

**Sampling and Analysis Plan  
Post Incident Site Investigation  
For Groundwater, Ash / Residue, and Collected Firewater  
Runoff  
(Revision No. 1)**

*Prepared for:*

**EQ-Industrial Services Inc.  
2701 North I-94 Service Drive  
Ypsilanti, MI 48198  
For the EQ-North Carolina Facility**

*Prepared by:*

**URS Corporation-North Carolina  
1600 Perimeter Park Drive  
Morrisville, NC 27560**

**October 15, 2006**

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## **1.0 INTRODUCTION**

This document presents the Sampling and Analysis Plan (SAP) for the Post Incident Site Investigation (SI) at the EQ-North Carolina (EQ-NC) facility located in Apex, NC. The location of EQ-NC Facility is illustrated on Figure 1.

### **1.1 PURPOSE AND SCOPE**

The purpose of this sampling plan investigation is to determine potential environmental impacts due to a release of hazardous waste at the EQ-North Carolina Facility. The potential release would have occurred during a fire that occurred at the facility on October 5, 2006. During an initial site visit, URS personnel noted that there appeared to be no sign of contaminant release outside of the facility footprint. Additionally, personnel involved with extinguishing the fire indicated that a sand berm was placed around the building before any extinguishing activities were initiated, and that all (if any) surface water run-off were contained and transferred to storage tanks on site.

The overall objective for this investigation includes:

- Collection of groundwater samples from on-site monitoring wells.
- Collection of potential ash or ash like residue from the remaining portions of the incident site
- Collect water samples from the on-site storage tanks that contain water (from firefighting and runoff) collected from the site.

This SAP presents objectives and the field activities necessary to collect the above referenced data. All work described herein will be completed in accordance with a site specific Health and Safety Plan (HASP) to be developed under separate cover.

### **1.2 WORK PLAN ORGANIZATION**

This WP is organized into four (4) sections plus appendices, as described below:

- Section 1 presents the introduction, purpose and scope, and WP organization.
- Section 2 presents the project organization, including responsibilities of key personnel and project schedule.
- Section 3 presents a field sampling plan (FSP), including Site background and planned field activities.
- Section 4 present the elements of Quality Assurance and Quality Control

- Appendix A presents the Standard Operating Procedures
- Appendix B provides examples of field sheets to be completed during field activities
- Appendix C presents the Contract Required Quantitation Limits

## 2.0 PROJECT ORGANIZATION

This section provides information on project organization for this sampling project, identifying the roles and responsibilities of key personnel and project schedule.

### 2.1 ROLES AND RESPONSIBILITIES

The project organization and the responsibilities of key personnel are defined below.

URS Management Team: The URS Project Management Team are responsible for assuring that projects are properly staffed and are ultimately responsible for the technical direction and quality of the work performed by URS personnel. They are responsible for establishing appropriate budgets and schedules, making available appropriate forms of training, and monitoring the performance of the staff. They are also responsible for monitoring the implementation of the quality assurance program. Specific responsibilities include:

- Assure the provision of necessary facilities, equipment, and funding;
- Support the efforts of the Field Manager, QA Officer (QAO), and Laboratory Manager(s) in all matters concerning the quality of work products; and
- Assure effective response to corrective action requirements identified by any member of the project team.

Task Leader: The URS Task Leader will be responsible for the day-to-day management of field operations. He schedules and plans the work activities of field staff, provides periodic reports on the progress of work, and reviews the field logs and other forms of field documentation. He will work closely with the QAO to plan and schedule audits, if any, assure proper training of field personnel, and immediately communicate any situations that may affect the quality of work products. The Task Leader is responsible for assuring that the work proceeds according to schedule, and bears responsibility for guaranteeing the technical quality of the work. Specific responsibilities include:

- Oversee and monitor performance of staff;
- Plan the activities of and coordinate field personnel on specific assignments;
- Provide a liaison between the client, field, laboratory staff, and any other subcontractors;

- Effectively carry out the URS QA Program and this QAP; and
- Assure completion of corrective actions, as needed, of deficiencies identified.

URS Quality Assurance Officer: The QAO is responsible for implementation of both the URS QA Manual (incorporated by reference) and the SAP in both field and laboratory operations. The Project Manager delegates to the QAO the authority to take any actions necessary to ensure the reliability and validity of work and deliverables according to this QAPP. The QAO has, by definition, a level of authority coequal to that of the Task Leader and Laboratory QA Manager. She is responsible for developing and implementing procedures to appropriately document all project activities, to provide specific means of measuring conformance to specifications, managing the corrective actions program, and providing periodic reports to management. Specific responsibilities include:

- Develop, document, and carry out QA activities to ensure that appropriate QC measures are being carried out and documented
- Ensure all records related to quality assurance are documented and maintained securely and retrievably;
- Conduct periodic performance audits and/or surveillances to measure conformance to specifications;
- Prepare periodic quality reports and QA sections of final reports;
- Ensure corrective actions are carried out and documented in a way that precludes future occurrences;
- Review and approve SOPs, training records, and purchasing actions; and
- Acquire and maintain required certifications, and manage performance evaluation tests.

Technicians and Analysts: Field staff and analysts are responsible for executing their work assignments in strict conformance to documented procedures and for the immediate identification of any conditions adverse to the quality performance of the work or work products. They are responsible for acquainting themselves with the technical requirements of any work assigned and seeking training or guidance as necessary to comply with those requirements. They are responsible for documenting their activities according to applicable SOPs and reviewing their own work and the work of others presented to them for peer review. They will immediately cause work to cease on any activity that in their judgment does not meet applicable quality and safety standards, will

appropriately document and report such conditions to management and will be active in the resolution of any such conditions. Specific responsibilities include the following:

- Ensure that all work is performed according to the applicable specifications;
- Ensure that QC measures are being carried out and documented;
- Ensure the quality of work and work products; and
- Communicate QA and safety concerns to management.

### *Laboratory Analytical Services:*

URS has in place several master service agreements with North Carolina Division of Water Quality (NC DWQ) certified labs. URS will select labs for individual sampling tasks based on capacity, analytical requirements and turn-around time. In this role, they will provide all of the equipment, materials, and manpower to perform the required laboratory analytical services inclusive of all QA/QC procedures and documentation.

### *Schedule*

Sampling will be initiated as soon as this plan is approved by the North Carolina Division of Waste Management. Due to the comprehensive nature of the analyses, laboratory turn-around time for some parameters is likely to be several days. Therefore, initiation of waste characterization and management activities will proceed prior to receipt of analytical data. Ongoing air monitoring will continue during work within the building footprint, and engineering controls will be exercised to minimize generation of any particulates during these activities.

## **3.0 FIELD SAMPLING PLAN**

This section presents the field sampling plan for the preliminary site investigation, including Site background and planned field activities.

### **3.1 SITE BACKGROUND**

The EQ facility is a RCRA Permitted waste management facility permitted to manage a variety of waste streams. Containerized wastes are stored in a 90' by 130' building located in the center of the property. There are six bays within the building where containers with similar waste characteristics are stored. Through the center of the building is a 16 foot wide concrete staging area elevated above the bays. On the west end of the building the staging area is 30 feet wide to allow a staging area dedicated to consumer commodities. Each of the bays is pitched toward the center of the building, where any spills or runoff are contained within the bay and pumped to a containment system. The building was constructed in 1992, and contained no insulation or other fibrous construction material.

On Thursday October 5, 2006 a fire began that destroyed the storage structure. The fire was for the most part allowed to burn out, with final extinguishing completed by an EQ contractor on Friday October 6, 2006. The metal structure was delicately removed with a backhoe to avoid disturbing the contents of the building, and consolidated into three piles.

### **3.2 PLANNED FIELD ACTIVITIES**

In order to meet the objectives outlined in Section 1, field activities have been planned to be performed concurrently and as soon as possible. These activities generally consists of sampling of three groundwater monitoring wells at the site, sampling of two storage tanks containing collected runoff, and collection of ash/residue samples from the remains of the structure.

A more detailed description of the field activities associated with this plan is presented in the following sections.

#### **3.2.1 Groundwater Sampling**

URS proposes to collect groundwater samples from the three on-site monitoring wells MW-1, MW-2, and MW-3 in accordance with the URS standard operating procedures included as **Appendix A**. Static water levels will be measured in all wells prior to purging using an electronic water-level indicator. All non-dedicated and non-disposable

equipment to go down the well will be decontaminated in accordance with URS standard operating procedures included as **Appendix A**.

Monitoring well purging and sampling procedures are described in the SOPs contained in **Appendix A**. Monitoring wells will be purged using a peristaltic pump with new, dedicated high density-polyethylene tubing. During groundwater purging, flow from the discharge tube will be directed into a flow-through cell for collection of field parameters (i.e., pH, temperature, specific conductivity, turbidity, DO, and ORP) using a multi-parameter meter(s) and recorded at every purge volume. Purge water will be containerized and placed in a storage tank currently on site.

After purging the appropriate volume of groundwater and achieving equilibration of field parameters, groundwater samples will be collected into laboratory provided sample containers. Samples for VOC analyses will be collected using a disposable PVC or HDPE bottom-loading bailer, while samples for all other analyses will be collected from the pump discharge line after being disconnected from the flow-through cell. Samples will then pack in an ice-filled cooler and submitted under chain-of-custody to a North Carolina certified environmental laboratory for analysis.

**Table 1** presents a list of laboratory analyses to be performed as well as the proposed field quality control samples. All monitoring well water level data, purge data, as well as sample data will be recorded on field data sheets as well as a field log book. Field data sheets are presented as **Appendix B**.

Analytical methods, bottleware requirements, hold times, and preservation type for each type of analysis is included as **Table 2**. Proposed laboratory analyte lists and contract required quantitation limits (CRQL) are presented in **Appendix C**.

It should be noted that the request for this plan was received on Friday October 13, 2006 at approximately 3:00 pm and due to NCDENR at 12:00 pm on Saturday October 14, 2006. The laboratory method detection limits must come from the laboratory(s) performing the analysis. It is anticipated that two or more laboratories will be used to accommodate the anticipated volume and requested turnaround times. The laboratory method detection limits will be submitted under separate cover. Any laboratory used will be currently certified by the NCDENR DWQ. The analysis will be reported to the MDL.

### 3.2.2 Collected Runoff Sampling

URS proposes to collect water samples from one 18,000 gallon frac tank and one 5,500 gallon vacuum truck currently at the site. The two vessels are currently used to store water collected during the fire fighting operations as well as run-off from precipitation events.

The samples will be collected in accordance the URS standard operating procedures included as **Appendix A**. Samples for will be collected using a disposable PVC or HDPE bottom-loading bailer. Samples will then pack in an ice-filled cooler and submitted under chain-of-custody to a North Carolina certified environmental laboratory for analysis.

**Table 1** presents a list of laboratory analyses to be performed. All sample data will be recorded on field data sheets as well as a field log book. Field data sheets are presented as **Appendix B**.

