S1025

AECOM

AECOM
101 Research Drive
Columbia, SC 29203

803.254.4400 tel
803.771.6676 fax

Letter of Transmittal

Attention: Mr. Addie Walker - SCDHEC
Date: 8-20-15

Project reference: Shakespeare – Newberry
Project number: 60328308

We are sending you the following:

Number of originals:	Number of copies:	Description:
	2	Revised SIWP Addendum

Hi Addie –

Please find attached one hard copy and one electronic copy of the updated version of the SIWP Addendum. This version includes the most recent revisions requested in your July 30, 2015 letter to Philips.

Should you have any questions or need anything else with respect to the attached, please let me know at your convenience.

Sincerely,

Scott E. Ross

RECEIVED
AUG 20 2015
SC Department of
Health and Environmental
Control

RECEIVED
AUG 20 2015
SITE ASSESSMENT,
REMEDIATION &
REVITALIZATION

(59)

AECOM Technical Services, Inc.

Submitted by:
AECOM
Columbia, S.C
July 2015

Site Investigation Work Plan Addendum
Shakespeare Composite Structures, LLC

Voluntary Cleanup Contract 14-6271-RP

File # 51025

19845 US Highway 76

Newberry, SC

AECOM Technical Services, Inc.

Site Investigation Work Plan Addendum
Shakespeare Composite Structures, LLC

Voluntary Cleanup Contract 14-6271-RP
File # 51025
19845 US Highway 76
Newberry, SC

Prepared By: Scott E. Ross, P.G.
Project Manager

Walter C. Gerald

Reviewed by: Walter Gerald, P.G
Sr. Program Manager

Contents

List of Figures

List of Tables

List of Appendices

List of Acronyms

BLS	below land surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cis-1,2 DCE	cis-1,2 - Dichloroethene
CVOCs	chlorinated volatile organic compounds
DI	deionized
DO	dissolved oxygen
DOT	Department of Transportation
EPA	United States Environmental Protection Agency
FBQSTP	Field Branches Quality System and Technical Procedures
HASP	Health and Safety Plan
HSA	hollow stem auger
IDW	investigation derived waste
MCL	maximum contaminant level
NGVD	National Geodetic Vertical Datum
NTu	Nephlometric Turbidity Units
µg/L	micrograms per liter
mg/L	milligrams per liter
ORP	oxidation-reduction potential
PCE	tetrachloroethene
PPE	personal protective equipment
QC	quality control
RECs	recognized environmental conditions
RI	remedial investigation

RSL	Regional Screening Level
SC	Specific Conductance
SESD	EPA Region IV Science and Ecosystems Support Division
SOPs	Standard Operating Procedures
SU	Standard Unit
TCE	Trichloroethene
TCL	Target Compound List
USCS	Unified Soil Classification System
VCC	voluntary cleanup contract
VOCs	volatile organic compounds

1.0 INTRODUCTION

The Shakespeare Composite Structures, LLC (Shakespeare) facility has been designing and producing fiberglass products at their manufacturing facility located in Newberry, South Carolina (the facility) since the mid-1960s. In December 2013, Shakespeare retained AECOM Technical Services, Inc. (AECOM) to perform a Phase I Environmental Site Assessment (Phase I ESA) at their facility. The Phase I ESA was followed by a Phase II ESA, which investigated several potential environmental impacts identified at the facility during the Phase I ESA. The Phase II ESA and subsequent phases of investigative efforts have identified concentrations of chlorinated volatile organic compounds (CVOCs) in soil and groundwater beneath the facility. As a result of the investigation findings to date, Shakespeare has requested AECOM assist with further evaluating groundwater conditions beneath the facility. This document serves as the Site Investigation Work Plan Addendum (Work Plan). The Work Plan outlines the rationale for performing additional investigative efforts and the technical approaches that will be used to collect additional data from the Site.

1.1 Physical Setting

The Shakespeare facility is located on US Highway 76, approximately 1 mile northwest of the City of Newberry (**Figure 1-1**). The Shakespeare facility occupies 24.24-acres. The property includes the main production building and the pole winder building, totaling approximately 250,000 square-feet under roof. The property also has several smaller structures located at the west end of the property including a less than 90-day hazardous waste storage building, a residual resin curing building, along with other smaller storage buildings.

An asphaltic employee parking lot is located to the southwest of the main building, which is accessed from U.S. Highway 76 to the southwest of the subject property. The south end of the property contains another asphalt-paved area, which is the former employee overflow parking area where equipment and other materials currently are staged. There is a covered shed area at the southeast end of the property where finished products are packaged for shipment. The area between the two buildings in the center of the property is mostly grassed and is used for equipment or material storage, and some grassed areas are present at the west and northwest sides of the property. Loading docks are located on the northwest and southeast corners of each building and are accessed via concrete-paved or asphalt-paved driveways from U.S. Highway 76. The northwest, northeast, and southeast perimeters of the subject property are fenced, and locking gates are present at the two driveways beyond the employee parking lot (**Figure 1-2**).

General land use surrounding the facility consists of agricultural, residential, undeveloped and commercial/light industrial properties. Uses of adjacent properties identified during the site visit are as follows:

<u>North:</u> The facility is bordered immediately to the north by a rail line and undeveloped land planted with pine trees. The property bounding the facility to the north is owned by J.L. Dickert.

<u>East</u>: The facility is bordered immediately to the east by a residential parcel, beyond which is vacant land (pine trees) and vacant buildings formerly occupied by the Dickert Lumber company. The property east of the private residence up to Lumber road is also owned by J.L. Dickert.

<u>South</u>: The facility is bordered to the south by U.S. Highway 76 and properties owned by the Newberry County Airport and Walter Shealy. The property owned by Mr. Shealy is primarily farmland with a few small residences located sporadically across more than 60 acres.

West: There three properties located immediately to the west of the facility. The property the bounds the facility is owned by Harriet Boazman. The properties to the west of the Boazman property are owned by Edna Ringer and Kimberly Chapman, respectively.

The Shakespeare site (the Site) includes the Shakespeare facility along with several of the properties referenced above, that lie to the south, west and north where investigative efforts have been performed to date.

1.2 Site Operational Background

According to information reviewed in previous documents and confirmed with Shakespeare personnel, the subject property was undeveloped, wooded land until purchased from Ruth Amis in 1965. The main building was constructed in the mid-1960s and used for fiberglass production; that building is constructed of concrete block covered with brick on three sides; the floor a concrete slab-on-grade foundation, with several observed subgrade sumps or vaults. The pole winder building reportedly was constructed in the late 1970s; it is a concrete block building with sheet metal siding on parts of the building, with a concrete slab on grade floor. Both buildings are one story although there are some elevated second floor offices in the main building, and the former “tower” area extends upward about two floors. Each building has several small, added-on portions, primarily consisting of the three LRB areas for wastewater treatment (fiberglass separation).

The facility is used for the design and manufacture of large fiberglass utility poles and cross arms, and other fiberglass outdoor products such as signs and sign posts. The manufacturing processes include the following categories: materials receiving, formulation of resin mixes, pultrusion of fiberglass products, extrusion of plastic products, winding of fiberglass poles, painting and heat curing of poles, testing of materials, warehouse/storage of finished goods, and packaging/shipping. Fiberglass rolls are wrapped around molds, and then a resin mix is applied as a coating. Sanding and grinding of poles occurs, and painting, drying, and heat curing are also performed. Manufacturing is conducted inside two separate buildings. The main building houses pultrusion and extrusion activities, and large and small poles are fabricated in the pole winder building. Manufactured materials are packaged indoors and outdoors for shipment (AECOM, 2013).

1.3 Summary of Previous Investigative Efforts

As mentioned above, Shakespeare retained AECOM to assist with multiple ESAs to determine if the facility had any environmental issues or concerns. The ESAs were followed by multiple phases of more in depth subsurface investigation both at the facility and on properties adjacent to the facility. The activities completed during each phase of work are briefly summarized in this section.

1.3.1 Phase I ESA

In December 2013, AECOM performed a Phase I ESA at the Newberry facility. In accordance with American Society of Testing and Materials (ASTM) standards the Phase I ESA included review of historical records for the facility, inspection of the property, and the identification of 11 areas which were determined to be known as recognized environmental conditions (RECs). Based on the identification of these RECs, Shakespeare requested that a follow-up Phase II ESA be performed at the facility (AECOM, 2013).

1.3.2 Phase II ESA

In January 2014, AECOM initiated the Phase II ESA at the facility. The Phase II included investigation of groundwater, soil, sediment, and surface water at various locations across the facility. In total 11 RECs were investigated. A brief list of the Phase II ESA activities is as follows:

- Installation and sampling of eight shallow temporary monitoring wells (TMW-1 through TMW-8)
- Collection and analysis of four surface soil samples;
- Collection and analysis of 15 subsurface soil samples;
- Collection of a sediment sample from a storm water drain in the eastern portion of the property (REC-7a); and
- Collection of a sediment and surface water sample from the storm water outfall located on the northwestern side of the property (REC-7b).

Samples of these media were analyzed for a variety of parameters. Analytical results from the Phase II indicated that the CVOC trichloroethene (TCE), and degradation compounds cis-1,2 Dichloroethene (Cis-1,2 DCE) and vinyl chloride (VC) are present above their respective drinking water standards (maximum contaminant levels – MCL) in groundwater beneath the facility. As a result of the detection of these CVOCs, Shakespeare requested that AECOM initiate a more thorough investigation of the facility. Results of the Phase II ESA are discussed in more detail in the Site Investigation Summary (AECOM, 2014a).

1.3.3 Site Investigation

In March 2014, AECOM developed the Site Investigation Work Plan (SIWP) (AECOM, 2014b). The SIWP outlined the rationale for performing additional investigative efforts at the Site and referenced technical approaches and methodologies to be used to collect additional data from the Site based on the results of the Phase II ESA. The SIWP included plans for additional soil and groundwater sampling. The SIWP was originally intended for submittal to Shakespeare only, however, it was prepared assuming it may be submitted to the South Carolina Department of Health and Environmental Control (SCDHEC) for review at a later date. Therefore, the SIWP was developed assuming the Site would eventually be evaluated utilizing procedures consistent with the National Contingency Plan (NCP) which are part of the USEPA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process. The SIWP included references to the USEPA Region 4 Standard Operating Procedures and guidance.

The original SIWP was implemented in April 2014. This sub-phase of work included the following efforts:

- Installation and sampling of 10 shallow temporary monitoring wells (TMW-9 through TMW-18) attempting to delineate the horizontal extent of groundwater impacts on the facility property.

- Installation of nine permanent monitoring wells (MW-1 through MW-9). Each of these wells was installed as replacements for temporary wells.
- Collection of additional subsurface soil samples from Phase II ESA boring locations B-12, B-13, and B-16. The intent of this phase of soil sampling was to focus on possible source areas based on their historical use and results from the initial Phase II ESA sampling efforts in these areas. Field personnel utilized the AQR Color-Tec® field screening tool to determine which subsurface samples from each boring would be submitted for chemical analysis.

Results of this phase of the site investigation indicated CVOC impacted groundwater may be migrating off-site and subsurface soils beneath portions of the facility contain low concentrations of CVOCs. Results of the Phase II ESA and soil and groundwater investigation efforts performed as part of this early phase of the Site Investigation are included in the Site Investigation Summary (AECOM, 2014a).

Following review of the first phase of SI results, AECOM and Shakespeare implemented a subsequent soil and groundwater sampling phase of work attempting to identify likely source areas for the CVOCs beneath the Site. This source investigation phase of work was initiated in May 2014 and included the following:

- Advancement of 28 soil borings at locations within and adjacent to the main production building and the pole winder building at the facility. The soil borings allowed collection of continuous subsurface soil cores from land surface to approximately 25 feet or drilling refusal. Soil samples were collected at one to two foot intervals screened using a photoionization detector (PID) and evaluated using the AQR Color-Tec® field screening tool to determine which soil samples from each boring would be submitted for chemical analysis.
- Installation of 15 shallow temporary monitoring wells to further delineate potential source areas and boundaries for CVOC impacts in groundwater.
- Collection of groundwater samples from four existing permanent monitoring wells for geochemical and biological analyses to determine attenuation conditions beneath the Site.
- Collection of samples from seven private water supply wells located on properties adjacent to the facility.

