWO ADJACENT PIECES WILL FIT BACK TOGETHER VERY CLOSELY. NATURAL FRACTURES OFTEN HAVE WEATHERING/MINERALIZATION ON THE FRACTURE SURFACE OR A ROUGH SURFACE CAUSED BY DISSOLUTION.

FRACTURE DESCRIPTION

FRACTURE TYPE: BEDDING PLANE, CROSS-CUTTING, JOINT (NO MOVEMENT), FAULT (MOVEMENT), PLANAR, ARCUATE.

ORIENTATION: HORIZONTAL, DIPPING (AND DEGREE OF DIP FROM HORIZONTAL), NEAR-VERTICAL, VERTICAL.

SPACING:

VERY CLOSE	<5 cm (<2 inches)
CLOSE	5 to 30 cm (2 inches to 12 inches)
MODERATE	0.3 to 1 metre (1 foot to 3 feet)
WIDE	1 to 3 metres (3 feet to 10 feet)
VERY WIDE	>3 metres (>10 feet)

ROUGHNESS: ROUGH, SMOOTH, SLICKENSIDED, WAVY.

APERTURE: PERPENDICULAR DISTANCE BETWEEN ADJACENT WALLS, TYPICALLY TIGHT (<0.25 mm), OPEN (>0.25 mm), CLOSED (ZERO APERTURE). DRILL CORE PIECES CANNOT BE FIT TOGETHER TO GET AN ACCURATE MEASURE OF APERTURE. APERTURE WIDTH STRONGLY AFFECTED BY DRILLING (WASHING, PLUCKING OF FRACTURE SURFACE).

WEATHERING:
- UNWEATHERED - NO VISIBLE WEATHERING
- SLIGHTLY WEATHERED - OXIDIZED
- MODERATELY WEATHERED - DISCOLOURED INTO ROCK MATRIX
- HIGHLY WEATHERED - ROCK MATRIX IS FRIABLE
- COMPLETELY WEATHERED - ROCK MATRIX IS SOIL-LIKE

INFILLING: SUCH AS CALCITE, GYPSUM, PYRITE, OR OTHER MINERALIZATION, SANDY, SILTY, CLAYEY, ETC.

RQD: ROCK QUALITY DESIGNATION. CALCULATED AS THE RATIO OF THE SUM OF THE LENGTH OF ALL PIECES OF CORE GREATER THAN 10 cm (4 inches) IN LENGTH (MEASURED ALONG THE CENTERLINE) DIVIDED BY THE TOTAL LENGTH OF THE CORE RUN (NOT THE LENGTH OF THE CORE RECOVERED). NOTE THAT MECHANICAL FRACTURES CAUSED BY THE DRILLING METHOD OR LONG VERTICAL FRACTURES DO NOT COUNT FOR THIS CALCULATION.

FRACTURE INDEX: NUMBER OF FRACTURES PER FOOT OF DRILL CORE, LISTED AS #FRACTURES/FOOT. FOR FRAGMENTED CORE USE "NON-INTACT" (NI).

Note: FOAM PIPE WRAP OR SIMILAR ITEMS ARE USEFUL SPACERS FOR MISSING OR REMOVED CORE. A NOTE SHOULD BE INCLUDED TO INDICATE THE DEPTH INTERVAL OF CORE REMOVED.

Date: ____________________ *Reference No.* ____________________

EQUIPMENT AND SUPPLY CHECKLIST
- **SURFACE WATER SAMPLING**
- **SEDIMENT SAMPLING**
- **FLOW MEASUREMENT**

INSTRUMENTS:

- ❑ Measuring tape
- ❑ Steel tape (100 ft)
- ❑ Air monitoring equipment
- ❑ Velocity meter
- ❑ Flow meter
- ❑ Depth recorder/data logger
- ❑ Calculator
- ❑ Laptop computer with communication cable
- ❑ Stop watch
- ❑ Camera

EQUIPMENT:

- ❑ Sampling telescopic pole
- ❑ Sampling scoop/bucket
- ❑ Boat/motor (if required)
- ❑ Bailers
- ❑ Kemmerer/Van Dorn sampler
- ❑ Peterson/Ponar Dredge
- ❑ Core sampler/split spoon sampler
- ❑ Stainless steel mix bowl
- ❑ Hand tools
- ❑ Other ____________________