Analytical methods, bottleware requirements, hold times, and preservation type for each type of analysis is included as **Table 2**. Proposed laboratory analyte lists and (CRQL) are presented in **Appendix C**. As referenced above, the laboratory will report to the MDL and proposed laboratory MDLs will be submitted under separate cover.

### 3.2.3 Ash/Residue Sampling

The Division of Air Quality has requested ash samples to define action levels for air monitoring and the potential elimination of constituents of concern (COCs) for off-site sampling. The request consists of four ash samples within each of the five bays, plus two from the “truck bay” for a total of 22 samples. Analyses are to include total VOCs, SVOCs, RCRA metals plus manganese, nickel, and beryllium, herbicides/pesticides, cyanide and dioxin.

#### *Difficulty*

An initial difficulty in fulfilling this request will be finding sufficient volume of ash. The accessible portions of the bay floors are covered with a combination of water, sludge, and waste residues. Any surface samples collected will largely consist of these materials and therefore will not be representative of particulate matter in the air during the fire. Since each sample will require approximately 20 ounces of ash, gathering one complete sample of ash per bay will be difficult in of itself.

### *Proposed Approach*

In good faith, EQ will collect four discrete samples per bay, and two from within the “truck bay” as requested. Samples will be collected in accordance with the SOPs in **Appendix A**. Samples will be assigned a sample identifier consistent with the Waste Characterization Plan for this site. Any samples collected that can be accurately designated Ash will have an “A” as the last digit in the identifier. Otherwise samples will be identified as waste residual with an “R”. Samples will be analyzed for the analytes identified in **Appendix C**. Disposable hand utensils will be utilized to collect the samples and, after sample collection, be left at the location of the sample and included with the waste for ultimate disposal. Sample collection work will be conducted by personnel operating under the site Health and Safety plan currently in effect for the site.

### *Methods*

**Table 1** presents a list of laboratory analyses to be performed. All sample data will be recorded on field data sheets as well as a field log book. Field data sheets are presented as **Appendix B**. Analytical methods, bottleware requirements, hold times, and preservation type for each type of analysis is included as **Table 2**. Proposed laboratory analyte lists and contract required quantitation limits (CRQL) are presented in **Appendix C**. The laboratory method detection limits will be below the CRQL for each analyte analyzed. As referenced above, the laboratory will report to the MDL and proposed laboratory MDLs will be submitted under separate cover.

## **4.0 PROJECT QUALITY ASSURANCE AND QUALITY CONTROL**

### **4.1 SAMPLE COLLECTION PROCEDURES**

Prior to the beginning of the sampling event(s), the task leader will meet with the assigned sampling personnel to review the purpose and objectives of the event. Topics of review and discussion will include sampling locations, types of samples to be collected, number of samples collected, sample numbering, preservation requirements, parameter(s) to be analyzed, sampling procedures, equipment decontamination procedures, and Chain-of-Custody requirements.

#### **4.1.1 Sample and Data Collection**

The field activities associated with this SAP are described in section 3.3. Detailed procedures are contained in the SOPs found in Appendix B.

#### **4.1.2 Sample Handling**

The Task Leader is responsible for ensuring that samples are collected in accordance with both the above listed SOPs and in accordance with the attached SAP.

#### **4.1.3 Sample Labeling**

Once samples are collected, each sample container will be affixed with a non-removable (even when wet) label. The following information will be written with permanent marker:

- Site name
- Sample identification
- Project number
- Date/time
- Sampler's initials
- Sample preservation
- Analysis required

#### **4.1.4 Sample Identification**

Identification numbers will trace each sample back to specific sites, sample location, sample type, and the round of sampling at a sample location. An identification number is designed to prevent misidentification and will be recorded on all field record

documentation. The unique numbers will be used to identify the sample during collection, storage, analysis, data review, and reporting.

## **4.2 EVALUATION OF RESULTS**

Laboratory data will be evaluated per the quality control procedures of the selected laboratory. The data evaluation will be modeled after the *Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review* (US EPA, October 1999 and 2004, respectively). Qualitative and quantitative limitations associated with the analytical results will be identified and defined based on the results of specific quality control (QC) criteria. Accuracy will be determined from the review of calibration data and spike recoveries. Precision will be based on the evaluation of laboratory and field duplicate results. Sensitivity will be evaluated by comparing reported detection limits to project-specific reporting limits. Representativeness will be evaluated from the review of holding times and blank data.

**TABLE 1  
SAMPLE AND QUALITY CONTROL BY AREA  
EQ INDUSTRIAL SERVICES  
APEX, NC**

Sample Matrix	Laboratory Parameters	Analytical Methods	Investigative Samples	NCDENR Split Samples	QC Samples <sup>(1)</sup>				Total <sup>3</sup>
					Field Duplicate Samples	Equipment Blank Samples	Trip <sup>(2)</sup> Blank Samples	MS/MSD Samples	
<b>Site Wells, Tanker Water</b>									
Groundwater	TCL-VOCs	SW-846 8260	5	5	1	1	1	1	9
	TCL-SVOCs	SW-846 8270	5	5	1	1		1	8
	RCRA Metals, Mn, Ni, Be	SW-846 6010/7000	5	5	1	1		1	8
	Cyanide	SW-846 9010	5	5	1	1		1	8
	Pesticides	SW-846 8081	5	5	1	1		1	8
	Herbicides	SW-846 8151	5	5	1	1		1	8
<b>Ash / Residual Samples</b>									
Solid	TCL-VOCs	SW-846 8260	22	22	0	3	4	3	32
	TCL-SVOCs	SW-846 8270	22	22	0	3		3	28
	RCRA Metals, Mn, Ni, Be	SW-846 6010/7000	22	22	0	3		3	28
	Cyanide	SW-846 9010	22	22	0	3		3	28
	Pesticides	SW-846 8081	22	22	0	3		3	28
	Herbicides	SW-846 8151	22	22	0	3		3	28
	Dioxin / Furan	ASTM standard	22	22	0	3		3	28

**Notes:**

(1) QC Samples will be collected at a rate of one per 10 investigative samples.

(2) Total number of trip blanks is estimated; one trip blank will be included with each sample cooler containing samples for VOC analysis

(3) Totals are only included for URS/EQ Collected samples, not NCDENR Split Samples

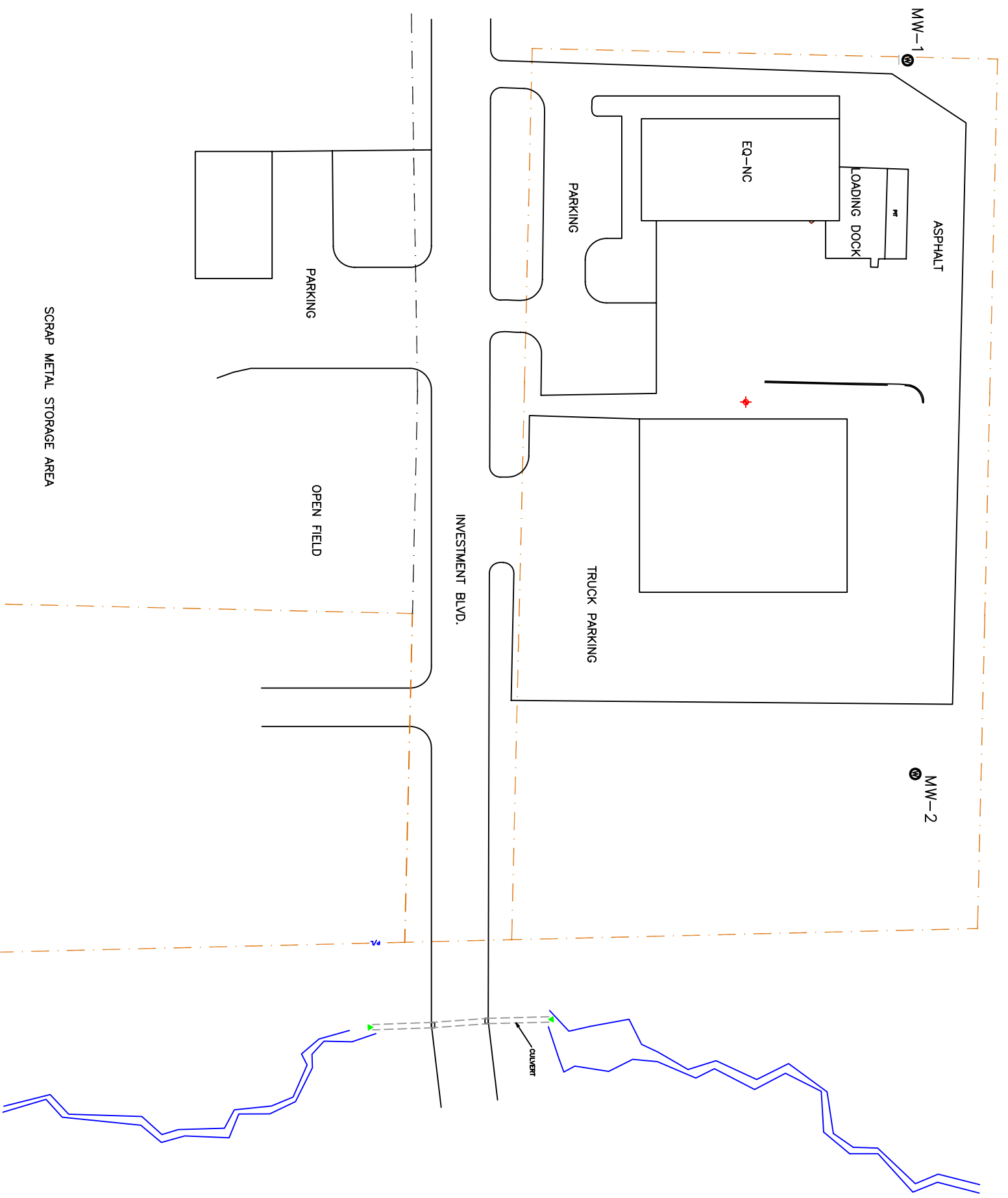
MS/MSD- Matrix Spike/ Matrix Spike Duplicate