This phase of investigative work detected CVOCs in soils beneath the Main Building and Pole Winder building. These results coupled with anecdotal information from facility personnel regarding historic use of solvents indicated a primary source area for CVOCs underlies the western portion of the Main Building with other, smaller source areas under the east central portion of the Main Building and under the western portion of the Pole Winder building. Although the CVOCs are present in subsurface soils, the majority of the concentrations do not exceed screening values and therefore no additional investigative efforts have been proposed for soils at the site.

Groundwater results generated during this phase of the investigation confirmed that CVOC impacted groundwater has migrated to the north and west of the Site. In addition, two private water wells located to the west and southwest of the Site were found to contain elevated CVOC concentrations. As a result, Shakespeare installed organic compound filter systems on these wells within days of the discovery of the presence of CVOCs. The results of this phase of work led to an even more elaborate groundwater investigation both on and off-site. Results of the Phase II ESA and soil and groundwater investigation efforts performed as part of the early phase of the Site Investigation are included in the Site Investigation Summary (AECOM, 2014a).

1.3.4 Expanded Investigation

Following a brief meeting with SCDHEC representatives in June 2014 to present results of the Phase II and Site Investigation efforts. Shakespeare submitted a brief work plan to SCDHEC presenting a scope of work for additional groundwater investigative activities and requesting a permit to perform these proposed efforts. This investigation effort was implemented in mid-July 2014 and completed in late August 2014. The additional phase of work (Expanded Investigation) included a more elaborate investigation of groundwater quality in multiple depth zones at locations on- and off-site the AQR Color-Tec® field screening tool in an attempt to delineate the extent of CVOCs in groundwater. Color-Tec® field screening results were used to guide the sampling efforts both vertically and horizontally. More specifically this investigation included the following:

- Collection of shallow and intermediate depth groundwater samples from 12 locations (TMW-34 through TMW-41, TMW-101 through TMW-107) on private properties to the south and west of the Shakespeare facility;
- Collection of shallow and intermediate depth groundwater samples from 57 locations (TMW-42 through TMW-99) on property that bounds the northern side of the Shakespeare facility;
- Collection of groundwater samples from intermediate depth intervals at seven locations (TMW-44, TMW-45, TMW-46, TMW-47, TMW-48, TMW-49, TMW-50, TMW-51, TMW-100, and TMW-106) beneath the Shakespeare property;
- Installation and sampling of four deep bedrock wells on the Shakespeare property (MW-2D, MW-3D, MW-6D, MW-7D);
- Installation and sampling of three deep bedrock wells on private properties to the south and west of the Shakespeare facility (RDW-1, RDW-2, and SDW-1); and
- Collection of three surface water samples (SW-1, SW-2, SW-3) from a small creek that bounds the northern end of the groundwater sampling grid on the property that bounds the northern side of the Shakespeare facility (Dickert Property).

Results of the initial portion of the Expanded Investigation have determined that CVOC impacted groundwater in the shallow zone has migrated several hundred yards to the north of the Shakespeare facility and to a lesser extent to the west of the facility. The investigation also determined that the competent surface of the underlying granite bedrock is deeper than originally anticipated. It has also become apparent that zones of partially weathered bedrock exist at relatively shallow depths across the Site and they may have an effect on the migration of shallow CVOC impacted groundwater. The investigation has also indicated that CVOC impacted groundwater is also migrating into the uppermost fracture zones in the granite bedrock underlying the Shakespeare facility and to the southwest.

Results of the Expanded Investigation efforts are discussed in more detail in the Summary of Investigative Efforts report (AECOM, 2014c).

1.4 Additional Site Investigation Objectives

As a result of the investigative efforts performed to date, Shakespeare entered into a responsible party - voluntary cleanup contract (RP-VCC) with the SCDHEC in September 2014. SCDHEC has reviewed the results of the investigative efforts performed to date and has requested Shakespeare submit a plan to complete the delineation of the vertical and horizontal extent of CVOC impacts to groundwater both on and off-site and to evaluate the potential risks these compounds pose to human health and the environment. The investigation and risk evaluation information will be used to determine if a remedy for the CVOC impacted groundwater is necessary.

This work plan addendum is intended to present the scope of the investigative efforts and the procedures to be used during the investigation. Based on the information collected to date from the Site, the objectives of the Site Investigation are as follows:

- Verify the horizontal extent of CVOCs off-site with the installation of permanent monitoring wells;
- Conduct further evaluation of groundwater quality in the intermediate zone on and off-site to determine the distribution of elevated CVOC concentrations at greater depths above bedrock;
- Delineate the vertical extent of impact in bedrock;
- Sampling of isolated bedrock fracture zones to determine possible routes of preferential migration;
- Implementation of a groundwater sampling program using the permanent monitoring well network to be established at the Site; and
- Provide data to be used in evaluation of the potential risks the CVOCs may pose to possible human and or ecological receptors.

The following sections of this SI Work Plan Addendum review the rationale for the investigation and describe, in detail, the sampling methods to be used during field activities.

2.0 RATIONALE FOR SITE INVESTIGATION

Previous rounds of investigation have included the collection of soil and groundwater samples from numerous locations across the Site and off-site. The results of the previous investigative efforts have indicated the presence of CVOCs TCE, cis-1,2 DCE and VC in groundwater above their respective drinking water standards in multiple groundwater samples from beneath the Site as well as locations on private property to the north and west of the Site. In accordance with the RP-VCC, Shakespeare has developed this plan presenting investigative efforts to be used to determine the extent of impact to environmental media at the Site. This section discusses the rationale and objectives for the implementation of the SI Work Plan Addendum.

2.1 Soil

During the Phase II ESA and initial phase of the (SI) numerous surface and subsurface soil samples were collected from beneath the Shakespeare facility. The results of the soil investigation efforts identified areas of limited impact and possible source areas for CVOCs in soil. Based on the results of the previous investigations, Shakespeare is not proposing additional soil investigation efforts in this work plan.

2.2 Groundwater

Investigative efforts to date have determined that elevated concentrations of CVOCs extend from beneath the facility to the north and west, in groundwater at multiple depths. The intent of the additional groundwater investigative efforts presented in this work plan is to fill data gaps for the shallow zone to the southwest of the Site, in the intermediate zone beneath facility, and in bedrock beneath the Site. This will be accomplished using a variety of methods including the installation and sampling of temporary wells, permanent well installation, and vertical profiling of groundwater quality.

2.2.1 Shallow Zone

As shown in **Figure 2-1**, the lateral extent of impacts to shallow groundwater has been delineated in all directions except to the south-southwest, near TMW107. As part of the next round of investigative work, Shakespeare will collect shallow groundwater samples from at least three locations surrounding TMW107 to determine the extent of impact to the shallow zone in this area. The Color-Tec® field screening methodology will be used to screen samples from these additional propose locations. Should field screening indicate the presence of CVOCs, additional borings will be advanced at locations in various directions to allow collection of additional samples for field screening. Results for samples collected from additional locations in this area will help determine where permanent wells will be installed on the Shealy property.

The extent of impact to the shallow zone in other directions off-site has primarily been delineated; therefore this investigative phase of work will include the installation of 14 shallow permanent monitoring wells at select off-site locations. **Figure 2-1** shows the extent of TCE in shallow zone groundwater and the proposed locations of permanent monitoring wells to be installed as part of this effort.

The locations of and rationale for the proposed shallow permanent wells is briefly discussed below:

- Based on the variations of concentrations and widespread distribution of CVOCs in groundwater, Shakespeare is proposing to install nine (9) shallow permanent wells on property to the north (Dickert Property) of the facility. This includes wells at the location with the highest TCE concentration detected at the Site to date (1600 ug/L at TMW-42) and at locations bounding the edges of the CVOC plume.
- Two (2) shallow wells are proposed for the Boazman property located west of the facility. One will be installed in the vicinity of the water well and one will also be installed between the former locations of TMWs 40 and 41.
- One (1) well is proposed for the Chapman property, as a downgradient monitoring point.
- One (1) shallow well on the south side of the main building on the plant site.
- Two (2) wells are proposed for the Shealy property, southwest of the facility, across US Highway 76, also as downgradient monitoring points.

Table 2-1 lists the proposed shallow wells to be installed during this effort.

2.2.2 Intermediate Zone

The previous phases of investigation have determined that multiple zones of groundwater beneath the area, including the upper section of granite bedrock, have been impacted by CVOCs. During the previous phase of work, AECOM utilized direct push drilling technology (DPT), field screening, and confirmatory analysis in a vertical profiling process to determine the impact to groundwater between the shallow zone (water table) and the underlying bedrock. However due to difficult drilling conditions and varying depths to zones of partially weathered bedrock beneath the area, the distribution of CVOCs within the intermediate depth interval beneath the Site has not been fully determined. Therefore, as part of this additional investigation efforts Shakespeare will be using roto-sonic drilling technology and push point sampling to allow further delineation of impact to groundwater quality in the intermediate aquifer zone. The intermediate zone sampling is proposed for nine locations, as shown on **Figure 2-2**.

The depths at which the intermediate samples will be collected will depend on the location of the borings. Some of the proposed locations are at points where previous attempts were made to perform the vertical profiling of groundwater quality including several former sample points on the facility property (TMW-42, TMW-44, TMW-45, TMW-47, and TMW-48). DPT drilling during the previous phase of work was halted at many of these locations by bedrock zones encountered at varying depths. The anticipated depths at which the profiling will be initiated at a particular location are presented in **Table 2-2**.

This vertical profiling effort will include on-site analysis of groundwater samples using the Color-Tec® screening methodology. Results of the vertical profiling field screening will be used to determine the location for and depth at which intermediate zone monitoring wells will be installed. For the purposes of this work plan, it is assumed that up to ten (10) intermediate zone wells will be installed as a result of this field screening effort.

Each of the permanent shallow and intermediate zone wells to be installed during this investigation will be constructed in accordance with SC Well Standards and Regulations (SC.R16-71). This will include installation of a two inch diameter Sch-40 PVC well screen; sand filter pack material, bentonite seal, cement grout and completion of each well at land surface with a concrete pad and 8 inch diameter bolt down steel cover. Well boring advancement and well installation procedures to be used during this investigation are discussed in Section 3.2.2.

Each well and boring location will also be surveyed for elevation and location by a SC Registered Land Surveyor.

2.2.3 Bedrock Groundwater Investigation

The bedrock well installation program completed in August 2014 determined the horizontal extent of CVOCs in several directions. However, SCDHEC has requested that additional bedrock wells be installed to more fully delineate the horizontal extent of CVOCs. As a result, two additional bedrock wells will be installed at locations requested by the SCDHEC, northeast of the former Shakespeare facility on private property and to the west of the Shakespeare facility on private property.

Results of the bedrock well installation program also indicated that at a minimum, the groundwater in the uppermost fracture zone in the underlying granite bedrock is impacted by elevated CVOC concentrations (**Figure 2-3**). It is currently unknown how many fracture zones are impacted by CVOCs. Shakespeare will perform vertical profiling in the bedrock by advancing an additional bedrock boring at the west end of the Shakespeare property, to allow testing of deeper fracture zones for the presence of CVOCs. The actual location of this bedrock well will be determined by AECOM, Shakespeare, and SCDHEC, The intent of this effort is to determine if CVOC impacted groundwater is isolated to the more shallow fracture zones or if it is migrating through fracture zones at multiple depths and to determine the vertical extent of CVOC impact in the bedrock in this area. Once its maximum depth is reached the bedrock boring will be converted to a monitoring well, with the well screen installed across a fracture zone that is found to not contain CVOCs during the field screening.

2.2.4 Well Development

Each of the permanent wells to be installed during this investigation will be developed in accordance with procedures to be referenced in Section 3.2.3. This will entail surging and over-pumping of each well to remove suspended silts and clays from the well by conditioning the surrounding sand filter pack. Water quality parameters including pH, specific conductivity (SC), temperature (Temp) and turbidity (Turb) will be monitored and recorded during the development process. All well development water will be containerized, handled and staged in accordance with procedures referenced in Section 3.2.7 below.

2.2.5 Groundwater Sampling

Each of the 19 existing groundwater monitoring wells and the 32 additional wells to be installed during this phase of work will be sampled as part of a site-wide sampling effort. Groundwater samples collected from each well will be analyzed for Target Compound List Volatile Organic Compounds (TCL VOCs). The wells to be sampled as part of this synoptic event will include the following:

- Nine (9) shallow wells located outside of the facility buildings (MW-1 through MW-9);
- Ten (10) shallow wells located within the Shakespeare facility buildings (TMW-21, TMW-22, TMW-23, TMW-24, TMW-25, TMW-29, TMW-30, TMW-31, TMW-32, and TMW-33);
- Six (6) previously installed bedrock wells (MW2D, MW3D, MW6D, MW7D, RDW1 and RDW2);
- Fifteen (15) newly proposed shallow wells;
- Nine (9) proposed intermediate wells; and
- Three proposed additional bedrock wells.