SUPPLIES

- ❑ Foil
- ❑ Paper towels
- ❑ Decontamination Fluids (as required by Work Plan)
- ❑ Deionized Water
- ❑ Labels
- ❑ Sample knives
- ❑ Trash bags
- ❑ Sample Glassware
- ❑ T-bars/stakes
- ❑ Duct tape
- ❑ Markers
- ❑ Film
- ❑ Paint
- ❑ Thumbtacks

DOCUMENTATION

- ❑ Topographic Maps
- ❑ Notebook/Field book
- ❑ Photolog
- ❑ Site pass/badge
- ❑ Site Map
- ❑ Work Plan

PERSONAL PROTECTIVE EQUIPMENT:

- ❑ Waders/overboots
- ❑ Tyveks (if required)
- ❑ Life vest
- ❑ Safety line
- ❑ Protective gloves
- ❑ Hardhat
- ❑ Safety glasses
- ❑ First Aid Kit
- ❑ Check Health and Safety Plan

Completed by: ____________________ *Date:* ____________________

CRA

*Date:*_______________________________ *Reference No.* ____________________

SURFACE WATER/SEDIMENT SAMPLING
• COMPLETION CHECKLIST

PRIOR PLANNING AND COORDINATION:

- ❑ Confirm sediment/water sample locations and number.
- ❑ Confirm required flow measurements have been collected
- ❑ Review of project documents and site-specific Health and Safety Plan.
- ❑ Site access notification/utility clearance coordination.
- ❑ Prior equipment preparation, calibration or maintenance.

FIELD PROCEDURE:

- ❑ Instruments calibrated daily.
- ❑ Equipment decontaminated in accordance with QAPP.
- ❑ Sampling details logged in appropriate field book or on field form.
- ❑ Sample site survey or field ties completed (if required).
- ❑ Flow measurement details collected and checked.

FOLLOW-UP ACTIVITIES:

- ❑ Final confirmation that all sample flow requirements were accomplished.
- ❑ Field notes reviewed, checked, and distributed.
- ❑ All equipment has been maintained and returned.
- ❑ Expendable stock supplies replaced.

*Completed by:*_______________________________ *Date:* ____________________

CRA

SINGLE WELL RESPONSE TEST - DATA

Project No.: ____________________ Well Number: ____________________

Date: ____________________ Time: ____________________

Location: ______________ Well Dia. __________ Borehole Dia. ______________

CRA Supervisor: ____________________ Slug Dimensions (l x ø) ______________

Slug Displacement (H - Ho) ______________ Screen Interval ________ to ________ amsl

Aquifer Thickness: __________ Datum Point ______ Datum Point Elevation (amsl)

Static Water Level Conditions ☐ Rising ☐ Falling

Run 1						Run 2					
Time			Water Level			Time			Water Level		
Hr.	Min.	Sec.	(h)	H-h	$\frac{H-h}{H-Ho_1}$	Hr.	Min.	Sec.	(h)	H-h	$\frac{H-h}{H-Ho_2}$

CRA 1001/29/FORM SP-24

CRA 1001 (29) Rev. 3, September 13, 1999, Form SP-24

APPENDIX F

REPORTING AND DATA VALIDATION

REPORTING AND DATA VALIDATION

CRA will develop a Hydrogeologic Investigation Report (Report) following completion of the investigation activities. The Report will present the data that has been gathered as part of the investigation, an analysis of the data, and conclusions about the tritium in groundwater at the Station and the potential impacts that could be considered as candidates for remedial action. If, based on the investigation results, additional phases of work are required, CRA will prepare an interim report that contains the figures and tables described below. The Report will include the following information:

- A description of the various field activities performed during the course of the investigation;
- A description of the physical characteristics of the Station and Station setting, including topography, hydrology, hydrogeology, and geology;
- An identification of potential exposure pathways;
- A description of the extent of tritium in groundwater, and the interaction of that tritium in groundwater with surface water bodies;
- A discussion of potential routes of migration for the tritium in groundwater and factors expected to affect migration;
- An identification of areas where interim response activities could be required;
- An identification of areas where remedial action could ultimately be considered including an evaluation of the types of remedial action that could be implemented;
- Additional relevant information, including but not limited to, Station-specific documents, field forms, and analytical data; and
- A data validation report, including a brief summary of QA/QC information, as is described below.