TCL - Target Compound List

TAL - Target Analyte List

**Table 2. Requirements for Containers, Preservation and Holding Times**

Parameter	Analytical Methods	Sample Container		Preservation		Holding Time	
		Aqueous	Solid	Aqueous	Solid	Aqueous	Solid
Volatile organic Compounds (VOCs)	SW8260B	3 X 40 mL glass VOA vial, PTFE septum caps No headspace <b>Note: Small bubbles</b> may occur during shipping and handling. Samples with bubbles are not acceptable.	1 wm glass jar with PTFE-lined cap	pH < 2 with HCL Cool to 4 °C	Cool to 4 °C	7 days (no preservative) 14 days (preservative added)	48 hours if only cooled to 4 °C
Semivolatile Organic Compounds (SVOCs)	SW8270C	2 X 1-Liter amber glass bottles with PTFE-lined lids per parameter	250 mL amber glass wide-mouth jar (or can be clear if stored in dark)  <b>Note: All parameters can be taken from same jar</b>	Cool to 4 °C.	Cool to 4 °C	7 days until extraction and extracts analyzed within 40 days after extraction	14 days until extraction and extracts analyzed within 40 days after extraction
Organochlorine pesticides	SW8081A						
Dioxins and furans	SW8280A	2 X 1-Liter amber glass bottles with PTFE-lined lids per parameter	250 mL amber wide-mouth glass jar (or can be clear if stored in dark)	Cool to 4 °C. Store in dark.	Cool to 4 °C Store in dark	30 days until extraction and extracts analyzed within 45 days after extraction	30 days until extraction and extracts analyzed within 45 days after extraction
Metals (except Hg)	SW6010B	1 Liter glass or HDPE bottle	250 mL wide-mouth glass jar	HNO <sub>3</sub> to pH < 2	Cool to 4 °C	180 days	180 days
Mercury	SW7470A (aqueous)/ SW7471A (solid)					28 days	28 days
Cyanide, total and amenable to chlorination	SW9010B/ SW9012A	1 Liter glass or HDPE bottle	250 mL wide-mouth glass jar	Adjust pH to > 12 with 50% NaOH. Cool to 4 °C	Cool to 4 °C	14 days	14 days)



LEGEND:  
 - - - - - PROPERTY LINE  
 - - - - - CHAIN LINK GATE FENCE

SOURCE: DWBA, P.A., ENGINEERING-SURVEYING, FILE NO. 741,  
 DATED: 03/02/05, DESIGN FILE: 050203PT.DGN

- NOTES:  
 1. THIS DOES NOT CONSTITUTE A BOUNDARY SURVEY BY THIS OFFICE.  
 2. ALL DISTANCES ARE HORIZONTAL GROUND DISTANCES UNLESS OTHERWISE NOTED.  
 3. MONITORING WELL LOCATIONS ARE APPROXIMATE



SCALE	AS SHOWN		DRAWING TITLE	
DESIGNED BY	DATE	DESIGNED BY	DATE	Figure 1. Site Map
DRAWN BY	DATE	DRAWN BY	DATE	EQ North Carolina
CDF	13OCT06	CDF	13OCT06	Apex, North Carolina
CHECKED BY	DATE	CHECKED BY	DATE	
JC	13OCT06	JC	13OCT06	
APPROVED BY	DATE	APPROVED BY	DATE	
CONTRACT NO.		DRAWING NO.		REV.
J3-00000000.01		FIG-1		0



**APPENDIX A**

**STANDARD OPERATING PROCEDURES**

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# SOP NO. 1 - DECONTAMINATION

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## 1. INTRODUCTION AND TYPES OF CONTAMINATION

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This document defines the standard operating procedure (SOP) for decontamination of field equipment. This SOP is to be used together with the sampling and analysis plan. Personnel decontamination procedures are discussed in the on site Health and Safety Plan.

*NOTE: Investigation-derived waste (IDW) resulting from decontamination will be handled as specified in the project-specific workplan.*

### **Site and/or Sample Cross-Contamination**

The overall objective of multimedia sampling programs is to obtain samples that accurately depict the chemical, physical, and/or biological conditions at the sampling site. Extraneous contaminants can be brought onto the sampling location and/or introduced into the medium of interest during the sampling program (e.g., using sampling equipment that is not properly or fully decontaminated). Trace quantities of contaminants can consequently be captured in a sample and lead to false positive analytical results and, ultimately, to an incorrect assessment of the contaminant conditions associated with the site. Decontamination of sampling equipment (e.g., all non-disposable equipment that will come in direct contact with samples) and field support equipment (e.g., drill rigs, vehicles) is, therefore, required prior to, between, and after use to ensure that sampling cross-contamination is prevented and that on-site contaminants are not transported off-site.

## 2. PROCEDURE

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A decontamination pad will be constructed at a location believed to be free of contamination and agreed upon by the appropriate facility personnel. The pad will be constructed to contain all products of the decontamination process. The temporary pad will be lined with water impermeable material. Liquids will be removed frequently from the pad to prevent overflowing of the pad. The pad shall be constructed on a level surface, and wooden racks shall be placed on the plastic pad floor to place equipment on during cleaning. At the end of the site activities, the pad will be taken apart and properly disposed.

## **2.1 DECONTAMINATION PROCEDURE**

Decontamination procedures for field equipment are presented below:

### **Sampling Equipment and Hand Tools**

The following steps will be used to decontaminate sampling equipment:

- Personnel will dress in suitable safety equipment to reduce personal exposure as required by the HASP.
- Gross contamination on equipment will be scraped off at the sampling or construction site.
- Equipment will be placed in a wash tub containing Alconox, Liquinox or low-sudsing non-phosphatic detergent along with potable water and scrubbed with a bristle brush or similar tool. Equipment will be rinsed with tap water in a second wash tub followed by a deionized water rinse.
- Rinse and detergent water will be replaced with new solutions before they get too saturated with contaminated media.

Following decontamination, equipment will be placed in a clean area or on clean plastic sheeting to prevent contact with other contaminated media. If the equipment is not used immediately after decontamination, the equipment will be covered or wrapped in aluminum foil to minimize potential contact with contaminants.

### **Drilling and Heavy Equipment**

Drilling/ Direct Push rigs will be decontaminated at a decontamination station located near a central staging area. The decontamination station may consist of a temporary or permanent structure capable of collecting all decontamination fluids. Mobile decontamination trailers may be used to decontaminate heavy equipment at each site. The following steps will be used to decontaminate drilling and heavy equipment:

- Personnel will dress in suitable PPE to reduce personal exposure as required by the Basewide SSHP.
- Equipment showing gross contamination or having caked-on soil will be scraped with a flat-bladed scraper at the sampling or construction site.
- Equipment will be washed with a hot water, high-pressure sprayer then rinsed with potable water.
- Following decontamination, equipment will be moved to a clean area. If the equipment is not used immediately, it should be stored in a designated clean area.

### **Equipment Leaving the Site**

Vehicles used for activities in non-contaminated areas shall be cleaned on an as-needed basis, as determined by the appropriate field personnel, using soap and water

on the outside and vacuuming the inside. On-site cleaning will be required for very dirty vehicles leaving the area. Construction equipment such as trucks, drilling rigs, backhoes, trailers, etc., will be pressure washed before the equipment is removed from the site to limit exposure of off-site personnel to potential contaminants.

## **2.2 DOCUMENTATION**

Sampling personnel will be responsible for documenting the decontamination of sampling and drilling equipment. The documentation will be recorded with waterproof ink in the sampler's field notebook with consecutively numbered pages.

## **3. QUALITY ASSURANCE REQUIREMENTS**

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Equipment rinsate samples of the decontaminated sampling equipment may be taken to verify the effectiveness of the decontamination procedures. The rinsate sampling procedure will include rinsing deionized water through or over a decontaminated sampling tool (such as sample tubing) and collecting the rinsate water into the appropriate sample bottles. The rinsate sampling procedure, including the sample number, will be recorded in the field notebook. Rinsate samples will be identified and handled in accordance with the project-specific work plan and/or QAPP.

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## **SOP NO. 2 –SOIL SAMPLING**

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### **1. PURPOSE AND SCOPE**

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The purpose of this document is to define the standard operating procedure (SOP) for collection of soil samples. This SOP gives descriptions of equipment, and field procedures, implemented for the collection of subsurface soil samples. Sampling locations are specified in the project-specific work plan.

These procedures are intended to be used in conjunction with the project-specific SAP and other related SOPs. Other related SOPs are listed below:

- SOP No. 1 - Decontamination

### **2. EQUIPMENT**

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The following list details the equipment used to install soil borings, perform soil headspace screening, and collect surface and subsurface soil samples.

- Bound field log book and field documentation forms
- Appropriate health and safety equipment, as specified in the Health and Safety Plan (HASP)
- Disposable trowels
- Appropriate sample containers as specified in the SAP
- Appropriate decontamination equipment and supplies (i.e. liquinox and deionized water)

### **3. PROCEDURE**

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#### **SOIL ENVIRONMENTAL SAMPLE COLLECTION**

Soil samples will be collected from the the selected areas by following the below listed procedures:

- Record the boring location on a site map and in the field logbook such that the locations can be accurately relocated.
- Collect the soil samples using the disposable trowel.
- Attempt to identify the residue / ash content of the sample.
- Collect the VOC sample (if required) immediately after opening the sample jar.

- After collecting the VOC sample, composite the remaining soil by thoroughly mixing the soil in a clean stainless steel bowl with the disposable trowel. Collect any required SVOC samples immediately after compositing the soil, then collect soil for any remaining parameters, using the appropriate containers. The required analyses and appropriate volume of containers of soil will be stated in the project specific SAP.
- Label, store, transport, and document the samples (depending on the purpose of the sample) according to the project specific SAP.
- Investigative derived waste (IDW) will be managed as hazardous waste.

#### **4. SAMPLE IDENTIFICATION AND HANDLING**

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Samples will be identified, handled and recorded as described in the project-specific SAP. The parameters for analysis and preservation will be specified in the project-specific SAP.

#### **5. DOCUMENTATION**

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Each field activity must be properly documented to facilitate a timely and accurate reconstruction of events in the field, to provide verification of the proper acquisition of samples, and to provide a permanent record of field activities. Field activities will be documented in a bound logbook in accordance with the project-specific SAP. Sample collection field sheets will be completed for all soil samples submitted for chemical analysis. A copy of a scfs is included in the project specific SAP.

A scientist or engineer will complete a boring log for each completed boring in the field. The following information, as applicable, will be included on the boring log:

- Project name
- Drilling company name
- Date drilling started and finished
- Type of bit and size
- Size of augers (inside and outside diameters)
- Well completion details
- Driller's name
- Field geologist's name
- Type of drill rig
- Boring number and location
- Surface elevation (if available)
- Ground surface condition (grass, pavement)
- Sample depths and times

- Sample characteristics with depth, such as lithology, grain size, sorting, texture, structure, bedding, strength, color, water content, soil type, the Unified Soil Classification Symbol (if in unconsolidated geologic material) and a description of the geologic origin (if applicable).
- Headspace and breathing zone readings (if any)
- Other pertinent information

A copy of a boring log is included in **Appendix A**.