Table 2-3 lists the wells to be sampled during this phase of work and the proposed analytical parameters for each well. Temporary monitoring wells and permanent wells will be purged and sampled in accordance with protocols referenced in section 3.2.4 below.

2.2.6 Water Well Sampling

In addition to the monitoring well network, groundwater samples will also be collected from a select number of water wells located to the west of the Site. The wells to be sampled include the Boazman Well, five wells located on the Shealy Property (PW-1, PW-2, PW-3, PW-5, and an unused well located to the north of PW-2), and the Chapman well (PW-4). **Table 2-3** also lists the water wells to be sampled during this phase of work.

Water wells will be purged and sampled in accordance with protocols referenced in section 3.2.4 below.

2.3 Surface Water

Based on field observations during previous phases of work at the Site, it appears that shallow groundwater may discharge to shallow creeks that bound the northern and western portions of the Site (**Figure 2-4**). During the recently completed expanded investigation phase of work, three surface water samples (SW-1 though SW-3) were collected from a shallow creek that bounds the northern portion of the Site on the Dickert property. A trace amount of CVOC daughter compound Cis-1,2 DCE was detected in one sample (SW-1) at 0.51 ug/L.

As part of this investigative effort, Shakespeare will collect additional surface water samples from three locations on the Dickert property and from approximately four locations on the creek that bounds the western portion of the Site, on the Shealy Property (**Table 2-4**). The proposed sample locations are depicted on **Figure 2-4**. Procedures to be used for surface water sample collection are discussed in Section 3.2.5.

2.4 Sample Analysis

Based on the analytical results for previous investigative efforts all groundwater samples collected during this investigation will be analyzed for the Target Compound List (TCL) of volatile organic compounds (TCL VOCs) using EPA SW-846 analytical method 8260c. The full TCL VOC analysis is a typical suite of parameters that would be required when following Remedial Investigation (RI) procedures in accordance with USEPA and SCDHEC VCC guidance. In addition, at the request of the SCDHEC, groundwater samples collected from one upgradient well (MW-1) and one downgradient well (MW-7) will also be analyzed for Target Analyte List Metals (TAL Metals). MW-1 was chosen for TAL Metals analysis as it is a background well. MW-7 was selected for TAL Metals analysis because it is within the area of shallow zone TCE impacts. However the CVOC concentrations and water quality conditions are not at levels that are believed to readily promote dissolution of metals. As indicated above, **Tables 2-3** and **2-4** list the samples to be collected during this investigation and the parameters for which samples will be analyzed during this round of investigation.

3.0 FIELD ACTIVITIES

This section of the SI Work Plan Addendum discusses the methods to be used when performing the investigative efforts. Procedures detailed in the USEPA Region 4 Science and Ecosystem Support Division (SESD) Field Branches Quality System and Technical Procedures (FBQSTP) will be used during the execution of the investigative efforts. Where the SESD Technical documents do not specify procedures for activities described in this work plan, AECOM Standard Operating Procedures (SOPs) or other appropriate procedures are referenced. Copies of the referenced procedures are included in Appendix A.

A site-specific Health and Safety Plan (HASP) has also been prepared by AECOM for this project. The HASP is being submitted under separate cover.

3.1 Field Investigation Preparation Activities

Preparation for field work will include: resolution of Site access issues; selection and procurement of qualified subcontractors for analytical and field work; procurement of necessary field and sampling equipment; establishment of a field headquarters; designation of an IDW storage area; and designation and construction of a temporary equipment decontamination area.

3.1.1 Resolution of Access Issues and Permits

Prior to the commencement of field activities, written permission for access to all properties where sampling will be performed will be obtained. Additionally, the accessibility of all proposed sampling locations will be confirmed (i.e., potential obstacles to drilling such as underground water, sewer, gas, electric and telephone lines or above-ground cables, buildings or other above-ground structures will be identified). Should the relocation of any sampling locations be deemed necessary, minor adjustments in sampling locations of 50 feet or less will be considered to be in conformance with the Work Plan and will not require client approval. Significant changes in sampling locations of greater than 50 feet will be proposed for the client's approval during the sampling activities. Sampling relocations, regardless of their magnitude, will be documented in the field log including the reason for the change and summarized in the Source Investigation report.

In accordance with the South Carolina Well Standards [R.61-71(H)(1)(a)], a permit for well installation is required prior to initiation of drilling activities. AECOM will acquire the well permit on behalf of Shakespeare as part of this effort. Submittal of this Work Plan will serve as the written request for the permit to perform the drilling activities referenced herein.

3.1.2 Selection of Qualified Subcontractors

Qualified subcontracting firms will be procured prior to implementation of the field program. The criteria to be utilized for subcontractor selection are presented in the following sections.

3.1.2.1 Drilling Subcontractor

The well installation program will require procurement of a SC well drilling contractor. The drilling firm will be required to meet the following criteria:

- Proven experience on a variety of hazardous waste sites;
- Proven technical capabilities;
- Suitably experienced staff;
- Adequate drilling equipment and supplies;
- State of South Carolina Registration for boring advancement and monitoring well installation;
- Employee health and safety training certification in accordance with the provisions of OSHA 29 CFR 1910, SARA Section 126(d), and AECOM contractor health and safety criteria, and
- Appropriate contractor and worker liability insurance.

Selection of a drilling subcontractor and all appropriate contractual agreements will be finalized prior to initiation of the field program.

3.1.2.2 Land Surveying Subcontractor

The new monitoring wells will be appropriately located and their elevations determined with respect to the most recent geodetic datum using a licensed surveyor. AECOM will utilize an in-house South Carolina Professional Land Surveyor, based in South Carolina to perform the survey effort.

3.1.2.3 Laboratory Subcontractor

AECOM will contract a SCDHEC-certified laboratory to perform the sample analysis required for this project. The laboratory will be National Environmental Laboratory Accreditation Conference (NELAC) certification and will also be certified by the SCDHEC. Shealy Environmental Services, Inc. (Shealy) based in West Columbia, South Carolina has been selected to perform chemical analyses.

3.2 Site Investigation Procedures

As discussed in Section 2, the Site Investigation will consist of an additional phase of groundwater investigation as well as a limited investigation of surface water quality. This section of the Work Plan details the procedures that will be used to investigate both media along with quality and other project related efforts to be performed.

3.2.1 Groundwater Investigation

As indicated in Section 2.2 above the groundwater investigation will include the following:

- Installation and sampling of approximately three shallow temporary monitoring wells;
- Installation of 14 shallow permanent monitoring wells;

- Vertical profiling of intermediate groundwater quality beneath the Site;
- Installation of up to nine intermediate monitoring wells;
- Vertical profiling of groundwater quality in bedrock fractures;
- Development and sampling of the newly installed permanent wells; Collection of groundwater elevation data from the expanded well network;
- Collection of groundwater samples from the Site monitoring well network; and
- Collection of groundwater samples from water wells.

The proposed locations for the temporary wells and additional permanent wells are shown in **Figures 2-1 through 2-3**. The temporary well points and permanent shallow wells will be installed in accordance with procedures described in the USEPA Region 4 SESD protocol (USEPA 2008) for Design and Installation of Monitoring Wells (SESD GUID-101-R0; (**Appendix A**) with drill rig capable of utilizing direct push technology and/or hollow stem augers (HSAs) as well as roto-sonic technology. Well boring advancement and well installation procedures are discussed below.

3.2.1.1 Well Boring Advancement

Soil borings advanced during this phase of work for shallow temporary monitoring well installation will be advanced using a DPT/Geoprobe^{TM}, roto-sonic or HSA style drilling rigs. The well borings will be advanced to depths determined appropriate by information collected in the field and as determined by the AECOM field hydrogeologist.

During well boring advancement, soil cores/samples will be obtained for geologic characterization and soil classification. Soil core collection will entail the use of a variety of tools depending on the drill technology. Depending on the drilling technology that will be used, these sampling tools include two-inch diameter by two foot stainless steel split spoons utilized during HSA drilling, 2-1/4-inch diameter by 5 foot Geoprobe^{TM} soil core barrel with acetate liner, or a 4 inch diameter, 10 foot long stainless steel core barrel utilized by roto-sonic drill rig. Soil cores will be collected continuously from land surface to the target depth for a boring in order to identify potential confining layers if present, and to accurately determine the water table depth. Soil recovery and soil type will be determined and logged.

Soils collected during the well boring process will be visually classified and described on boring logs using the Unified Soil Classification System (USCS). Copies of the boring logs will be included in the SI Report to be prepared following completion of this investigation.

Borings advanced as part of the intermediate zone vertical profiling will be advanced using roto-sonic drilling techniques. The roto-sonic drilling procedure will utilize a 10 foot long, 4 inch inside diameter (5 ¾ inch outside diameter) core barrel that will be advanced into the subsurface. Once the core barrel is advanced its maximum length, a 6 inch inside diameter outer casing will be advanced over the core barrel to the same depth. The core barrel is then removed from inside the casing allowing extraction of a soil core. The intermediate zone vertical profiling borings will be advanced at locations and depths specified in **Table 2-2**. The methods to be used to collect groundwater samples for field screening from these borings are discussed in Section 3.2.1.3, below.

In the event that it becomes necessary to terminate a boring short of its intended completion depth (i.e., a boulder or other obstacle is encountered), the boring will be abandoned in accordance with the SC Well Standards [R.61-71(H)(2)(e)]. Borehole abandonment will include backfilling of the borehole with a cement and bentonite grout (at a mixture of approximately nine to one) via tremie pipe from the bottom up. A new boring will be advanced as close as possible, within 10 feet from the abandoned boring. Soil coring will be resumed below the abandoned boring termination depth.

Soil cuttings generated during boring installation will be containerized in Department of Transportation (DOT) approved 55-gallon drums and staged on site. Handling and disposal of the soil cuttings is addressed in Section 3.2.7 which discusses investigation derived waste (IDW). Soil sampling equipment will be constructed of stainless steel. Soil boring and sampling equipment will be decontaminated between borings in accordance with procedures described in Section 3.2.7.

3.2.1.2 Shallow Temporary Well Installation

As indicated above, the results from previous rounds of investigation have indicated the presence of elevated concentrations of CVOCs in shallow groundwater beneath the various portions of the Site. The lateral extent of impact in the shallow zone has been primarily delineated. A data gap has been identified to the southwest of the facility on the Shealy property in the vicinity of location TMW107. In order to delineate the extent of elevated CVOCs in this area several additional temporary wells will be installed to allow collection of groundwater samples for field screening and confirmatory analysis. The proposed locations of the temporary monitoring wells are shown on **Figure 2-1.**

The shallow temporary wells will be constructed using 1-inch diameter, flush-threaded, schedule 40 PVC casing and 10-foot long 0.010 slotted PVC screens. This will entail the advancement of a soil boring to target depths between 25 and 30 feet BLS, if possible. Total well depth and placement of the screen interval will be based on location-specific data needs, local geology, and depth to the static water table, and will be determined by the geologist in the field. Once the soil boring advancement is completed, well materials including the screen and riser pipe will be installed through a temporary outer casing advanced as the soil boring core barrel is advanced. Once the well materials are in place the outer casing will be removed.

Temporary wells will remain in place in place long enough to allow for the collection of a groundwater sample. If the temporary well is to be left in place for more than 48 hours, the annulus surrounding the well pipe will be back-filled with clean silica sand to within two feet of land surface. The remaining annulus will be back-filled with bentonite pellets to land surface. The bentonite pellets will then be hydrated, which will allow a seal to develop around the temporary well at land surface preventing surface water infiltration. If the temporary well will be sampled immediately after installation, an outer filter pack and surface seal will not be installed around the well material.

Groundwater samples collected from the temporary wells will be screened on-site using the AQR Color-Tec® screening method. The Color-Tec® screening method utilizes a tetrachloroethene (PCE) colorimetric gas detector tube to estimate the concentration of total chlorinated ethenes. This method can detect the presence of PCE and /or related degradation products; however, it cannot quantify the concentration for a specific compound. A more detailed description of the AQR Color-Tec® methodology is included in **Appendix A** to this report. If the screening method has a positive result, an additional temporary well boring will be advanced at a location to be determined by Shakespeare and the AECOM field Hydrogeologist. This methodology will continue at a location until field screening results determine the lateral extent of the CVOCs has been determined.