CRA's data validation of the analytical data will be conducted to establish the representativeness and completeness of the data reported. CRA will evaluate the following data in a data validation that will be appended to the Report. The data validation will include the following information and evaluations:

- Instrument performance;
- Initial and continuing calibration;
- Laboratory method blanks and field blanks;
- System monitoring and surrogate compounds;
- Matrix spike/matrix spike duplicate samples;

- Laboratory control samples;
- Internal standards;
- Interference check samples;
- Serial dilution samples;
- Compound quantitation;
- System performance;
- Field QC sample data; and
- Overall data assessment.

The report will also include a series of tables that will present and summarize the data collected during the investigation. The tables will include the following at a minimum:

TABLE 1	SUMMARY OF PERMANENT AND TEMPORARY MONITORING WELL SPECIFICATIONS
TABLE 2	SUMMARY OF MONITORING WELL PURGING PARAMETERS
TABLE 3	SUMMARY OF GROUNDWATER ELEVATIONS
TABLE 4	SUMMARY OF PRIVATE WATER WELLS IN THE VICINITY OF THE STATION
TABLE 5	SUMMARY OF VERTICAL GRADIENTS AT WELL CLUSTER LOCATIONS *(if applicable)*
TABLE 6	SUMMARY OF GENERAL WATER QUALITY IN BLOWDOWN LINE AND BACKGROUND GROUNDWATER SAMPLES *(if applicable)*
TABLE 7	SUMMARY OF TRITIUM CONCENTRATIONS IN MONITORING WELLS AND SURFACE WATER SAMPLES
TABLE 8	SUMMARY OF TRITIUM CONCENTRATIONS IN PRIVATE WELLS *(if applicable)*

The report will include, at a minimum, the following figures to present the results of the investigation:

FIGURE 1	SITE LOCATION MAP
FIGURE 2	GENERAL SITE BOUNDARIES AND FEATURES
FIGURE 3	PRIVATE WATER SUPPLY WELL LOCATIONS
FIGURE 4	SCHEMATICS
FIGURE 5	GROUNDWATER MONITORING LOCATIONS
FIGURE 6	SURFACE WATER MONITORING LOCATIONS
FIGURE 7	REGIONAL STRATIGRAPHIC CROSS-SECTION
FIGURE 8	SITE-SPECIFIC GEOLOGIC CROSS-SECTION
FIGURE 9	HYDROGEOLOGIC UNIT ISOPACH *(if applicable)*
FIGURE 10	VERTICAL GROUNDWATER GRADIENTS *(if applicable)*
FIGURE 11	GROUNDWATER ELEVATION CONTOURS - SHALLOW ZONE
FIGURE 12	GROUNDWATER ELEVATION CONTOURS - DEEP ZONE *(if applicable)*
FIGURE 13	TRITIUM RESULTS - SHALLOW GROUNDWATER ZONE
FIGURE 14	TRITIUM RESULTS - DEEP GROUNDWATER ZONE *(if applicable)*
FIGURE 15	MAXIMUM DETECTIONS OF TRITIUM IN THE SHALLOW GROUNDWATER ZONE
FIGURE 16	MAXIMUM DETECTIONS OF TRITIUM IN THE DEEP GROUNDWATER ZONE *(if applicable)*
FIGURE 17	HYDROGEOLOGIC CROSS-SECTION LOCATIONS
FIGURE 18	HYDROGEOLOGIC CROSS-SECTION (A-A')
FIGURE 19	HYDROGEOLOGIC CROSS-SECTION (B-B')
FIGURE 20	MAXIMUM DETECTIONS OF TRITIUM IN PRIVATE WELLS *(if applicable)*

The data analysis and conclusions presented in the Report will form the basis for potential remedial action, if required. Data gaps identified in the hydrogeologic investigation that are necessary to complete the Report will be identified and filled by the collection of additional data after receiving authorization from Exelon.

The Report will also indicate a proposed Groundwater Monitoring Plan for the Station. CRA will develop the monitoring plan details with Exelon. The monitoring plan details will be presented in an appendix to the Report.