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# SOP NO. 4 - WATER LEVEL MEASUREMENTS

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## 1. PURPOSE AND SCOPE

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This document defines the standard operating procedure (SOP) for measuring water levels in borings and monitoring wells. This procedure is intended to be used in conjunction with the project-specific work plan and/or QAPP and other SOPs. Other related SOPs are listed below:

- SOP No. 1 - Decontamination

## 2. WATER LEVEL MEASUREMENT PROCEDURE

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### 2.1 EQUIPMENT LIST

The equipment necessary to measure water levels includes:

- Water level probe with 0.01-foot increments
- Appropriate health and safety equipment, as specified in the Health and Safety Plan (HASP)
- Appropriate decontamination equipment and supplies

### 2.2 MEASUREMENT PROCEDURE

Appropriate health and safety equipment, as described in the HASP, should be worn during well opening, water level measurement, and decontamination. The following procedures will be completed when measuring water levels:

- The water level probe will be decontaminated prior to use in each monitoring well. Decontamination procedures are discussed in SOP No. 1.
- The well will be approached from upwind, the well cap unlocked and removed, and the air quality monitored in the casing and breathing zone with an OVA or equivalent. Air quality measurements will be recorded in the field notebook.
- Observations regarding the condition of the well, including the well pad, and protective casing, will be documented in the field notebook. The well will be allowed to equilibrate to atmospheric pressure prior to measuring the water level.
- The static water level and the total well depth will be measured using an electronic water level indicator. The measuring point for all the wells will be the top of PVC or steel monitoring well casing. For standardization of measurements, all well readings will be referenced to the north rim of the monitoring well riser pipe or to a marked reference point on the casing rim.

- The static water level and the total depth of the well will be measured with the probe, recorded in the logbook or a water level data sheet, and then immediately rechecked before the probe is removed from the well.
- All columns of field data sheets will be completed, including time of measurement. An example water level data sheet is included in work plan. If measurements are taken over a several-day period, the date and time of each measurement should be clearly indicated on the form. Section 2.4 describes the required documentation.
- The measured depth to water, in feet below the measuring point, will be subtracted from the measuring point elevation to determine the elevation of the static water level. The resulting elevation will be checked in the field to see that it is reasonable and that the subtraction was performed correctly. If there is a discrepancy, the water level will be measured again.
- Care will be taken to verify the readings during each water level measurement period. Any significant changes in water level will be noted by comparing the most recent measurement with past measurements.
- After any measurement is taken, the water level probe will be decontaminated as described in Section 2.3.

### **2.3 DECONTAMINATION**

The water level indicator must be decontaminated before use, between wells, and at the conclusion of measurements. The probe will be decontaminated according to the procedure for decontamination of sampling equipment described in SOP No. 1.

### **2.4 DOCUMENTATION**

A water level data sheet will be completed during each measuring event at groundwater monitoring wells. Field data sheets will include date, time, well number, total well depth, water level, static water elevation, and comments. A field notebook will also be kept during monitoring well water level measurement activities describing decontamination procedures, calibration procedures, monitoring procedures, and other observations.

Water levels measured during drilling, well installation and aquifer testing procedures will be recorded in a field logbook and any applicable forms identified in applicable SOPs. Date, time of measurement and the point of measurement will be recorded for each measurement.

Both the data sheets and notebook will be filled out using legible handwriting, and will be signed and dated by the person completing the page.

### **3. CALIBRATION**

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The length of the water level measurement probe cord should be calibrated at least once per month or more often as needed to ensure the desired accuracy during water level measuring events. The calibration check consists of laying out 50 feet of steel tape next to 50 feet of the probe cord. Note any measurement discrepancies between the two at 1-foot intervals. The probe cord will be rechecked if there is a possibility that it was stretched or damaged during water level measurements.

The procedures followed during calibration and verification of equipment will be documented in the field notebook along with any calculations. If a correction is required, the probe will be tagged to indicate the correction.

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# SOP NO. 6 - GROUNDWATER MONITORING WELL SAMPLING

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## 1. PURPOSE AND SCOPE

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This document defines the standard operating procedure (SOP) for collecting groundwater samples. This SOP gives descriptions of equipment and field procedures necessary to collect groundwater samples. Sampling locations will be specified in the project-specific SAP.

This SOP is to be used together with the SAP and other appropriate SOPs. Other related SOPs are listed below:

- SOP No. 1 – Decontamination
- SOP No. 4 - Water Level Measurement

## 2. GROUNDWATER SAMPLING EQUIPMENT AND PROCEDURES

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### 2.1 EQUIPMENT LIST AND CALIBRATION REQUIREMENTS

Equipment used during well purging and sampling:

- Well keys
- Water level probe with 0.01-foot increments
- Appropriate pump (submersible, peristaltic, or bladder)
- Temperature meter (or Multi-Meter)
- Turbidity meter (or Multi-Meter)
- Dissolved oxygen meter (or Multi-Meter)
- Oxidation-reduction potential (ORP) meter (or Multi-Meter)
- pH meter (with automatic temperature compensation) (or Multi-Meter)
- Conductivity meter (or Multi-Meter)
- Calibration fluids
- Polyethylene or glass container (for field parameter measurements)
- Plastic buckets or truck-mounted tank for holding purged water
- Appropriate health and safety equipment, as specified in the Health and Safety Plan
- Well completion information

Before any purging or sampling activities begin, all applicable sampling devices will be decontaminated according to the procedures in the SAP and SOP No. 1, Equipment Decontamination. Each piece of reusable purging or sampling equipment will be decontaminated before sampling operations and between each well. The decontamination solutions will be replaced with clean solutions between each well. Used solutions will be placed in the container with purged well water for disposal as investigation-derived waste (IDW) in accordance with the SAP.

Before going into the field, all water quality meters will be tested to ensure they are operating properly. The pH, turbidity and conductivity meters require calibration prior to use every day and must be recalibrated if they have been turned off. Dissolved oxygen and ORP meters will be calibrated according to the manufacturer's recommended frequencies. Calibration times and readings will be recorded in a notebook to be kept by the field sampling team. Specific instructions for calibrating the instruments are given in the instrument manuals.

## **2.2 SAMPLING PROCEDURE**

This section gives the step-by-step procedures for collecting groundwater samples in the field. Prior to sampling, all wells will be purged. Purging and sampling of a monitoring well will proceed only after a minimum of 48 hours following well development.

All monitoring well purging and sampling will utilize procedures outlined in EPA Ground Water Issue Paper EPA/540/5-95/504 "Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures" by Puls and Barcelona (included as Attachment 1 at the end of this SOP). Observations made during sample collection should be recorded in the field logbook and field log sheet.

### **2.2.1 Well Purging**

The purpose of well purging is to remove stagnant water from the well and obtain representative water from the geologic formation being sampled while minimizing disturbance to the collected samples. Before a sample is taken, the well will be purged until a minimum of three consecutive readings of the field parameters have stabilized. All wells will be purged on the same day that samples are taken. Evacuated well water will be contained for proper disposal in accordance with the QAPP, and necessary precautions will be taken to prevent spilling of water.

Before well purging begins, the following procedures will be performed at each well:

- The condition of the outer well casing, concrete well pad, and any unusual conditions of the area around the well will be noted in the field logbook.
- The condition of the inner well cap and casing will be noted.

- The depth of static water level will be measured (to nearest 0.01 foot) and recorded from a measuring point on the well casing. The water level and time of measurement should be recorded in the field logbook.
- The total depth of the well from the same measuring point on the casing will be measured and recorded.
- The volume of water in the well casing will be calculated in gallons based on feet of water and casing diameter (0.16 gallons per foot of water for a two-inch ID well).
- The pump intake will be positioned in the top one-third of the saturated area of the screen.
- An initial sample will be obtained for field measurements of temperature, conductivity, turbidity, and pH for observation of water quality. This sample will not be retained after these initial measurements are recorded.
- Water in the casing will be evacuated using low-flow purging (0.1 to 0.5 liter/min) which will achieve minimal (< 0.33-foot) to no drawdown in the static water level in the well (see Attachment 1 to this SOP for specific instructions).
- Temperature, dissolved oxygen, ORP, conductivity, turbidity, and pH measurements will be taken every 3 to 5 minutes (based on pump rate of 0.1 to 0.5 liter/min) to determine whether the water chemistry has stabilized for three consecutive readings. Generally, pH values within  $\pm 0.1$  pH unit, temperature within  $\pm 0.5^{\circ}\text{C}$ , conductivity within  $\pm 3\%$ , dissolved oxygen within 10% and  $\pm 10\text{mV}$  for ORP between consecutive readings indicate adequate stability of the water chemistry. A target value of 10 NTUs will be used to indicate acceptable turbidity levels prior to sample collection. However, if turbidity is consistently within  $\pm 10\%$  then turbidity will be considered unattainable and sample collection will proceed.

### 2.2.2 Sample Collection

Samples for chemical analysis will be collected immediately following purging. Only sampling with a low-flow peristaltic pump is discussed below. Other sampling methods will be proposed in project-specific QAPPs.

The following sampling procedure is to be used when using a positive displacement pump and after purging has been completed:

1. The pump rate will remain the same as for purging.
2. Any in-line water quality measurement equipment (e.g., flow-through cell) should be disconnected or bypassed during sample collection.
3. The individual sample bottles should be filled in the order given in the SAP
4. VOC sample will be collected using a disposable PVC or HDPE bailer. Parameter will be collected using the peristaltic pump and tubing.

Bottle and preservative requirements can be found in the SAP.

VOC sample vials should be completely filled so the water forms a convex meniscus at the top and then capped so that no air space exists in the vial. Turn the vial over and tap it to check for bubbles in the vial which indicate air space. If air bubbles are observed in the sample vial, discard the sample vial and repeat the procedure until no air bubbles appear.

Fill bottles for metals and general minerals almost full.

5. Label the sample jars and place on ice.
6. Replace and lock the well cap.
7. Complete field documentation (discussed below).

### **2.3 SAMPLE IDENTIFICATION, HANDLING, AND DOCUMENTATION**

Each field activity must be properly documented to allow a timely and accurate reconstruction of events in the field, to provide verification of the proper acquisition of samples, and to provide a permanent record of field activities. Field activities will be documented in a bound logbook. A field sampling sheet will be completed for all groundwater samples submitted for chemical analysis. Water quality data obtained during purging will be recorded in the field logbook and on the field sampling sheet.

Logbook entries for groundwater sampling should include the following at a minimum:

- Names of personnel
- Weather conditions
- Location and well number
- Date and time of sampling
- Condition of the well
- Decontamination information
- Initial static water level and total well depth
- Depth of sample
- Calculations (e.g., calculation of purged volume)
- Analyses that will be performed by the laboratory
- Equipment calibration information
- Headspace analysis (if taken)
- Volume of water purged prior to sampling
- Disposition of IDW

**ATTACHMENT NO. 1 TO SOP NO. 6**  
**LOW-FLOW (MINIMAL DRAWDOWN) GROUNDWATER SAMPLING PROCEDURES**



# Ground Water Issue

## LOW-FLOW (MINIMAL DRAWDOWN) GROUND-WATER SAMPLING PROCEDURES

by Robert W. Puls<sup>1</sup> and Michael J. Barcelona<sup>2</sup>

### Background

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange information related to ground-water remediation at Superfund sites. One of the major concerns of the Forum is the sampling of ground water to support site assessment and remedial performance monitoring objectives. This paper is intended to provide background information on the development of low-flow sampling procedures and its application under a variety of hydrogeologic settings. It is hoped that the paper will support the production of standard operating procedures for use by EPA Regional personnel and other environmental professionals engaged in ground-water sampling.