Confirmation samples will be collected from select shallow temporary well locations and submitted to an SCDHEC certified laboratory for analysis. The locations at which the confirmation samples will be collected will be determined by the AECOM field hydrogeologist during the sampling program.

After sampling of a temporary well has been completed, it will be abandoned in accordance with the SC Well Standards and Regulations as referenced above.

3.2.1.3 Intermediate Vertical Profiling Borings

As indicated above the intermediate zone vertical profiling borings will be advanced using roto-sonic drilling technology. Once a boring has been advanced to a specific target depth, a two inch diameter, five foot long, stainless steel well point sampler will be lowered through the outer casing and then advanced into the undisturbed subsurface to the desired screen interval. A submersible pump will then be used to purge water from this interval to for field screening and possible confirmatory analysis. A sample from the interval will be collected in a 40 milliliter vial for field screening. Purging efforts and sample collection procedures will be performed in accordance with groundwater sampling procedures described in Section 3.2.3.2.

Once a sample has been collected from a depth interval, it will be screened on site using the Field personnel will use the Color-Tec® screening method to evaluate groundwater for the presence of CVOCs. If the screening method has a positive result, the intermediate boring will be advanced 10 more feet to allow for collection of a groundwater sample from a deeper zone. This methodology will continue at a location until field screening results are non-detect or competent bedrock is encountered.

Confirmation samples will be collected from various intervals in an intermediate boring and submitted to an SCDHEC certified laboratory for analysis. The depths at which the confirmation samples will be collected will be determined by the field geologist during boring advancement.

3.2.1.4 Bedrock Vertical Profiling Boring

As indicated in Section 2.2.3 above, some fracture zones within the underlying granitic bedrock contain elevated concentrations of CVOCs. The distribution of the CVOCs within fracture zones has not been determined, therefore during this phase of work, one additional bedrock boring is proposed for a location on-site to determine the fracture zone intervals and to test the intervals separately for the presence of CVOCs. The proposed location for this bedrock well will be determined by AECOM, Shakespeare, and SCDHEC during the field program.

The proposed bedrock well borings will be advanced using either roto-sonic or a combination of mud-rotary and wireline coring techniques. Core samples will be visually examined by an AECOM field Hydrogeologist to identify separate fracture zones. When a separate fracture zone is encountered, field personnel will direct the purging of the fracture zone to allow collection of a groundwater sample for field screening using the Color-Tec® method. As the boring is advanced deeper into the bedrock, and separate fracture zones are identified an inflatable packer system will be used to isolate the deepest fracture zone from influence of groundwater from overlying fractures. The packer system will be inflated, sealing the borehole above the deepest fracture zone, Groundwater will then be purged from an isolated fracture zone using a submersible pump. Groundwater quality parameters will be monitored during this purging effort and recorded as indicted in Section 3.2.3.3 below. Once purging of an interval is complete, a sample will be collected for field screening using the Color-Tec® screening method. Should field screening results for a sample from the fracture zone indicate that CVOCs are present; the bedrock boring will continue to be advanced until field screening indicates that CVOCs are not present in an underlying fracture zone. The total depth of this bedrock boring will be determined based on field screening results.

Once its maximum depth is reached, the bedrock boring will be converted to a monitoring well. Well screen placement will be set across a fracture zone that is found to not contain CVOCs during the field screening. The bedrock well to be constructed at that location will include a five foot long pre-packed 2 inch diameter well screen, surrounded by additional sand filter pack, as needed to fill the annular space. The bentonite clay well seal and grout will be installed to ensure impacted groundwater encountered in overlying fracture zones does not migrate downward into an unimpacted fracture zone. Well seal, grouting and wellhead completion will also be constructed in accordance with the SC Well Standards and Regulations (SC.R61-71).

3.2.1.5 Permanent Monitoring Well Installation Procedures

During this phase of SI, 15 shallow, up to ten intermediate zone monitoring wells, and three bedrock wells will be installed at the site to allow monitoring of groundwater elevations and water quality (**Figures 2-1 through 2-3**).

Permanent monitoring wells will be installed in accordance with SESD GUID-101-R0 protocol using a roto-sonic drilling rig. Shallow and intermediate permanent monitoring wells will be constructed using two-inch diameter, flush-threaded, schedule 40 PVC casing and 10 foot long, 0.010-inch slotted PVC screens. Total well depth and placement of the screen interval will be based on location-specific data needs, local geology, and will be determined by the geologist in the field.

As discussed in Section 3.2.1.1 above, soil and/or rock cores will be collected during well bore advancement to allow examination and classification of sediments and to help determine the depths at which to install the wells. Once shallow and/or intermediate well boring advancement is completed, the well materials will be installed through the six inch diameter sonic casing. Shallow and intermediate permanent monitoring wells will be centered within a borehole while an appropriately graded clean silica sand is placed in the annular space surrounding the well screen to a depth of approximately two feet above the top of the screen. The filter pack will be directly overlain by a layer of bentonite chips no less than two feet thick. The bentonite seal will be hydrated prior to installation of a cement/bentonite grout. The grout seal, containing a mixture of approximately nine pounds cement to one pound bentonite, will extend from the top of the bentonite seal to a depth of two to three feet below ground surface.

Each bedrock well will have a surface casing that fully penetrates the weathered residuum and saprolite overlying the bedrock. The surface casing will be grouted in place and allowed to cure for up to 48 hours before drilling into bedrock will commence.

AECOM will utilize a rock coring system to obtain samples of the bedrock. Core samples will be collected continuously on five foot intervals from the top of the bedrock to a depth determined in the field by the AECOM geologist. Information obtained from the rock cores will be used to determine the depth at which the bedrock wells will be completed. Ideally, wells will be set to capture groundwater from obvious fracture zones encountered in the bedrock. Once the well boring has been sampled to a desired depth, the borehole will be flushed with fresh water to remove any drilling fluid and/or debris generated during drilling. The bedrock wells will then be completed as an open hole and will not have any internal well screen or filter materials.

Each of the shallow and intermediate permanent monitoring wells will be completed flush with the ground surface using an 8-inch diameter cast iron bolt-down well cover setinto a 2 ft x 2 ft x 6 inch concrete pad. The bedrock wells will have a 12 inch diameter cast iron bolt down cover. Each permanent monitoring well will also be secured with a cap and lock.

All well construction details and/or boring information will be noted on monitoring well construction logs to be completed during the field investigation.

3.2.1.6 Well Development

Following their installation, each permanent well will be developed in accordance with the USEPA Region 4 SESD GUID-101-R0. Well development will be performed to remove fine-grained materials from the monitoring wells and to enhance the hydraulic connection between the screen interval and the surrounding aquifer. If not removed, fine-grained materials may clog the well sand pack and screen, potentially diminishing well productivity and preventing the collection of representative groundwater samples.

The permanent monitoring wells will be developed no sooner than 24 hours following installation, to allow the well construction materials to set. Water quality parameters will also be measured using a YSI 556 water quality meter and HF Scientific or equivalent turbidity meter. During well development the following water quality parameters will be monitored:

- pH;
- Temperature;
- Specific Conductance; and
- Turbidity.

Adequate well development is achieved when the pH, specific conductance, and temperature of the groundwater have stabilized and the turbidity has either stabilized or is below 10 Nephlometric Turbidity Units (NTu). Stabilization shall be generally defined as pH constant within 0.1 Standard Unit (SU), temperature and SC constant within 10%.

A minimum of three well volumes will be removed before a well may be considered developed. If, after removal of three well volumes, the development criteria have not been achieved, the process will continue until either the criteria have been met, or ten well volumes have been removed. It is then at the discretion of the project manager to consider a well developed or whether development activities should continue.

Water generated by well development activities will be stored in 55-gallon drums, polyethylene totes or comparable containers. The development water containers will be labeled as such with the date of generation and applicable source information. The containers will be transported to a designated on-storage area and characterized for off-Site disposal at the conclusion of the SI field activities.

3.2.2 Groundwater Sampling

As indicated above, groundwater samples will be collected from each of the newly installed temporary and permanent wells. Groundwater samples will be collected from the new monitoring wells in accordance with procedures detailed in the USEPA Region IV SESD protocol for Groundwater Sampling (SESDPROC-301-R2; **Appendix A**) as described below. The sampling procedures are described in this section.

3.2.2.1 Temporary Wells

The temporary wells will be purged and sampled as soon after their installation as possible. Field personnel will utilize a peristaltic pump to develop/purge a temporary well prior to sample collection. Field personnel will measure and record field parameters including pH, specific conductance, temperature, and turbidity during the development/purge effort.

3.2.2.2 Intermediate Vertical Profile Borings

Sampling of groundwater in the intermediate profiling borings will be performed using a stainless steel submersible pump. The roto-sonic drilling process uses water to charge the outer surface casing during borehole advancement, when necessary. During profiling interval purging efforts, field parameters will be monitored to ensure water quality parameters indicate representative groundwater is being evacuated for sampling. Field personnel will measure and record field parameters including pH, specific conductance, temperature, and turbidity during the purge effort. Samples for field screening will be collected when the field parameters have stabilized.

If possible samples for field screening will be collected using the submersible pump, however if volatilization during purging and sampling becomes a concern then field personnel may utilize a disposable bailer to collect a sample from the well point.

3.2.2.3 Bedrock Vertical Profile Boring

Sampling of groundwater in the bedrock vertical profile boring will be performed using a stainless steel submersible pump. During profiling interval purging efforts, field parameters will be monitored to ensure water quality parameters indicate representative groundwater is being evacuated for sampling. Field personnel will measure and record field parameters including pH, specific conductance, temperature, and turbidity during the purge effort. Samples for field screening will be collected when the field parameters have stabilized.

Samples for field screening will be collected using a submersible pump and dedicated, disposable tubing. When using a submersible pump, the flow rate of the pump will be adjusted to as low a speed as possible to limit the possibility of volatilization of organics during purging and sampling process.

3.2.2.4 Permanent Monitoring Wells

Permanent monitoring wells will be purged and sampled using the low flow-low volume sampling procedures with either a peristaltic pump or submersible pump. The primary choice of equipment for sampling a well using this method is the peristaltic pump; however, should the water column be deeper than the depth from which a peristaltic pump can evacuate water, a submersible pump will be used to purge a deep well. Disposable Teflon lined tubing will be used with either the peristaltic pump or submersible pump during the purging and/or sampling process.

Prior to purging a well, clean polyethylene sheeting will be placed on the ground around the well to provide a clean working surface. Total depth and depth to water from the top of the PVC casing will be measured with an electronic water level indicator and recorded in the field log and groundwater collection record. The volume of the standing water column will then be calculated in order to determine the required purge volume. The volume of the standing water column in a well is calculated using the following general equation:

$V = 0.041(D^2)(H)$

Where: H = length of water column in feet

D = diameter of well in inches

V = volume of water in gallons

The volume per linear foot for a 2-inch well equals 0.163 gallons per foot. The length of the water column (total depth minus depth to water) may be multiplied by 0.163 to obtain the volume of standing water within a 2-inch diameter well.

When purging with a peristaltic pump, a section of ¼-inch diameter, disposable Teflon lined polyethylene, or dedicated Teflon extraction tubing will be inserted into the middle portion of the water column in a well. The extraction tubing will be connected to a disposable section of 3/8 inch diameter silicon tubing that runs through the pump device. This tubing is connected to another section of ¼-inch diameter tubing that is used for discharge tubing. Purging of a well will be performed from within the screened interval.

Water quality parameters (pH, specific conductance, temperature, turbidity, dissolved oxygen (DO), and oxidation reduction potential (ORP) will be measured using a water quality meter equipped with a flow-through cell (YSI or equivalent). Turbidity may also be measured with a HF Scientific, LaMotte, or equivalent turbidity meter. The water quality meter(s) will be calibrated twice per day, prior to field use each morning and after field use each evening.

As a general rule, water quality readings will be taken periodically to determine when purging is completed. An adequate well purge is achieved when the pH, specific conductance and temperature of the groundwater have stabilized and the turbidity has either stabilized or is below 10 NTU. Should the low flow-low volume sampling procedure not be appropriate for sampling wells due to lack of stabilization, field personnel will utilize alternative methods specified in the USEPA SOP for groundwater sampling (SESDPROC-301-R2). There are no criteria establishing the number of readings required to determine stability. However, if the parameters have not stabilized within five purge volumes, it is the discretion of the project manager whether to collect a sample or to continue purging.