For further information contact: Robert Puls, 405-436-8543, Subsurface Remediation and Protection Division, NRMRL, Ada, Oklahoma.

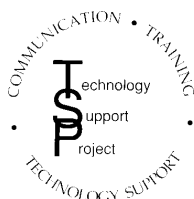
### I. Introduction

The methods and objectives of ground-water sampling to assess water quality have evolved over time. Initially the emphasis was on the assessment of water quality of aquifers as sources of drinking water. Large water-bearing

units were identified and sampled in keeping with that objective. These were highly productive aquifers that supplied drinking water via private wells or through public water supply systems. Gradually, with the increasing awareness of subsurface pollution of these water resources, the understanding of complex hydrogeochemical processes which govern the fate and transport of contaminants in the subsurface increased. This increase in understanding was also due to advances in a number of scientific disciplines and improvements in tools used for site characterization and ground-water sampling. Ground-water quality investigations where pollution was detected initially borrowed ideas, methods, and materials for site characterization from the water supply field and water analysis from public health practices. This included the materials and manner in which monitoring wells were installed and the way in which water was brought to the surface, treated, preserved and analyzed. The prevailing conceptual ideas included convenient generalizations of ground-water resources in terms of large and relatively homogeneous hydrologic *units*. With time it became apparent that conventional water supply generalizations of *homogeneity* did not adequately represent field data regarding pollution of these subsurface resources. The important role of *heterogeneity* became increasingly clear not only in geologic terms, but also in terms of complex physical,

<sup>1</sup>National Risk Management Research Laboratory, U.S. EPA

<sup>2</sup>University of Michigan



Superfund Technology Support Center for  
Ground Water

National Risk Management Research Laboratory  
Subsurface Protection and Remediation Division  
Robert S. Kerr Environmental Research Center  
Ada, Oklahoma

Technology Innovation Office  
Office of Solid Waste and Emergency  
Response, US EPA, Washington, DC

Walter W. Kovalick, Jr., Ph.D.  
Director

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chemical and biological subsurface processes. With greater appreciation of the role of heterogeneity, it became evident that subsurface pollution was ubiquitous and encompassed the unsaturated zone to the deep subsurface and included unconsolidated sediments, fractured rock, and *aquifers* or low-yielding or impermeable formations. Small-scale processes and heterogeneities were shown to be important in identifying contaminant distributions and in controlling water and contaminant flow paths.

It is beyond the scope of this paper to summarize all the advances in the field of ground-water quality investigations and remediation, but two particular issues have bearing on ground-water sampling today: aquifer heterogeneity and colloidal transport. Aquifer heterogeneities affect contaminant flow paths and include variations in geology, geochemistry, hydrology and microbiology. As methods and the tools available for subsurface investigations have become increasingly sophisticated and understanding of the subsurface environment has advanced, there is an awareness that in most cases a primary concern for site investigations is characterization of contaminant flow paths rather than entire aquifers. In fact, in many cases, plume thickness can be less than well screen lengths (e.g., 3-6 m) typically installed at hazardous waste sites to detect and monitor plume movement over time. Small-scale differences have increasingly been shown to be important and there is a general trend toward smaller diameter wells and shorter screens.

The hydrogeochemical significance of colloidal-size particles in subsurface systems has been realized during the past several years (Gschwend and Reynolds, 1987; McCarthy and Zachara, 1989; Puls, 1990; Ryan and Gschwend, 1990). This realization resulted from both field and laboratory studies that showed faster contaminant migration over greater distances and at higher concentrations than flow and transport model predictions would suggest (Buddemeier and Hunt, 1988; Enfield and Bengtsson, 1988; Penrose et al., 1990). Such models typically account for interaction between the mobile aqueous and immobile solid phases, but do not allow for a mobile, reactive solid phase. It is recognition of this third *phase* as a possible means of contaminant transport that has brought increasing attention to the manner in which samples are collected and processed for analysis (Puls et al., 1990; McCarthy and Degueudre, 1993; Backhus et al., 1993; U. S. EPA, 1995). If such a phase is present in sufficient mass, possesses high sorption reactivity, large surface area, and remains stable in suspension, it can serve as an important mechanism to facilitate contaminant transport in many types of subsurface systems.

Colloids are particles that are sufficiently small so that the surface free energy of the particle dominates the bulk free energy. Typically, in ground water, this includes particles with diameters between 1 and 1000 nm. The most commonly observed mobile particles include: secondary clay minerals; hydrous iron, aluminum, and manganese oxides; dissolved and particulate organic materials, and viruses and bacteria.

These reactive particles have been shown to be mobile under a variety of conditions in both field studies and laboratory column experiments, and as such need to be included in monitoring programs where identification of the *total* mobile contaminant loading (dissolved + naturally suspended particles) at a site is an objective. To that end, sampling methodologies must be used which do not artificially bias *naturally* suspended particle concentrations.

Currently the most common ground-water purging and sampling methodology is to purge a well using bailers or high speed pumps to remove 3 to 5 casing volumes followed by sample collection. This method can cause adverse impacts on sample quality through collection of samples with high levels of turbidity. This results in the inclusion of otherwise immobile artificial particles which produce an overestimation of certain analytes of interest (e.g., metals or hydrophobic organic compounds). Numerous documented problems associated with filtration (Danielsson, 1982; Laxen and Chandler, 1982; Horowitz et al., 1992) make this an undesirable method of rectifying the turbidity problem, and include the removal of potentially mobile (contaminant-associated) particles during filtration, thus artificially biasing contaminant concentrations low. Sampling-induced turbidity problems can often be mitigated by using low-flow purging and sampling techniques.

Current subsurface conceptual models have undergone considerable refinement due to the recent development and increased use of field screening tools. So-called hydraulic *push* technologies (e.g., cone penetrometer, Geoprobe®, QED HydroPunch®) enable relatively fast screening site characterization which can then be used to design and install a monitoring well network. Indeed, alternatives to conventional monitoring wells are now being considered for some hydrogeologic settings. The ultimate design of any monitoring system should however be based upon adequate site characterization and be consistent with established monitoring objectives.

If the sampling program objectives include accurate assessment of the magnitude and extent of subsurface contamination over time and/or accurate assessment of subsequent remedial performance, then some information regarding plume delineation in three-dimensional space is necessary prior to monitoring well network design and installation. This can be accomplished with a variety of different tools and equipment ranging from hand-operated augers to screening tools mentioned above and large drilling rigs. Detailed information on ground-water flow velocity, direction, and horizontal and vertical variability are essential baseline data requirements. Detailed soil and geologic data are required prior to and during the installation of sampling points. This includes historical as well as detailed soil and geologic logs which accumulate during the site investigation. The use of borehole geophysical techniques is also recommended. With this information (together with other site characterization data) and a clear understanding of sampling

objectives, then appropriate location, screen length, well diameter, slot size, etc. for the monitoring well network can be decided. This is especially critical for new in situ remedial approaches or natural attenuation assessments at hazardous waste sites.

In general, the overall goal of any ground-water sampling program is to collect water samples with no alteration in water chemistry; analytical data thus obtained may be used for a variety of specific monitoring programs depending on the regulatory requirements. The sampling methodology described in this paper assumes that the monitoring goal is to sample monitoring wells for the presence of contaminants and it is applicable whether mobile colloids are a concern or not and whether the analytes of concern are metals (and metalloids) or organic compounds.

## II. Monitoring Objectives and Design Considerations

The following issues are important to consider prior to the design and implementation of any ground-water monitoring program, including those which anticipate using low-flow purging and sampling procedures.

### A. Data Quality Objectives (DQOs)

Monitoring objectives include four main types: detection, assessment, corrective-action evaluation and resource evaluation, along with *hybrid* variations such as site-assessments for property transfers and water availability investigations. Monitoring objectives may change as contamination or water quality problems are discovered. However, there are a number of common components of monitoring programs which should be recognized as important regardless of initial objectives. These components include:

- 1) Development of a conceptual model that incorporates elements of the regional geology to the local geologic framework. The conceptual model development also includes initial site characterization efforts to identify hydrostratigraphic units and likely flow-paths using a minimum number of borings and well completions;
- 2) Cost-effective and well documented collection of high quality data utilizing simple, accurate, and reproducible techniques; and
- 3) Refinement of the conceptual model based on supplementary data collection and analysis.

These fundamental components serve many types of monitoring programs and provide a basis for future efforts that evolve in complexity and level of spatial detail as purposes and objectives expand. High quality, reproducible data collection is a common goal regardless of program objectives.

High quality data collection implies data of sufficient accuracy, precision, and completeness (i.e., ratio of valid analytical results to the minimum sample number called for by the program design) to meet the program objectives. Accuracy depends on the correct choice of monitoring tools and procedures to minimize sample and subsurface disturbance from collection to analysis. Precision depends on the repeatability of sampling and analytical protocols. It can be assured or improved by replication of sample analyses including blanks, field/lab standards and reference standards.

### B. Sample Representativeness

An important goal of any monitoring program is collection of data that is truly representative of conditions at the site. The term *representativeness* applies to chemical and hydrogeologic data collected via wells, borings, piezometers, geophysical and soil gas measurements, lysimeters, and temporary sampling points. It involves a recognition of the statistical variability of individual subsurface physical properties, and contaminant or major ion concentration levels, while explaining extreme values. Subsurface temporal and spatial variability are facts. Good professional practice seeks to maximize representativeness by using proven accurate and reproducible techniques to define limits on the distribution of measurements collected at a site. However, measures of representativeness are dynamic and are controlled by evolving site characterization and monitoring objectives. An evolutionary site characterization model, as shown in Figure 1, provides a systematic approach to the goal of consistent data collection.

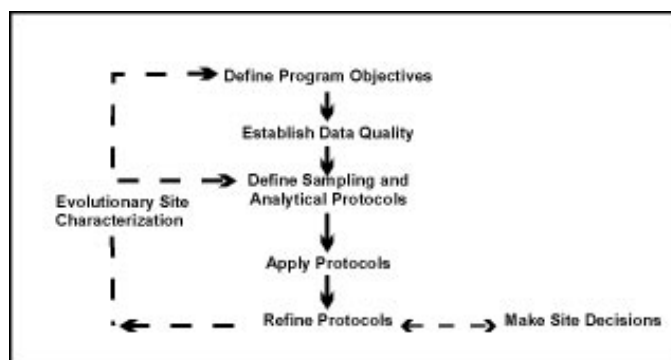


Figure 1. Evolutionary Site Characterization Model

The model emphasizes a recognition of the causes of the variability (e.g., use of inappropriate technology such as using bailers to purge wells; imprecise or operator-dependent methods) and the need to control avoidable errors.

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## 1) Questions of Scale

A sampling plan designed to collect representative samples must take into account the potential scale of changes in site conditions through space and time as well as the chemical associations and behavior of the parameters that are targeted for investigation. In subsurface systems, physical (i.e., aquifer) and chemical properties over time or space are not statistically independent. In fact, samples taken in close proximity (i.e., within distances of a few meters) or within short time periods (i.e., more frequently than monthly) are highly auto-correlated. This means that designs employing high-sampling frequency (e.g., monthly) or dense spatial monitoring designs run the risk of redundant data collection and misleading inferences regarding trends in values that aren't statistically valid. In practice, contaminant detection and assessment monitoring programs rarely suffer these *over-sampling* concerns. In corrective-action evaluation programs, it is also possible that too little data may be collected over space or time. In these cases, false interpretation of the spatial extent of contamination or underestimation of temporal concentration variability may result.

## 2) Target Parameters

Parameter selection in monitoring program design is most often dictated by the regulatory status of the site. However, background water quality constituents, purging indicator parameters, and contaminants, all represent targets for data collection programs. The tools and procedures used in these programs should be equally rigorous and applicable to all categories of data, since all may be needed to determine or support regulatory action.

### **C. Sampling Point Design and Construction**

Detailed site characterization is central to all decision-making purposes and the basis for this characterization resides in identification of the geologic framework and major hydro-stratigraphic units. Fundamental data for sample point location include: subsurface lithology, head-differences and background geochemical conditions. Each sampling point has a proper use or uses which should be documented at a level which is appropriate for the program's data quality objectives. Individual sampling points may not always be able to fulfill multiple monitoring objectives (e.g., detection, assessment, corrective action).

#### 1) Compatibility with Monitoring Program and Data Quality Objectives

Specifics of sampling point location and design will be dictated by the complexity of subsurface lithology and variability in contaminant and/or geochemical conditions. It should be noted that, regardless of the ground-water sampling approach, few sampling points (e.g., wells, drive-points, screened augers) have zones of influence in excess of a few

feet. Therefore, the spatial frequency of sampling points should be carefully selected and designed.

#### 2) Flexibility of Sampling Point Design

In most cases *well-point* diameters in excess of 1 7/8 inches will permit the use of most types of submersible pumping devices for low-flow (minimal drawdown) sampling. It is suggested that *short* (e.g., less than 1.6 m) screens be incorporated into the monitoring design where possible so that comparable results from one device to another might be expected. *Short*, of course, is relative to the degree of vertical water quality variability expected at a site.

#### 3) Equilibration of Sampling Point

Time should be allowed for equilibration of the well or sampling point with the formation after installation. Placement of well or sampling points in the subsurface produces some disturbance of ambient conditions. Drilling techniques (e.g., auger, rotary, etc.) are generally considered to cause more disturbance than *direct-push* technologies. In either case, there may be a period (i.e., days to months) during which water quality near the point may be distinctly different from that in the formation. Proper development of the sampling point and adjacent formation to remove fines created during emplacement will shorten this water quality *recovery* period.

### **III. Definition of Low-Flow Purging and Sampling**

It is generally accepted that water in the well casing is non-representative of the formation water and needs to be purged prior to collection of ground-water samples. However, the water in the screened interval may indeed be representative of the formation, depending upon well construction and site hydrogeology. Wells are purged to some extent for the following reasons: the presence of the air interface at the top of the water column resulting in an oxygen concentration gradient with depth, loss of volatiles up the water column, leaching from or sorption to the casing or filter pack, chemical changes due to clay seals or backfill, and surface infiltration.

Low-flow purging, whether using portable or dedicated systems, should be done using pump-intake located in the middle or slightly above the middle of the screened interval. Placement of the pump too close to the bottom of the well will cause increased entrainment of solids which have collected in the well over time. These particles are present as a result of well development, prior purging and sampling events, and natural colloidal transport and deposition. Therefore, placement of the pump in the middle or toward the top of the screened interval is suggested. Placement of the pump at the top of the water column for sampling is only recommended in unconfined aquifers, screened across the water table, where this is the desired sampling point. Low-

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flow purging has the advantage of minimizing mixing between the overlying stagnant casing water and water within the screened interval.

### **A. Low-Flow Purging and Sampling**

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface which can be affected by flow regulators or restrictions. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established site sampling objectives. Typically, flow rates on the order of 0.1 - 0.5 L/min are used, however this is dependent on site-specific hydrogeology. Some extremely coarse-textured formations have been successfully sampled in this manner at flow rates to 1 L/min. The effectiveness of using low-flow purging is intimately linked with proper screen location, screen length, and well construction and development techniques. The reestablishment of natural flow paths in both the vertical and horizontal directions is important for correct interpretation of the data. For high resolution sampling needs, screens less than 1 m should be used. Most of the need for purging has been found to be due to passing the sampling device through the overlying casing water which causes mixing of these stagnant waters and the dynamic waters within the screened interval. Additionally, there is disturbance to suspended sediment collected in the bottom of the casing and the displacement of water out into the formation immediately adjacent to the well screen. These disturbances and impacts can be avoided using dedicated sampling equipment, which precludes the need to insert the sampling device prior to purging and sampling.

Isolation of the screened interval water from the overlying stagnant casing water may be accomplished using low-flow minimal drawdown techniques. If the pump intake is located within the screened interval, most of the water pumped will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. However, if the wells are not constructed and developed properly, zones other than those intended may be sampled. At some sites where geologic heterogeneities are sufficiently different within the screened interval, higher conductivity zones may be preferentially sampled. This is another reason to use shorter screened intervals, especially where high spatial resolution is a sampling objective.

### **B. Water Quality Indicator Parameters**

It is recommended that water quality indicator parameters be used to determine purging needs prior to sample collection in each well. Stabilization of parameters such as pH, specific conductance, dissolved oxygen, oxida-

tion-reduction potential, temperature and turbidity should be used to determine when formation water is accessed during purging. In general, the order of stabilization is pH, temperature, and specific conductance, followed by oxidation-reduction potential, dissolved oxygen and turbidity. Temperature and pH, while commonly used as purging indicators, are actually quite insensitive in distinguishing between formation water and stagnant casing water; nevertheless, these are important parameters for data interpretation purposes and should also be measured. Performance criteria for determination of stabilization should be based on water-level drawdown, pumping rate and equipment specifications for measuring indicator parameters. Instruments are available which utilize in-line flow cells to continuously measure the above parameters.

It is important to establish specific well stabilization criteria and then consistently follow the same methods thereafter, particularly with respect to drawdown, flow rate and sampling device. Generally, the time or purge volume required for parameter stabilization is independent of well depth or well volumes. Dependent variables are well diameter, sampling device, hydrogeochemistry, pump flow rate, and whether the devices are used in a portable or dedicated manner. If the sampling device is already in place (i.e., dedicated sampling systems), then the time and purge volume needed for stabilization is much shorter. Other advantages of dedicated equipment include less purge water for waste disposal, much less decontamination of equipment, less time spent in preparation of sampling as well as time in the field, and more consistency in the sampling approach which probably will translate into less variability in sampling results. The use of dedicated equipment is strongly recommended at wells which will undergo routine sampling over time.

If parameter stabilization criteria are too stringent, then minor oscillations in indicator parameters may cause purging operations to become unnecessarily protracted. It should also be noted that turbidity is a very conservative parameter in terms of stabilization. Turbidity is always the last parameter to stabilize. Excessive purge times are invariably related to the establishment of too stringent turbidity stabilization criteria. It should be noted that natural turbidity levels in ground water may exceed 10 nephelometric turbidity units (NTU).

### **C. Advantages and Disadvantages of Low-Flow (Minimum Drawdown) Purging**

In general, the advantages of low-flow purging include:

- samples which are representative of the *mobile* load of contaminants present (dissolved and colloid-associated);
- minimal disturbance of the sampling point thereby minimizing sampling artifacts;
- less operator variability, greater operator control;

- reduced stress on the formation (minimal drawdown);
- less mixing of stagnant casing water with formation water;
- reduced need for filtration and, therefore, less time required for sampling;
- smaller purging volume which decreases waste disposal costs and sampling time;
- better sample consistency; reduced artificial sample variability.

Some disadvantages of low-flow purging are:

- higher initial capital costs,
- greater set-up time in the field,
- need to transport additional equipment to and from the site,
- increased training needs,
- resistance to change on the part of sampling practitioners,
- concern that new data will indicate a *change in conditions* and trigger an *action*.

#### IV. Low-Flow (Minimal Drawdown) Sampling Protocols

The following ground-water sampling procedure has evolved over many years of experience in ground-water sampling for organic and inorganic compound determinations and as such summarizes the authors' (and others) experiences to date (Barcelona et al., 1984, 1994; Barcelona and Helfrich, 1986; Puls and Barcelona, 1989; Puls et. al. 1990, 1992; Puls and Powell, 1992; Puls and Paul, 1995). High-quality chemical data collection is essential in ground-water monitoring and site characterization. The primary limitations to the collection of *representative* ground-water samples include: mixing of the stagnant casing and *fresh* screen waters during insertion of the sampling device or ground-water level measurement device; disturbance and resuspension of settled solids at the bottom of the well when using high pumping rates or raising and lowering a pump or bailer; introduction of atmospheric gases or degassing from the water during sample handling and transfer, or inappropriate use of vacuum sampling device, etc.

##### A. Sampling Recommendations

Water samples should not be taken immediately following well development. Sufficient time should be allowed for the ground-water flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

Well purging is nearly always necessary to obtain samples of water flowing through the geologic formations in the screened interval. Rather than using a general but arbitrary guideline of purging three casing volumes prior to

sampling, it is recommended that an in-line water quality measurement device (e.g., flow-through cell) be used to establish the stabilization time for several parameters (e.g., pH, specific conductance, redox, dissolved oxygen, turbidity) on a well-specific basis. Data on pumping rate, drawdown, and volume required for parameter stabilization can be used as a guide for conducting subsequent sampling activities.

The following are recommendations to be considered before, during and after sampling:

- use low-flow rates (<0.5 L/min), during both purging and sampling to maintain minimal drawdown in the well;
- maximize tubing wall thickness, minimize tubing length;
- place the sampling device intake at the desired sampling point;
- minimize disturbances of the stagnant water column above the screened interval during water level measurement and sampling device insertion;
- make proper adjustments to stabilize the flow rate as soon as possible;
- monitor water quality indicators during purging;
- collect unfiltered samples to estimate contaminant loading and transport potential in the subsurface system.

##### B. Equipment Calibration

Prior to sampling, all sampling device and monitoring equipment should be calibrated according to manufacturer's recommendations and the site Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). Calibration of pH should be performed with at least two buffers which bracket the expected range. Dissolved oxygen calibration must be corrected for local barometric pressure readings and elevation.