As indicated in Section 2.4, groundwater samples collected during this investigation will be analyzed for TCL VOCs using SW-846 Method 8260C.

3.2.3 Surface Water Sampling

As indicated in Section 2.3, surface water samples will be collected from three locations on the Dickert Property.

Surface water samples will be collected in accordance with procedures described in the USEPA FBQSTP SESDPROC-201. Samples will be collected by submerging bottles directly into the water column where the water column is sufficiently deep enough to allow, without inadvertently elevating turbidity. A sample bottle will be lowered into the water column with the cap in-place. Once the mouth of the bottle is at the desired sampling depth, the cap will be removed allowing water to fill the container. For bottles containing preservative, the bottle will be submerged enough to allow surface water to slowly fill the bottle preventing the preservative from washing out of the sample container.

When possible, water quality parameters will also be measured in the field at the time of sample collection using a YSI 556 water quality meter. The field parameters measured during surface water sampling will be pH, specific conductance, temperature, DO and ORP. At locations where surface water samples are to be collected, field parameters will be measured by submerging the water quality instrument probe into flowing surface water. Field measurements and visual observations including color and a description of the general conditions at each surface water sampling location will be recorded on surface water sampling logs.

3.2.4 Well and Sample Location and Elevation Survey

Subsequent to the completion of SI field activities, all borings, new monitoring wells and surface water sample points will be located using standard global positioning system (GPS) and/or conventional survey methodology by a registered land surveyor.

Wells, borings and sample points will be surveyed for elevation referenced to the National Geodetic Vertical Datum (NGVD) and horizontal location referenced to the SC State Plane Coordinate System North American Datum (NAD-83) by a qualified professional land surveyor (see Section 3.1.2.2) in accordance with the USEPA Region 4 SESD protocol for Global Positioning Systems (USEPA, 2011) (**Appendix A**). Surveying of monitoring well locations will provide horizontal control and vertical data for the ground surface, the top of the outer protective casing, and the top of the PVC well casing at each location. The top of PVC casing elevation will be surveyed at a permanently designated point marked into the top of the well casing. The designated point should be exposed only when the protective cap is removed and be the point from which all water level measurements are taken. Vertical elevation data should be surveyed to an accuracy of 0.01 feet and horizontal position data to an accuracy of 0.1 feet.

3.2.5 Investigation-Derived Waste (IDW)

IDW generated during the field program will be managed in accordance with the USEPA Region 4 SESD protocol for Management of Investigation Derived Waste (USEPA, 2010) (**Appendix A**). Materials which may become IDW include: personal protective equipment (PPE), disposable equipment, soil cuttings from drilling or hand auguring, sediments, groundwater obtained through well development or well purging, and cleaning and decontamination fluids. All soil cuttings, residual sample materials, groundwater, cleaning and decontamination fluids will be containerized in DOT approved 55-gallon drums or a roll-off container and temporarily staged at a central Site location pending results of laboratory analyses and selection of final disposal method(s). IDW materials such as non-hazardous

PPE, disposable equipment, and general refuse will also be placed into a separate drum, roll-off container, or existing refuse bin, and disposed in accordance with applicable guidance.

Based on the results of previous investigative phases at the Site, solid and liquid IDW will be handled as disposed of a as non-hazardous waste. Final disposal options will be determined following completion of field activities, after review of validated analytical data for samples collected from the Site. Analytical results for groundwater samples will be compared to the corresponding Toxicity Characteristic Leaching Procedure (TCLP) concentrations. If groundwater sample results do not exceed the TCLP concentrations, then liquid IDW can be disposed of as non-hazardous.

IDW generated in areas of obvious impacts will be segregated and containerized separately from other IDW. If areas with DNAPL are encountered during the investigation, if required by a disposal facility, samples collected from the Site may be analyzed for an expanded list of parameters including TCLP). These data will also be utilized to determine an appropriate disposal method for IDW from the obviously impacted areas.

3.2.6 Quality Control (QC) and Handling Procedures

The QC and handling procedures for equipment and samples collected at the site are briefly described below.

3.2.6.1 Sample Containment, Handling and Shipping

To minimize sample leakage and breakage, sample containers will be sealed and placed in shipping containers surrounded by bubble wrap or equivalent packing material. Ice will be included for those samples that require refrigeration. Chain-of-custody forms, identifying each sample contained in a shipping container, will be completed. One copy of the chain-of-custody form will be retained for the field records; the remaining copies will be placed inside a Ziploc™-type bag, and the bag sealed and taped to the inside cover of the shipping container. Chain-of-custody procedures are described in AECOM SOP 7510 (**Appendix A**).

Samples will be delivered daily to the Shealy Environmental Services, Inc. facility by AECOM field personnel. All samples will be handled and shipped in accordance with the procedures included in the USEPA Region 4 SESD protocol for Packaging, Marking, Labeling and Shipping of Environmental and Waste Samples (USEPA, 2011) (**Appendix A**).

3.2.6.2 Field Equipment Calibration

Sampling activities detailed in this work plan call for the use of field equipment including a photoionization detector (PID), water quality meter turbidity meter, electronic water level indicator, and a GPS. The water quality meter will be capable of measuring pH, specific conductance, temperature, DO, and ORP. All field equipment will be calibrated prior to each use (at the beginning of each day) and a post-calibration check performed at the conclusion of each use (at the end of each day). All instruments will be calibrated, maintained, and operated in accordance of the manufacturer's specifications.

3.2.7 Field Equipment Decontamination

Reusable equipment used in the field investigations at the site will be cleaned between sample collection efforts. Cleaning of equipment is performed to prevent cross-contamination between samples and to maintain a clean working environment for all personnel. Cleaning of sampling equipment will be performed in accordance with the USEPA Region 4 SESD protocol for Field Equipment Cleaning and Decontamination (USEPA, 2011) (**Appendix A**).

For all sampling equipment used for the collection of samples for trace organic compounds and/or metals analyses:

- clean equipment with tap water and a laboratory grade non-phosphate detergent,
- rinse thoroughly with tap water,
- rinse thoroughly with deionized (DI) water,
- double rinse with organic free water
- wrap with aluminum foil, place in a plastic bag, and seal to prevent contamination if equipment is going to be stored or transported.

Cleaning and decontamination of all down hole drilling equipment will be conducted in accordance with Section 3.7 of the Region 4 SESD protocol for Field Equipment Cleaning and Decontamination (USEPA, 2011).

Solvents, detergents, and rinse waters used to clean field equipment will not be reused during field decontamination. Procedures for handling and disposition of IDW, including used wash water, rinse water, and spent solvents will be conducted in accordance with Section 3.2.7.

4.0 Site Investigation Report

Following completion of the SI Work Plan addendum efforts, Shakespeare will prepare a Phase II Remedial Investigation (RI) Report. The Phase II RI Report will be a comprehensive report including data generated during from the Phase II ESA through the most recent round of investigation. The report will discuss the results for soil, groundwater and surface water samples collected from the Site during this investigative process. The Phase II RI Report will include figures depicting sample locations and contaminant distribution; data summary tables, data validation details, conclusions regarding the information collected to date and possible recommendations for future efforts. Appendices will contain all lithologic logs, individual monitoring well construction details, well development logs, groundwater sampling logs, laboratory reports (original data sheets), and laboratory validation notes.

5.0 REFERENCES

Field Branches Quality System and Technical Procedures Manual. Region IV, Science and Ecosystem Support Division, Athens, GA. May, 2009.

SC Well Standards [R.61-71(H)(2)(e)]

USEPA, 2001. Field Equipment Cleaning and Decontamination Operating Procedure (SESDPROC-205-R2). Region IV. Science and Ecosystem Support Division, Athens, GA. December 20, 2011.

USEPA, 2008. Design and Installation of Monitoring Wells (SESDGUID-101-R0). Region IV. Science and Ecosystem Support Division, Athens, GA. February 2, 2008.

USEPA, 2010. Management of Investigation Derived Waste (SESDPROC-202-R2). Region IV. Science and Ecosystem Support Division, Athens, GA. October 15, 2010.

USEPA, 2011. Groundwater Sampling (SESDPROC-301-R2). Region IV. Science and Ecosystem Support Division, Athens, GA. October 28, 2011.

USEPA, 2011. Global Positioning System (SESDPROC-110-R3). Region IV. Science and Ecosystem Support Division, Athens, GA. April 20, 2011.

USEPA, 2011. Packing, Marking, Labeling and Shipping of Environmental and Waste Samples. Region IV. Science and Ecosystem Support Division, Athens, GA. April 20, 2011.

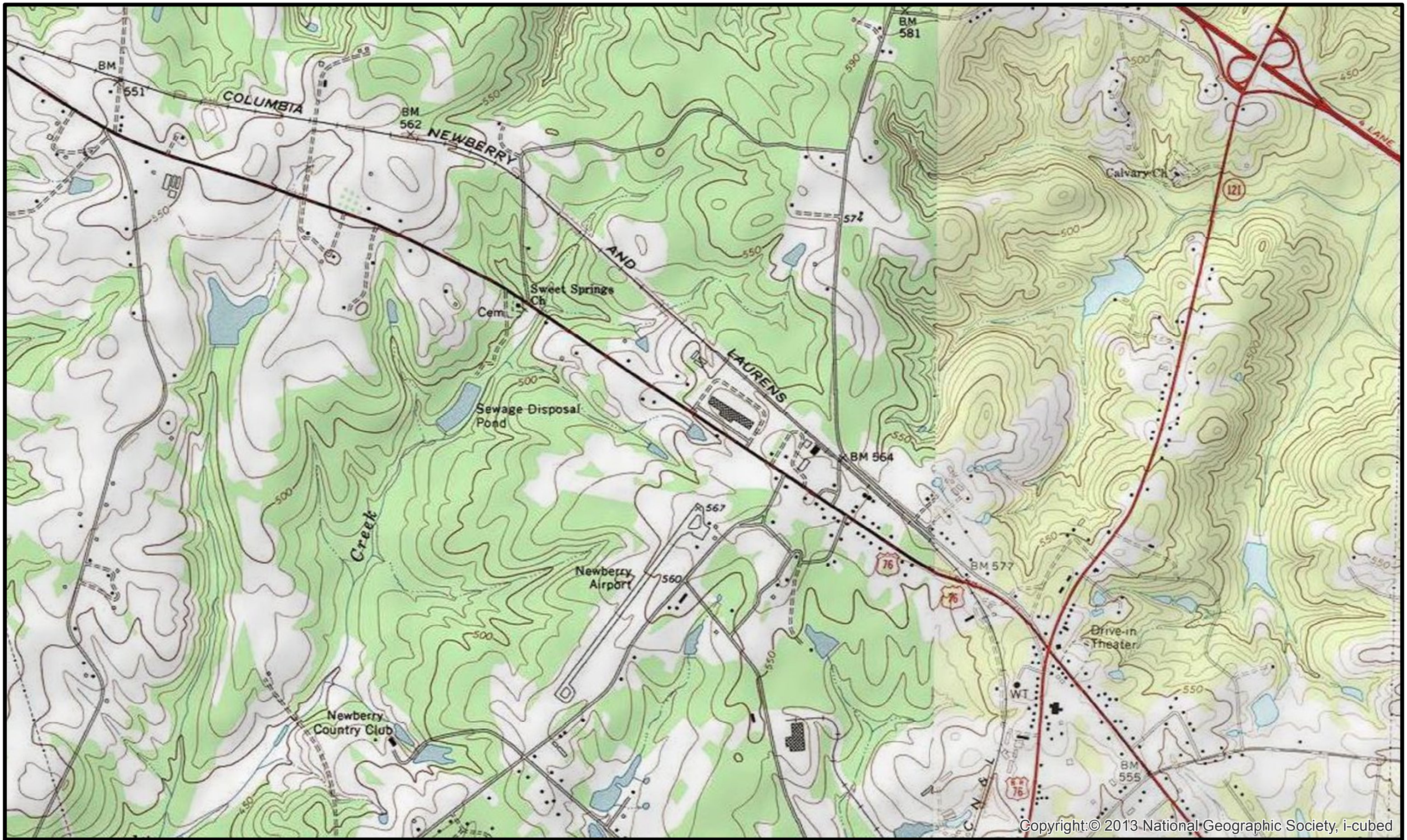
AECOM, 2014a. Site Investigation Summary, Shakespeare Composite Structures, Newberry, South Carolina. June 2014.

AECOM, 2014b. Site Investigation Work Plan, Shakespeare Composite Structures, Newberry, South Carolina. April 2014.

AECOM, 2013. Phase I Environmental Site Assessment, Shakespeare Composite Structures, LLC. Newberry, South Carolina. January 2014.

AECOM, 2014c. Summary of Investigative Efforts Report, Shakespeare Composite Structures, Newberry, South Carolina. September 2014.

FIGURES



Copyright:© 2013 National Geographic Society, i-cubed

Source:
Newberry West and Newberry East Quadrangles from
ArcGIS Map Service, USA_Topo_Maps.
(http://services.arcgisonline.com/ArcGIS/services)

Map Projection:
NAD 83
South Carolina State Plane, Feet
Fips3900

Datum:
North American 1983

N
W E
S

2,000 1,000 0 2,000
Feet
1:24,000

AECOM

10 Patewood Drive, Building 6, Suite 500
Greenville, SC 29615
T: (864) 234-3000 F: (864)234-3069

Site Location Map

Shakespeare Composite Structures
Newberry, South Carolina

PROJECT NO.	PREPARED BY:	DATE:	
60164311	RJS	12/9/2014	**Figure 1-1**

MapPath: L:\Group\earth\60318382 Shakespeare Composites\GIS\Maps\Site Location Map.mxd

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Map Projection:
NAD 83
South Carolina State Plane, Feet
Fips3900

Datum:
North American 1983

N
W E
S

300 150 0 300
Feet
1:3,600

AECOM

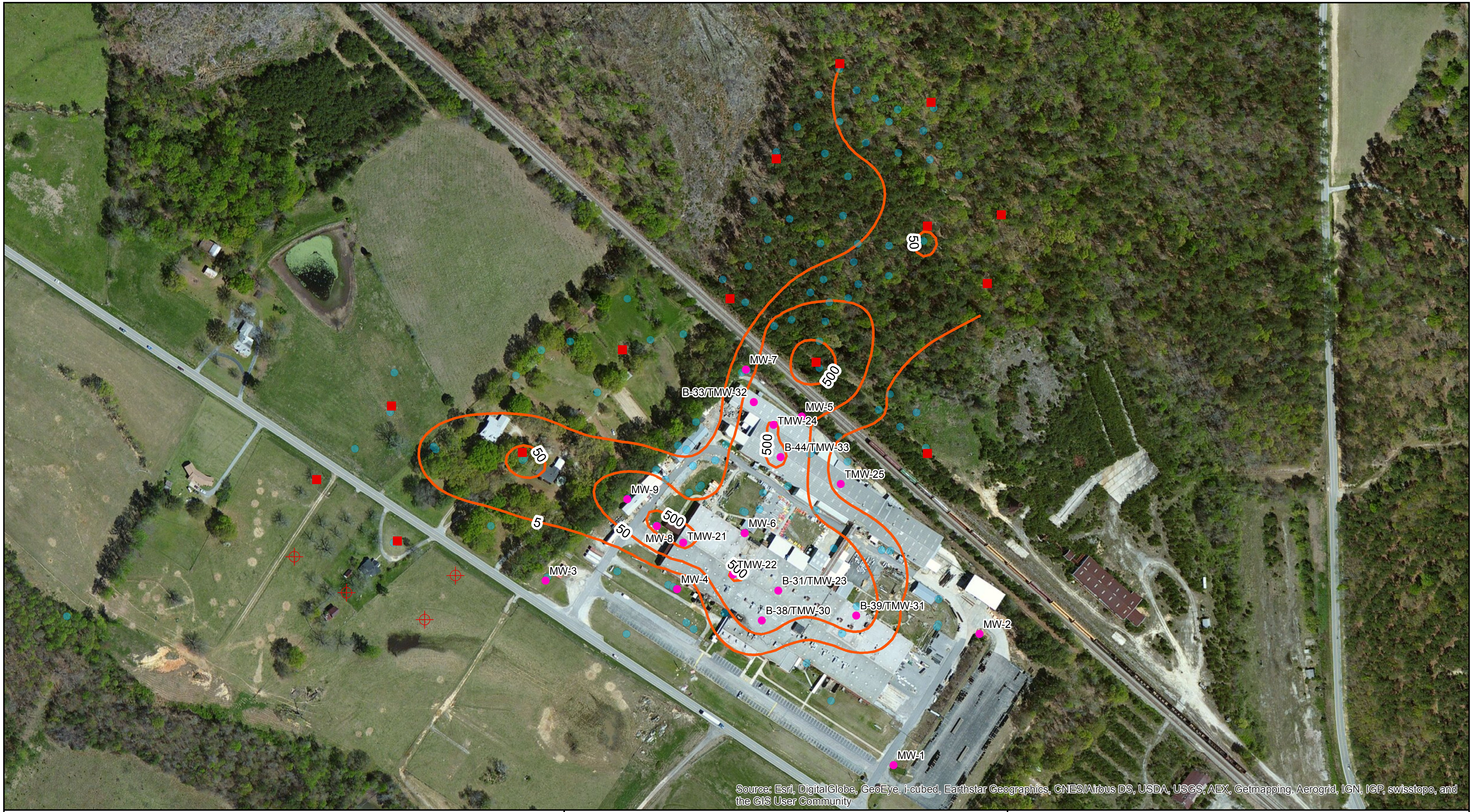
10 Patewood Drive, Building 6, Suite 500
Greenville, SC 29615
T: (864) 234-3000 F: (864)234-3069

Site Plan

Shakespeare Composite Structures
Newberry, South Carolina

PROJECT NO.	PREPARED BY:	DATE:	
60328308	RJS	12/8/2014	**Figure 1-2**

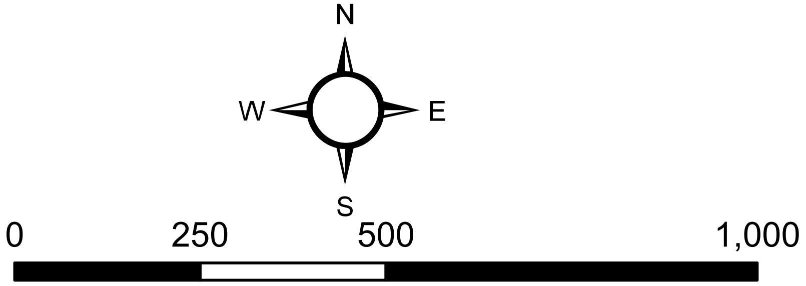
Document Path: L:\Group\earth\60318382 Shakespeare Composites\GIS\Maps\60318382_025 Site Map With Aerial.mxd



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

- ⌖ Proposed Temporary Shallow Groundwater Monitoring Well Location
- ■ Proposed Shallow Well Location
- ● Existing Shallow Zone Monitoring Well
- ● Abandoned Temporary Wells
- — Shallow TCE Isoconcentration Contour (μg/L)



Feet

G:\Projects\Active\60328308_Shakespeare\map\wells_II.mxd

AECOM

10 Patewood Drive, Building 6, Suit 500
Greenville, SC 29615
T: (864) 234-3000 F: (864) 234-3069

Locations of Shallow Zone Wells

Shakespeare Composition Structures
Newberry, South Carolina

Project No.: 60328308; Prepared by: JC; Date: 7/30/2015; Figure 2-1

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

▲	Surface Water Sample Location
●	Shallow Zone Groundwater Sample Location
●	Proposed Intermediate Zone Vertical Profile Sample Location
⊕	Bedrock Well

N
W E
S

0 250 500 1,000

Feet

G:\Projects\Active\60328308_Shakespeare\map\wells.mxd

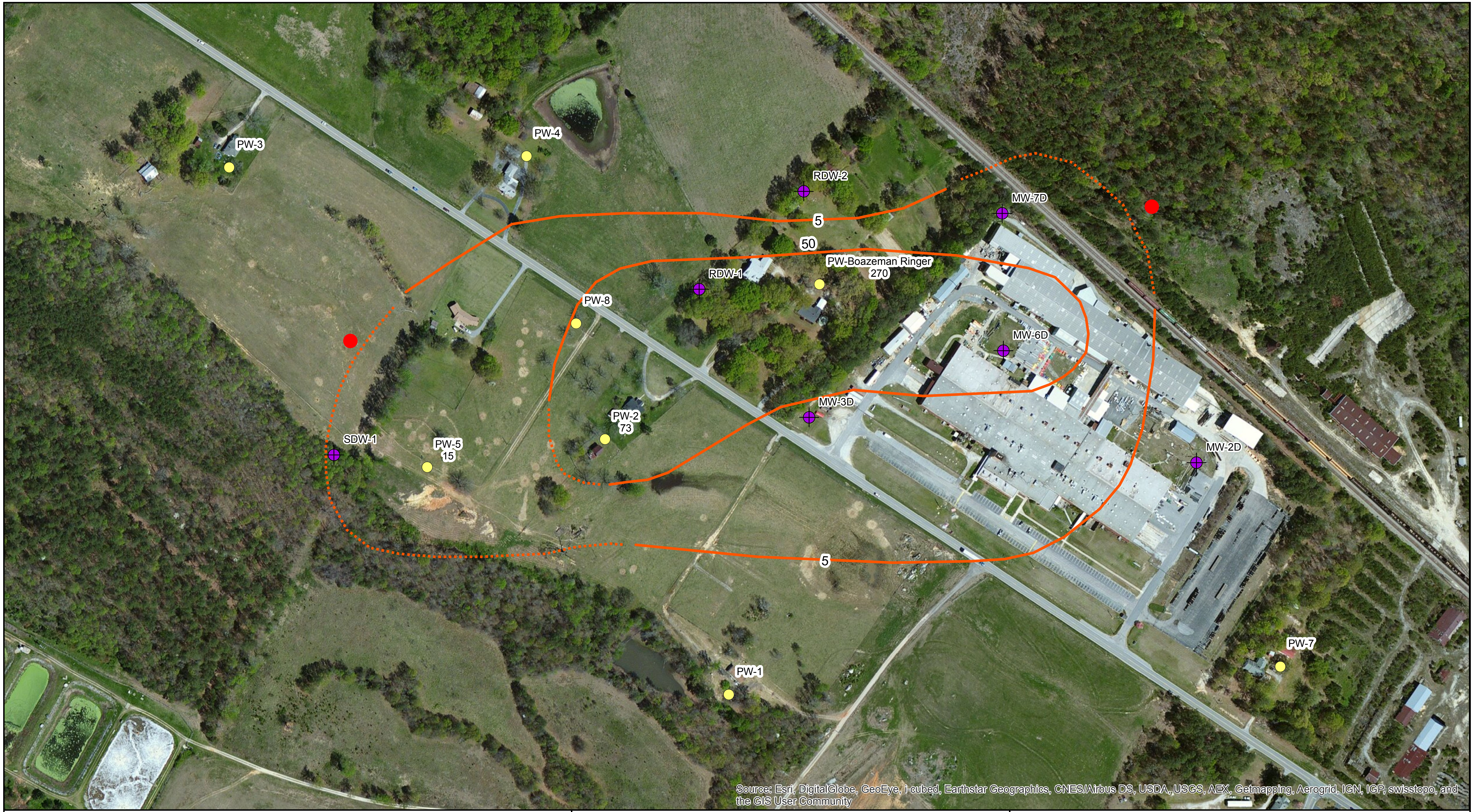
AECOM

10 Patewood Drive, Building 6, Suit 500
Greenville, SC 29615
T: (864) 234-3000 F: (864) 234-3069

Intermediate Zone Sample Locations

Shakespeare Composition Structures
Newberry, South Carolina

Project No.: 60328308; Prepared by: JC; Date: 7/7/2015; Figure 2-2



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

- ○ Water Supply Well
- ● Proposed Deep Well
- ⊕ Bedrock Well
- — Bedrock TCE Isoconcentration Contour (ug/L)
- ⋯ Inferred Bedrock TCE Isoconcentration Contour (ug/L)

N
W E
S

0 250 500 1,000
Feet

G:\Projects\Active\60328308_Shakespeare\map\BedrockWells.mxd

AECOM

10 Patewood Drive, Building 6, Suit 500
Greenville, SC 29615
T: (864) 234-3000 F: (864) 234-3069

Locations of Bedrock and Water Wells

Shakespeare Composition Structures
Newberry, South Carolina

Project No.: 60328308; Prepared by: JC; Date: 7/7/2015; Figure 2-3

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

- ● Shallow Zone Monitoring Well
- ⊕ Intermediate Zone Monitoring well
- ⊕ Deep Zone Monitoring Well
- ▲ Surface Water Locations