##### C. Water Level Measurement and Monitoring

It is recommended that a device be used which will least disturb the water surface in the casing. Well depth should be obtained from the well logs. Measuring to the bottom of the well casing will only cause resuspension of settled solids from the formation and require longer purging times for turbidity equilibration. Measure well depth after sampling is completed. The water level measurement should be taken from a permanent reference point which is surveyed relative to ground elevation.

##### D. Pump Type

The use of low-flow (e.g., 0.1-0.5 L/min) pumps is suggested for purging and sampling all types of analytes. All pumps have some limitation and these should be investigated with respect to application at a particular site. Bailers are inappropriate devices for low-flow sampling.

## 1) General Considerations

There are no unusual requirements for ground-water sampling devices when using low-flow, minimal drawdown techniques. The major concern is that the device give consistent results and minimal disturbance of the sample across a range of *low* flow rates (i.e., < 0.5 L/min). Clearly, pumping rates that cause minimal to no drawdown in one well could easily cause *significant* drawdown in another well finished in a less transmissive formation. In this sense, the pump should not cause undue pressure or temperature changes or physical disturbance on the water sample over a reasonable sampling range. Consistency in operation is critical to meet accuracy and precision goals.

## 2) Advantages and Disadvantages of Sampling Devices

A variety of sampling devices are available for low-flow (minimal drawdown) purging and sampling and include peristaltic pumps, bladder pumps, electrical submersible pumps, and gas-driven pumps. Devices which lend themselves to both dedication and consistent operation at definable low-flow rates are preferred. It is desirable that the pump be easily adjustable and operate reliably at these lower flow rates. The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and some volatiles loss. Gas-driven pumps should be of a type that does not allow the gas to be in direct contact with the sampled fluid.

Clearly, bailers and other *grab* type samplers are ill-suited for low-flow sampling since they will cause repeated disturbance and mixing of *stagnant* water in the casing and the *dynamic* water in the screened interval. Similarly, the use of inertial lift foot-valve type samplers may cause too much disturbance at the point of sampling. Use of these devices also tends to introduce uncontrolled and unacceptable operator variability.

Summaries of advantages and disadvantages of various sampling devices are listed in Herzog et al. (1991), U. S. EPA (1992), Parker (1994) and Thurnblad (1994).

### E. Pump Installation

Dedicated sampling devices (left in the well) capable of pumping and sampling are preferred over any other type of device. Any portable sampling device should be slowly and carefully lowered to the middle of the screened interval or slightly above the middle (e.g., 1-1.5 m below the top of a 3 m screen). This is to minimize excessive mixing of the stagnant water in the casing above the screen with the screened interval zone water, and to minimize resuspension of solids which will have collected at the bottom of the well. These two disturbance effects have been shown to directly affect the time required for purging. There also appears to be a direct correlation between size of portable sampling devices relative to the well bore and resulting purge volumes and times. The key is to minimize disturbance of water and solids in the well casing.

## F. Filtration

Decisions to filter samples should be dictated by sampling objectives rather than as a *fix* for poor sampling practices, and field-filtering of certain constituents should not be the default. Consideration should be given as to what the application of field-filtration is trying to accomplish. For assessment of truly dissolved (as opposed to operationally *dissolved* [i.e., samples filtered with 0.45 µm filters]) concentrations of major ions and trace metals, 0.1 µm filters are recommended although 0.45 µm filters are normally used for most regulatory programs. Alkalinity samples must also be filtered if significant particulate calcium carbonate is suspected, since this material is likely to impact alkalinity titration results (although filtration itself may alter the CO<sub>2</sub> composition of the sample and, therefore, affect the results).

Although filtration may be appropriate, filtration of a sample may cause a number of unintended changes to occur (e.g. oxidation, aeration) possibly leading to filtration-induced artifacts during sample analysis and uncertainty in the results. Some of these unintended changes may be unavoidable but the factors leading to them must be recognized. Deleterious effects can be minimized by consistent application of certain filtration guidelines. Guidelines should address selection of filter type, media, pore size, etc. in order to identify and minimize potential sources of uncertainty when filtering samples.

In-line filtration is recommended because it provides better consistency through less sample handling, and minimizes sample exposure to the atmosphere. In-line filters are available in both disposable (barrel filters) and non-disposable (in-line filter holder, flat membrane filters) formats and various filter pore sizes (0.1-5.0 µm). Disposable filter cartridges have the advantage of greater sediment handling capacity when compared to traditional membrane filters. Filters must be pre-rinsed following manufacturer's recommendations. If there are no recommendations for rinsing, pass through a minimum of 1 L of ground water following purging and prior to sampling. Once filtration has begun, a filter cake may develop as particles larger than the pore size accumulate on the filter membrane. The result is that the effective pore diameter of the membrane is reduced and particles smaller than the stated pore size are excluded from the filtrate. Possible corrective measures include prefiltering (with larger pore size filters), minimizing particle loads to begin with, and reducing sample volume.

### G. Monitoring of Water Level and Water Quality Indicator Parameters

Check water level periodically to monitor drawdown in the well as a guide to flow rate adjustment. The goal is minimal drawdown (<0.1 m) during purging. This goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience. In-line water quality indicator parameters should be continuously monitored during purging. The water quality

indicator parameters monitored can include pH, redox potential, conductivity, dissolved oxygen (DO) and turbidity. The last three parameters are often most sensitive. Pumping rate, drawdown, and the time or volume required to obtain stabilization of parameter readings can be used as a future guide to purge the well. Measurements should be taken every three to five minutes if the above suggested rates are used. Stabilization is achieved after all parameters have stabilized for three successive readings. In lieu of measuring all five parameters, a minimum subset would include pH, conductivity, and turbidity or DO. Three successive readings should be within  $\pm 0.1$  for pH,  $\pm 3\%$  for conductivity,  $\pm 10$  mv for redox potential, and  $\pm 10\%$  for turbidity and DO. Stabilized purge indicator parameter trends are generally obvious and follow either an exponential or asymptotic change to stable values during purging. Dissolved oxygen and turbidity usually require the longest time for stabilization. The above stabilization guidelines are provided for rough estimates based on experience.

#### **H. Sampling, Sample Containers, Preservation and Decontamination**

Upon parameter stabilization, sampling can be initiated. If an in-line device is used to monitor water quality parameters, it should be disconnected or bypassed during sample collection. Sampling flow rate may remain at established purge rate or may be adjusted slightly to minimize aeration, bubble formation, turbulent filling of sample bottles, or loss of volatiles due to extended residence time in tubing. Typically, flow rates less than 0.5 L/min are appropriate. The same device should be used for sampling as was used for purging. Sampling should occur in a progression from least to most contaminated well, if this is known. Generally, volatile (e.g., solvents and fuel constituents) and gas sensitive (e.g.,  $\text{Fe}^{2+}$ ,  $\text{CH}_4$ ,  $\text{H}_2\text{S}/\text{HS}^-$ ; alkalinity) parameters should be sampled first. The sequence in which samples for most inorganic parameters are collected is immaterial unless filtered (dissolved) samples are desired. Filtering should be done last and in-line filters should be used as discussed above. During both well purging and sampling, proper protective clothing and equipment must be used based upon the type and level of contaminants present.

The appropriate sample container will be prepared in advance of actual sample collection for the analytes of interest and include sample preservative where necessary. Water samples should be collected directly into this container from the pump tubing.

Immediately after a sample bottle has been filled, it must be preserved as specified in the site (QAPP). Sample preservation requirements are based on the analyses being performed (use site QAPP, FSP, RCRA guidance document [U. S. EPA, 1992] or EPA SW-846 [U. S. EPA, 1982]). It may be advisable to add preservatives to sample bottles in a controlled setting prior to entering the field in order to reduce the chances of improperly preserving sample bottles or

introducing field contaminants into a sample bottle while adding the preservatives.

The preservatives should be transferred from the chemical bottle to the sample container using a disposable polyethylene pipet and the disposable pipet should be used only once and then discarded.

After a sample container has been filled with ground water, a Teflon™ (or tin)-lined cap is screwed on tightly to prevent the container from leaking. A sample label is filled out as specified in the FSP. The samples should be stored inverted at 4°C.

Specific decontamination protocols for sampling devices are dependent to some extent on the type of device used and the type of contaminants encountered. Refer to the site QAPP and FSP for specific requirements.

#### **I. Blanks**

The following blanks should be collected:

- (1) field blank: one field blank should be collected from each source water (distilled/deionized water) used for sampling equipment decontamination or for assisting well development procedures.
- (2) equipment blank: one equipment blank should be taken prior to the commencement of field work, from each set of sampling equipment to be used for that day. Refer to site QAPP or FSP for specific requirements.
- (3) trip blank: a trip blank is required to accompany each volatile sample shipment. These blanks are prepared in the laboratory by filling a 40-mL volatile organic analysis (VOA) bottle with distilled/deionized water.

#### **V. Low-Permeability Formations and Fractured Rock**

The overall sampling program goals or sampling objectives will drive how the sampling points are located, installed, and choice of sampling device. Likewise, site-specific hydrogeologic factors will affect these decisions. Sites with very low permeability formations or fractures causing discrete flow channels may require a unique monitoring approach. Unlike water supply wells, wells installed for ground-water quality assessment and restoration programs are often installed in low water-yielding settings (e.g., clays, silts). Alternative types of sampling points and sampling methods are often needed in these types of environments, because low-permeability settings may require extremely low-flow purging (<0.1 L/min) and may be technology-limited. Where devices are not readily available to pump at such low flow rates, the primary consideration is to avoid dewatering of

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the well screen. This may require repeated recovery of the water during purging while leaving the pump in place within the well screen.

Use of low-flow techniques may be impractical in these settings, depending upon the water recharge rates. The sampler and the end-user of data collected from such wells need to understand the limitations of the data collected; i.e., a strong potential for underestimation of actual contaminant concentrations for volatile organics, potential false negatives for filtered metals and potential false positives for unfiltered metals. It is suggested that comparisons be made between samples recovered using low-flow purging techniques and samples recovered using passive sampling techniques (i.e., two sets of samples). Passive sample collection would essentially entail acquisition of the sample with no or very little purging using a dedicated sampling system installed within the screened interval or a passive sample collection device.

### **A. Low-Permeability Formations (<0.1 L/min recharge)**

#### **1. Low-Flow Purging and Sampling with Pumps**

- a. "portable or non-dedicated mode" - Lower the pump (one capable of pumping at <0.1 L/min) to mid-screen or slightly above and set in place for minimum of 48 hours (to lessen purge volume requirements). After 48 hours, use procedures listed in Part IV above regarding monitoring water quality parameters for stabilization, etc., but do not dewater the screen. If excessive drawdown and slow recovery is a problem, then alternate approaches such as those listed below may be better.
- b. "dedicated mode" - Set the pump as above at least a week prior to sampling; that is, operate in a dedicated pump mode. With this approach significant reductions in purge volume should be realized. Water quality parameters should stabilize quite rapidly due to less disturbance of the sampling zone.