Map Projection:
NAD 83
South Carolina State Plane, Feet
Fips3900

Datum:
North American 1983

N
W E
S

300 150 0 300
Feet
1:3,600

AECOM

10 Patewood Drive, Building 6, Suite 500
Greenville, SC 29615
T: (864) 234-3000 F: (864)234-3069

Proposed Surface Water Sample Locations

Shakespeare Composite Structures
Newberry, South Carolina

PROJECT NO.	PREPARED BY:	DATE:	
60328308	RJS	12/15/2014	**Figure 2-4**

Document Path: L:\Group\earth\60318382 Shakespeare Composites\GIS\Maps\60318382_029 Proposed Surface Water Sample Locations.mxd

TABLES

Table 2-1
Proposed Shallow Well Locations
Site Investigation Work Plan Addendum
Shakespeare Composite Structures
Newberry, South Carolina

Historic Sample Location ID	Depth of Historic Sample	Proposed Depth for Permanent Well	Location Description and Rationale
TMW-42	30	30	Dickert Property. Permanent sample point at location with highest TCE results for Site to date (TCE - 1600 ppb)
TMW-58	30	30	Permanent sample point at southwest edge of sample grid on Dickert Property where TCE was ND.
TMW-72	17.5	>/= 17.5	Permanent sample point at southeast edge of sample grid on Dickert Property where TCE was ND.
TMW-73	31.5	32	Permanent sample point at location at west-cental edge of sample grid on Dickert Property. Color Tec results were positive. No confirmatory results available.
TMW-89	19	>/= 19	Permanent sample point at northernmost point in sample grid on Dickert Property.
TMW-97	10	>/= 10	Permanent sample point to allow monitoring at location south of creek where TCE was detected at 17 ppb.
TMW-98	10	>/= 10	Permanent sample point at location east of TMW-98 to allow monitoring of water quality near creek
TMW-99	18	>/= 18	Permanent sample point at location on east cental edge of sample grid on Dickert Property where TCE was detected at 74 ppb.
TMW-99	18	>/= 19	Permanent sample point at location east of TMW-99 to allow monitoring of water quality near creek
TMW-36/TMW-41	35	35	Monitoring point on Boazman/Ringer property boundary
TMW-38	35	35	Shallow monitoring point near Boazman well
TMW-105	15	>/= 15	Shallow monitoring point on Chapman Property at west end of plume boundary
TMW-109	25	25	Shallow monitoring point on Shealy Property at southwest edge of plume boundary
TBD		TBD	Shallow monitoring point on Shealy property southwest of TMW-107. To be determined based on results of the additional temporary shallow well sampling.
TBD	25-30	TBD	South side of main building, between MW-1 and MW-4.

Table 2-2
Proposed Locations for Intermediate Zone Profiling
Site Investigation Work Plan Addendum
Shakespeare Composite Structures
Newberry, SC

Location ID	Depth of Historic Samples	Historic Color Tec Result (ppm)	Proposed Depth Interval to initiate vertical profiling	Other information
TMW42	30	NS	40	Lab results TCE - 1600 ppb
TMW44	34 44 50	1.3 0.1 ND	60	
TMW45	32 42 56	0.6 2.3 3.5	65	
TMW46	30	NS	35	Between MW2D and closest shallow TMW - TMW-10
TMW47	35 45	28.2	45	
TMW48	35	ND	45	Near MW3/MW3D
TBD	---	---	40	Location at Ringer/Boazman property boundary
TBD	---	---	40	East of MW-5 on north side of Shakespeare facility
TBD	---	---	40	Near Boazman well
TBD	---	---	40	Shealy property near TMW107

Table 2-3
Proposed Groundwater Sampling Summary
Site Investigation Work Plan Addendum
Shakespeare Composite Structures
Newberry, South Carolina

Well ID	Location	TD	Screen Interval	Proposed Analysis
Shallow Monitoring Wells				
MW-1	East side of Shakespeare property	14.2	4.2 - 14.2	TCL VOCs, TAL Metals
MW-2	East side of Shakespeare property	26	14.7-24.7	TCL VOCs
MW-3	Southwest corner of Shakespeare property	26	14.7-24.7	TCL VOCs
MW-4	South side of Main Building	26	15.2-25.2	TCL VOCs
MW-5	North side of Pole Winder Building	26	15.8-25.8	TCL VOCs
MW-6	North side of Main Building	26	15.7-25.7	TCL VOCs
MW-7	Northwest corner of Shakespeare property	26	14.8-24.8	TCL VOCs, TAL Metals
MW-8	West end of Main Building	26	15.5-25.5	TCL VOCs
MW-9	West side of Shakespeare property	26	15.8-25.8	TCL VOCs
TMW-21	Inside west end of Main Building	23.5	13.5-23.5	TCL VOCs
TMW-22	Inside west end of Main Building	25	15-25	TCL VOCs
TMW-23	Inside central portion of Main Building	25	15-25	TCL VOCs
TMW-24	Inside west end of Pole Winder Buiding	25	15-25	TCL VOCs
TMW-25	Inside west end of Pole Winder Buiding	25	15-25	TCL VOCs
TMW-29	Inside east central portion of Main Building	13	8-13	TCL VOCs
TMW-30	Inside southcentral portion of Main Building	25	15-25	TCL VOCs
TMW-31	Inside east central portion of Main Building	21	11-21	TCL VOCs
TMW-32	Inside west end of Pole Winder Buiding	25	15-25	TCL VOCs
TMW-33	Inside west end of Pole Winder Buiding	25	15-25	TCL VOCs
Bedrock Wells				
MW-2D	Between East end of Main Building and Pole Winder Building	84.9	79 - 84.9	TCL VOCs
MW-3D	Southwest corner of Shakespeare property	105.02	88.5 - 105.02	TCL VOCs
MW-6D	North side of Main Building	105.08	99- 105.08	TCL VOCs
MW-7D	Northwest corner of Shakespeare property	94.87	88.5-94.87	TCL VOCs
RDW-1	Southwest side of Ringer Property	95	77-95	TCL VOCs
RDW-2	West side of Ringer Property	85	71-85	TCL VOCs
SDW-1	Shealy Property, west of PW-5	86	76-86	TCL VOCs
TBD	Ringer/Boazman Property Boundary	TBD	TBD	TCL VOCs
TBD	Boazman Property	TBD	TBD	TCL VOCs
Water Wells				
Boazman/Ringer Well	Boazman/Ringer property Boundary	TBD	Unknown	TCL VOCs
PW-1	Shealy Property, south of Shakespeare	Unknown	Unknown	TCL VOCs
PW-2	Shealy Property, southwest of Shakespeare	160	Open hole from 37 to 160	TCL VOCs
PW-3	Shealy Property, southwest of Shakespeare	Unknown	Unknown	TCL VOCs
PW-4	Chapman Property, west of Shakespeare	Unknown	Unknown	TCL VOCs
PW-5	Shealy Property, southwest of Shakespeare	160	Open hole from 35 to 160	TCL VOCs
Unused well	Shealy Property, southwest of Shakespeare	160	Open hole from 25 to 160	TCL VOCs
New Shallow Wells*				
TMW-42	Vicinity of TMW-42 on Dickert Property	30	TBD	TCL VOCs
TMW-58	Vicinity of TMW-58 on Dickert Property	30	TBD	TCL VOCs
TMW-72	Vicnity of TMW-72 on Dickert Property	>/= 17.5	TBD	TCL VOCs
TMW-73	Vicnity of TMW-73 on Dickert Property	32	TBD	TCL VOCs
TMW-89	Vicnity of TMW-89 on Dickert Property	>/= 19	TBD	TCL VOCs
TMW-97	Vicnity of TMW-97 on Dickert Property	>/= 10	TBD	TCL VOCs
TMW-98	East of TMW-98 on Dickert Property	>/= 10	TBD	TCL VOCs
TMW-99	Vicinity of TMW-99 on Dickert Property	>/= 18	TBD	TCL VOCs
TMW-99	East of TMW-99 on Dickert Property	>/= 19	TBD	TCL VOCs
TBD	Between TMW-36/TMW-41 on Boazman/Ringer Property	35	TBD	TCL VOCs
TBD	Vicinify of TMW-38 on Boazman Property	35	TBD	TCL VOCs
TBD	Vicinity of TMW-105 on Chapman Property	>/= 15	TBD	TCL VOCs
TBD	TMW-109 on Shealy Property	25	TBD	TCL VOCs
TBD	Sheal Property	TBD	TBD	TCL VOCs
New Intermediate Wells*				
TBD	Vicinity of TMW-42	TBD	TBD	TCL VOCs
TBD	Vicinity of TMW-44	TBD	TBD	TCL VOCs
TBD	Vicinity of TMW-45	TBD	TBD	TCL VOCs
TBD	Vicinity of TMW-46	TBD	TBD	TCL VOCs
TBD	Vicinity of TMW-47	TBD	TBD	TCL VOCs
TBD	Vicinity of TMW-48	TBD	TBD	TCL VOCs
TBD	Vicinity of Boazman/Ringer Well	TBD	TBD	TCL VOCs
TBD	Between TMW-36/TMW-41 on Boazman/Ringer Property	TBD	TBD	TCL VOCs
TBD	East of MW-5 on Shakespeare Property	TBD	TBD	TCL VOCs
TBD	Shealy Property near TMW-107	TBD	TBD	TCL VOCs

* Approximate depths for new wells. Actual dpeths will be determined during installation.

Table 2-4
Proposed Surface Water Sample Summary
Site Investigation Work Plan Addendum
Shakespeare Composite Structures
Newberry, South Carolina

Location ID	Location	Proposed Analysis
SW-1	Dickert Property	TCL VOCs
SW-2	Dickert Property	TCL VOCs
SW-3	Dickert Property	TCL VOCs

Appendix A

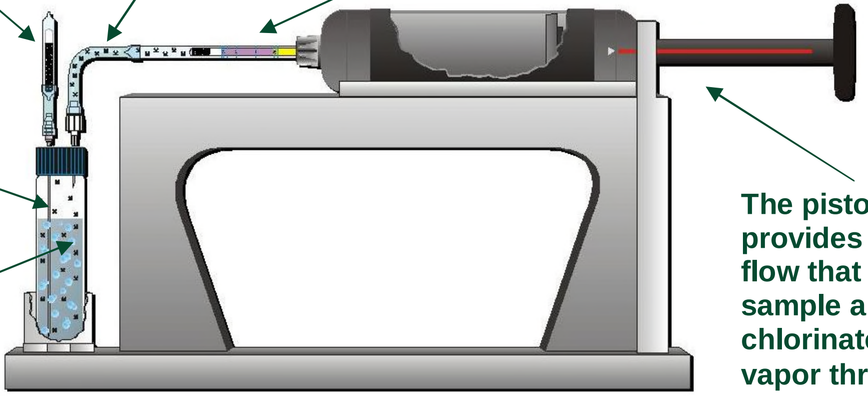
Standard Operating Procedures

AQR Color-Tec®

Method Procedures Manual

Field-Based Analysis of Chlorinated Volatile Organic Halocarbons

- **AQR Color-Tec combines sample purging with direct-read gas detector tubes to quickly detect low-levels of chlorinated compounds in liquid and solid samples.**
- **AQR Color-Tec detects concentrations of total chlorinated volatile organic halocarbons (CVOHs) below 3 µg/L in water and 3 µg/Kg in soil samples.**
- **AQR Color-Tec provides fast, low-level, economical, decision-quality data which maximizes sampling frequency and sampling coverage to locate source areas and delineate dissolved-phase contaminant plumes.**
- **Samples are analyzed by purging the volatile compounds from either liquid or solid samples through a colorimetric detector tube, which produces a distinct color change when exposed to any chlorinated compound.**



1 The piston-pump provides vacuum air flow that purges the sample and pulls the chlorinated volatile vapor through the tube

2 Ambient air enters the sample through a carbon filter

3 Filtered ambient air flows through the long purge needle to the bottom of the VOA vial

4 Ambient air purges and strips volatile compounds from the sample

5 The purged chlorinated volatile compounds are directed into the gas detector tube

6 A measured color change in the colorimetric tube is used to estimate the expected concentration of CVOHs in the sample

---

AQR Color-Tec® Contact and Ordering Information

- For more information visit www.aqrcolor-tec.com
- For kit orders contact Phil Pecevich at 919-918-7191

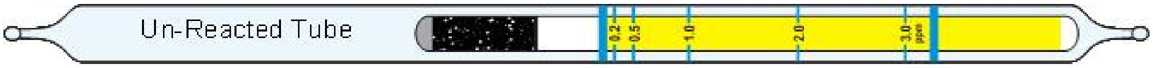
Table of Contents

1.0 Method History and Principles

The Color-Tec method was developed during 1997 by the environmental professionals at Ecology and Environment, Inc. while assessing/remediating the earliest sites addressed under the Florida Department of Environmental Protection's (FDEP) Drycleaning Solvent Cleanup Program. Since its development, the method has been used extensively at EPA, DOD, and various state regulatory agency sites to provide real-time, decision quality data at thousands of chlorinated solvent sites.