#### **2. Passive Sample Collection**

Passive sampling collection requires insertion of the device into the screened interval for a sufficient time period to allow flow and sample equilibration before extraction for analysis. Conceptually, the extraction of water from low yielding formations seems more akin to the collection of water from the unsaturated zone and passive sampling techniques may be more appropriate in terms of obtaining "representative" samples. Satisfying usual sample volume requirements is typically a problem with this approach and some latitude will be needed on the part of regulatory entities to achieve sampling objectives.

### **B. Fractured Rock**

In fractured rock formations, a low-flow to zero purging approach using pumps in conjunction with packers to isolate the sampling zone in the borehole is suggested. Passive multi-layer sampling devices may also provide the most "representative" samples. It is imperative in these settings to identify flow paths or water-producing fractures prior to sampling using tools such as borehole flowmeters and/or other geophysical tools.

After identification of water-bearing fractures, install packer(s) and pump assembly for sample collection using low-flow sampling in "dedicated mode" or use a passive sampling device which can isolate the identified water-bearing fractures.

## **VI. Documentation**

The usual practices for documenting the sampling event should be used for low-flow purging and sampling techniques. This should include, at a minimum: information on the conduct of purging operations (flow-rate, drawdown, water-quality parameter values, volumes extracted and times for measurements), field instrument calibration data, water sampling forms and chain of custody forms. See Figures 2 and 3 and "Ground Water Sampling Workshop -- A Workshop Summary" (U. S. EPA, 1995) for example forms and other documentation suggestions and information. This information coupled with laboratory analytical data and validation data are needed to judge the "useability" of the sampling data.

## **VII. Notice**

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**APPENDIX B**  
**FIELD SAMPLING LOG SHEETS**

# SOIL SAMPLE COLLECTION FIELD SHEET

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**GENERAL INFORMATION**

SITE NAME: \_\_\_\_\_ PROJECT NO. \_\_\_\_\_

SAMPLE NO. \_\_\_\_\_ BORING NO. \_\_\_\_\_

DATE/TIME COLLECTED: \_\_\_\_\_ PERSONNEL: \_\_\_\_\_

SAMPLE METHOD / DEPTH: \_\_\_\_\_

SAMPLE MEDIA: SOIL SEDIMENT SLUDGE

SAMPLE QA SPLIT: YES NO SPLIT SAMPLE NO. \_\_\_\_\_

SAMPLE QC DUPLICATE: YES NO DUPLICATE SAMPLE NO. \_\_\_\_\_

MS/MSD REQUESTED: YES NO

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**SAMPLE CONTAINERS, PRESERVATIVES, ANALYSIS**

<u>Sample Container</u>	<u>Preservative</u>	<u>Analysis Requested</u>
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

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**OVA MEASUREMENTS**

Background \_\_\_\_\_

Breathing zone \_\_\_\_\_

Boring \_\_\_\_\_

Headspace \_\_\_\_\_

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**SAMPLE DESCRIPTION**

DEPTH: \_\_\_\_\_ DESCRIPTION: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

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**GENERAL COMMENTS**

\_\_\_\_\_

\_\_\_\_\_





## **APPENDIX C**

### **CONTRACT REQUIRED QUANTITATION LIMITS**

**TABLE 1  
TARGET ANALYTES AND REPORTING LIMITS**

Target Analytes	WATER	SOIL	TEF
	Reporting Limit, pg/L	Reporting Limit, ng/Kg	Toxicity Equivalent Factors (NATO, 1989)
<b>Dioxin and Furan (SW-846 8290A)<sup>3</sup></b>			
2,3,7,8-Tetrachlorodibenzo-p-dioxin	10	1	1.0
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	50	5	0.5
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	50	5	0.1
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	50	5	0.1
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	50	5	0.1
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	50	5	0.01
1,2,3,4,6,7,8,9-Octachlorodibenzo(p)dioxin	100	10	0.001
2,3,7,8-Tetrachlorodibenzofuran	10	1	0.1
2,3,4,7,8-Pentachlorodibenzofuran	50	5	0.05
1,2,3,7,8-Pentachlorodibenzofuran	50	5	0.5
1,2,3,4,7,8-Hexachlorodibenzofuran	50	5	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	50	5	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	50	5	0.1
2,3,4,6,7,8-Hexachlorodibenzofuran	50	5	0.1
1,2,3,4,6,7,8-Heptachlorodibenzofuran	50	5	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	50	5	0.01
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	100	10	0.001

Reference: Multi-Media Multi-Concentration, Dioxin and Furan Analytical Service for Superfund (DLM02.0), US EPA OSWER, September 2005

Target Analytes	WATER	SOIL
	Reporting Limit, mg/L	Reporting Limit, mg/Kg
<b>Metals (6010/7000 series)<sup>1</sup></b>		
Arsenic	0.01	1
Barium	0.002	20
Beryllium	0.005	0.5
Chromium	0.01	1
Lead	0.01	1
Manganese	0.015	1.5
Mercury	0.0002	0.1
Nickel	0.04	4
Selenium	0.035	3.5
Silver	0.01	1
<b>(SW-846 9012A/9013)<sup>1</sup></b>		
Cyanide	0.01	2.5

Notes:  
 MDL Method detection limit  
 mg/Kg Milligram per kilogram  
 mg/L Milligram per liter  
 ng/L Nanograms per liter (parts per trillion)  
 ug/Kg Micrograms per kilogram  
 ug/L Micrograms per liter

Reference: Multi-Media Multi-Concentration, Inorganic Analytical Service for Superfund (ILM05.3), US EPA OSWER, February 2004



**Table 1. Target Compound List (TCL) and Contract Required Quantitation Limits (CRQLs) for SOM01.1\* (Con't)**

Quantitation Limits						Quantitation Limits					
	Low Water by SIM (µg/L)	Low Water (µg/L)	Low Soil by SIM (µg/kg)	Low Soil (µg/kg)	Med. Soil (µg/kg)	Low Water by SIM (µg/L)	Low Water (µg/L)	Low Soil by SIM (µg/kg)	Low Soil (µg/kg)	Med. Soil (µg/kg)	
<b>SEMIVOLATILES (CON'T)</b>						<b>SEMIVOLATILES (CON'T)</b>					
78. 1,1'-Biphenyl		5.0		170	5000	115. Benzo(a)pyrene	0.10	5.0	3.3	170	5000
79. 2-Chloronaphthalene		5.0		170	5000	116. Indeno(1,2,3-cd)pyrene	0.10	5.0	3.3	170	5000
80. 2-Nitroaniline		10		330	10000	117. Dibenzo(a,h)anthracene	0.10	5.0	3.3	170	5000
81. Dimethylphthalate		5.0		170	5000	118. Benzo(g,h,i)perylene	0.10	5.0	3.3	170	5000
82. 2,6-Dinitrotoluene		5.0		170	5000	119. 2,3,4,6-Tetrachlorophenol		5.0		170	5000
83. Acenaphthylene	0.10	5.0	3.3	170	5000	<b>PESTICIDES</b>	<b>Water (µg/L)</b>		<b>Soil (µg/kg)</b>		
84. 3-Nitroaniline		10		330	10000	120. alpha-BHC	0.050		1.7		
85. Acenaphthene	0.10	5.0	3.3	170	5000	121. beta-BHC	0.050		1.7		
86. 2,4-Dinitrophenol		10		330	10000	122. delta-BHC	0.050		1.7		
87. 4-Nitrophenol		10		330	10000	123. gamma-BHC (Lindane)	0.050		1.7		
88. Dibenzofuran		5.0		170	5000	124. Heptachlor	0.050		1.7		
89. 2,4-Dinitrotoluene		5.0		170	5000	125. Aldrin	0.050		1.7		
90. Diethylphthalate		5.0		170	5000	126. Heptachlor epoxide	0.050		1.7		
91. Fluorene	0.10	5.0	3.3	170	5000	127. Endosulfan I	0.050		1.7		
92. 4-Chlorophenyl phenyl ether		5.0		170	5000	128. Dieldrin	0.10		3.3		
93. 4-Nitroaniline		10		330	10000	129. 4,4'-DDE	0.10		3.3		
94. 4,6-Dinitro-2-methylphenol		10		330	10000	130. Endrin	0.10		3.3		
95. N-Nitrosodiphenylamine		5.0		170	5000	131. Endosulfan II	0.10		3.3		
96. 1,2,4,5-Tetrachlorobenzene		5.0		170	5000	132. 4,4'-DDD	0.10		3.3		
97. 4-Bromophenyl phenyl ether		5.0		170	5000	133. Endosulfan sulfate	0.10		3.3		
98. Hexachlorobenzene		5.0		170	5000	134. 4,4'-DDT	0.10		3.3		
99. Atrazine		5.0		170	5000	135. Methoxychlor	0.50		17		
100. Pentachlorophenol	0.20	10	6.7	330	10000	136. Endrin ketone	0.10		3.3		
101. Phenanthrene	0.10	5.0	3.3	170	5000	137. Endrin aldehyde	0.10		3.3		
102. Anthracene	0.10	5.0	3.3	170	5000	138. alpha-Chlordane	0.050		1.7		
103. Carbazole		5.0		170	5000	139. gamma-Chlordane	0.050		1.7		
104. Di-n-butylphthalate		5.0		170	5000	140. Toxaphene	5.0		170		
105. Fluoranthene	0.10	5.0	3.3	170	5000	<b>AROCLORS</b>	<b>Water (µg/L)</b>		<b>Soil (µg/kg)</b>		
106. Pyrene	0.10	5.0	3.3	170	5000	141. Aroclor-1016	1.0		33		
107. Butylbenzylphthalate		5.0		170	5000	142. Aroclor-1221	1.0		33		
108. 3,3'-Dichlorobenzidine		5.0		170	5000	143. Aroclor-1232	1.0		33		
109. Benzo(a)anthracene	0.10	5.0	3.3	170	5000	144. Aroclor-1242	1.0		33		
110. Chrysene	0.10	5.0	3.3	170	5000	145. Aroclor-1248	1.0		33		
111. Bis(2-ethylhexyl)phthalate		5.0		170	5000	146. Aroclor-1254	1.0		33		
112. Di-n-octylphthalate		5.0		170	5000	147. Aroclor-1260	1.0		33		
113. Benzo(b)fluoroanthene	0.10	5.0	3.3	170	5000	148. Aroclor-1262	1.0		33		
114. Benzo(k)fluoroanthene	0.10	5.0	3.3	170	5000	149. Aroclor-1268	1.0		33		

\* For volatiles, quantitation limits for medium soils are approximately 50 times the quantitation limits for low soils. For semivolatile medium soils, quantitation limits are approximately 30 times the quantitation limits for low soils.