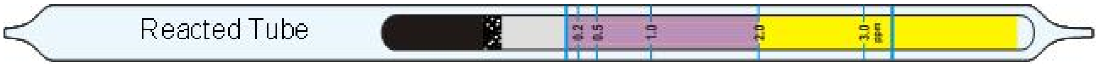
Color-Tec is a field-based analytical method which combines the use of colorimetric gas detector tubes (originally designed for occupational breathing-zone monitoring) with sample purging to detect very low (<3 µg/L or µg/Kg) concentrations of total chlorinated volatile organic halocarbons (CVOHs) in liquid and solid samples. Samples are analyzed by purging the volatile compounds from a groundwater or soil sample directly through the colorimetric tube, which is designed to produce a distinct color change when exposed to chlorinated compounds. Estimated sample concentrations are obtained by comparing the tube readings to a conversion table, which was developed based on comparison of Color-Tec readings to GC/MS analysis of split samples.

Each colorimetric tube contains an oxidizer (PbO_2) and a catalyst (H_2SO_4) which decomposes and converts the chlorinated compounds to hydrogen chloride, which discolors a reagent (4-phenylazodiphenylamine) in the tube from yellow to purple. The reaction formula provided by Gastec® for the PCE tube is as follows:



$$\mathbf{Cl_2C{:}CCl_2 + PbO_2 + H_2SO_4 \rightarrow HCl}$$

HCl + (4-Phenolazo) Diphenylamine → Chloride



The colorimetric tubes react positively to all chlorinated volatile organic halocarbons, including saturated and unsaturated chlorinated alkenes and alkanes. The total response indicated by the detector tube (the distance that the color change travels through the tube) reflects the sum of the concentration of each individual chlorinated compound present in the sample. The method is primarily qualitative (detects the presence/absence of a compound or class of compounds).

The colorimetric gas detector tubes used in the method are designed to detect CVOHs in ambient air. **Color-Tec is an alternate use of these tubes**, which purges CVOHs from a water or soil sample and concentrates them into the colorimetric tube. When using colorimetric tubes for the Color-Tec method, the units (ppmV) printed on the tubes do not directly reflect the quantity of CVOHs present in the water or soil sample being analyzed. The Color-Tec tube reading (the distance that the color change travels through the tube) is a **relative response** to the amount of chlorinated-compound molecules that have been purged from the sample and directed into the tube. Therefore, the Color-Tec tube reading is a **unit-less** value used only to record the **relative response** for each analysis in order to facilitate comparison of that response to laboratory GC/MS analysis.

THE COLOR-TEC TUBE READING IS NOT THE SAMPLE CONCENTRATION!

The tube reading is a unit-less value which must be compared to laboratory results from split samples in order to yield an estimate of the actual concentration present in the sample.

This manual provides a conversion table, developed using comparison of Color-Tec tube responses to split-sample GC/MS analyses conducted on thousands of samples, which can be used to provide an estimate of the expected sample concentration based on the tube reading (See Table 2 on page 15).

2.0 AQR Color-Tec Test Kit Description and Set-up

The Color-Tec Chlorinated VOH Soil/Water Test Kit System consists of two primary components:

1. A hardware kit which contains all **reusable equipment** needed to conduct the method, plus a carrying case; and
2. Expendables kits containing all **disposable components** needed for analysis of 20 water or soil samples using the following ranges of Gastec® 133-series tubes:
   a. Ultra low range 133-LL tubes (expected detection range ~ 3 to 1200 µg/L or µg/Kg)
   b. Low range 133-L tubes (expected detection range ~ 75 to 25,000 µg/L or µg/Kg)
   c. Medium range 133-M tubes (expected detection range ~ 500 to 130,000 µg/L or µg/Kg)

2.1 Materials Provided

2.1.1 Color-Tec Hardware KIT (See Figure 1)

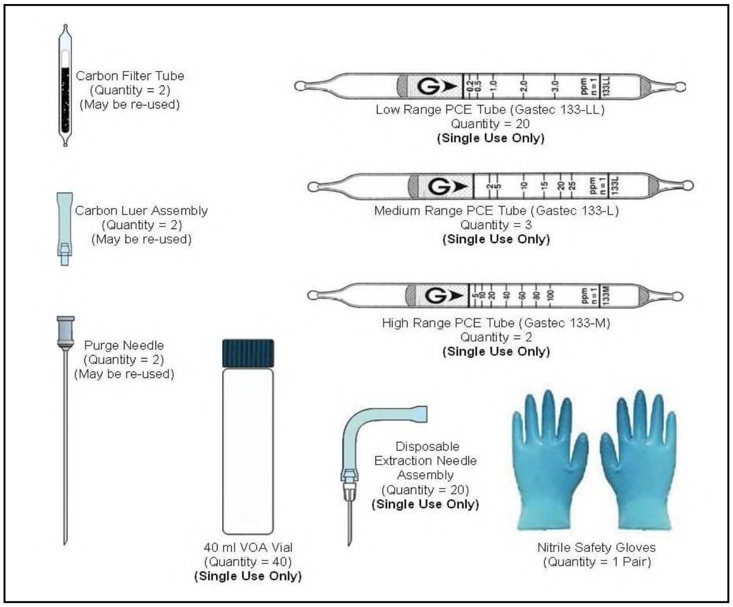
Item	Quantity
Piston pump	1
Color-Tec Pump Stand	1
Hot Plate	1
Stainless Steel Heating Pan	1
VOA Heating Rack	1
Thermometer	1
Decontamination Syringe	1
Pelican® hard case	1

2.1.2 Color-Tec 20-Sample Expendables Pack (See Figure 2) (Analyzes 20 samples)

Item	Quantity
Low-Range (133LL) Colorimetric Detector Tubes	20
Medium-Range (133L) Colorimetric Detector Tubes	3
High-Range (133M) Colorimetric Detector Tubes	2
Disposable Extraction Needle Assemblies **(single use only)**	25
40 Milliliter VOA Vials – empty (for samples)	40
Carbon Filter (may be re-used)	2
Carbon Filter Luer Assembly (may be re-used)	2
Purge Needle (may be re-used)	2
Nitrile Safety Gloves (pair)	1

Figure 1
Hardware Kit

Figure 2
Expendables Kit



2.2 Accessories Supplied by User

The following items (not provided in the AQR Color-Tec kit) are suggested for use with the Color-Tec method to perform the listed functions.

Item	Purpose
Organic-free water	for soil sample extraction and equipment decontamination
Safety gloves	personal protection
Safety glasses	personal protection
120V AC power source	for hot plate
Permanent marker	labeling sample bottles

Performance of the Color-Tec method requires the use of two standard, unpreserved VOA vials per sample. These VOA vials are not included in the standard expendables kits, but may be added as an option. The user may wish to collect a quantity of split samples for laboratory analysis to provide comparison data which may be used to determine site-specific method detection limits and/or to tentatively quantify Color-Tec results. Split sampling will likely require three pre-preserved VOA vials per sample. Pre-preserved VOA vials for split samples are not available in the Color-Tec expendables kits.

2.3 Storage & Stability of Colorimetric Tubes

The Gastec® colorimetric tubes have a shelf-life of two years with refrigeration. Tubes should be stored at or below a temperature of 10°C/50°F when not in use. Colorimetric detector tubes are single-use (one tube per analysis) and should be used immediately after the tips are broken. Tube readings should be recorded immediately following analysis because the intensity of the color-change fades over time. Each box of tubes has an expiration date printed in red ink on the top of each box. When heating the tubes for use with the Color-Tec method, it is recommended that the tube temperature does not exceed 40°C/104° F.

Other procedures and guidelines associated with the use of the tubes for their designed purpose (gas detection in ambient air) are included in the tube manufactures data sheets and tube instructions included in the tube packaging.

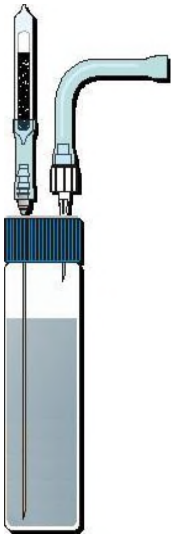
2.4 Heating Colorimetric Tubes and Samples

The colorimetric gas detector tubes used in the Color-Tec method were designed for the purpose of detecting volatile organic compounds (CVOHs) in ambient air. When using the tubes for analysis of ambient air, the calibrated operating temperature is 20°C/68°F. Using the tubes at temperatures above or below 20°C/68°F, for the purpose of testing ambient air, introduces error into the measurements requiring application of correction factors to correct that error. Because Color-Tec is an alternate use of the colorimetric tubes which concentrates CVOHs from water or soil samples into the tubes, the units (ppmV) printed on the tubes have no direct relationship to the quantity of CVOHs dissolved in the water/soil sample being analyzed and the temperature correction factors used for analysis of ambient air are not required when using the colorimetric tubes as part of the Color-Tec method. However, since the colorimetric tubes are more sensitive to the presence of chlorinated compounds at 40°C/104°F, and the purpose of the Color-Tec method is to detect the presence/absence of CVOHs in water at concentrations at the lowest concentrations possible, the tubes are heated to their optimum sensitivity (40°C/104°F) to maximize their detection capability.

The samples are also heated (in the VOA vials) to maximize contaminant volatilization and transfer of CVOHs from the water sample to the colorimetric tube. To heat the samples and colorimetric tubes, a hot plate is used to heat a water bath containing a test tube rack to hold the sample-filled VOA vials and unbroken colorimetric tubes. Special attention must be paid to the temperature of the water to avoid prolonged overheating the samples and tubes. The samples and colorimetric tubes should not be heated in excess of 40°C/104°F.

Given the size of the heating pan and VOA rack, generally only 3 sets of samples are heated at the same time. When a pair of VOAs is removed from the heating rack and placed on the pump stand, it can be replaced with a new pair for heating. After collection, samples should remain in a cool place until ready to be heated and analyzed. It is recommended to avoid heating the samples for more than about 2 minutes to avoid loss of CVOCs. Section 2.6 below, provides detailed water bath set-up and heating procedures.

2.5 Carbon Pre-Filter



Because ambient air is used to purge the samples, a carbon pre-filter is provided for attachment to the purge needle to prevent volatile airborne contaminants from passing through the sample and entering the detector tube during the purging process. To use the carbon pre-filter, break both tips of a carbon filter tube and insert the end of the tube onto the carbon lure assembly (make sure the air-flow arrows on the carbon tube point toward the carbon lure assembly), then tightly insert the male lure fitting on the carbon lure assembly into the female lure fitting on the purge needle (see Figure 2). At sites where little or no ambient air contamination is expected, a single pre-filter tube may be reused for several days. However, at sites where high concentrations of airborne chlorinated compounds are suspected or have been confirmed in the ambient air, the pre-filter tubes may need to be replaced more frequently. For most situations, one carbon filter per 10 samples is more than sufficient. Section 2.6 below, provides detailed carbon filter set-up and use procedures.

2.6 Color-Tec Work-Station Set-up

Pump Stand Set-up

1. Place the pump stand up-right on a flat stable surface.
2. Place the piston-pump into the curved tray on the top of the pump stand as shown.

Corning® Hot Plate Set-up

1. Connect the AC power cord to the back of the hot plate.
2. Connect the other end of the AC power cord to a USA 120VAC electric outlet.
3. Place the hot plate on a flat stable surface.
4. Set the hot plate thermostat control to between dial setting 4 and 5.

Hot Water Bath Set-up

1. Fill the stainless-steel water bath pan with tap water to approximately 1.5-inches from the rim.
2. Insert the VOA rack into the water-filled, stainless-steel, water bath pan.
3. Remove the cap from a 40ml VOA vial, fill the VOA vial with tap water and place it into the VOA Rack as shown. *Note: The bottom of the water-filled VOA vial should be slightly submersed in the water in the stainless-steel pan.*
4. Place the stainless-steel water bath pan onto the heating surface of the hot-plate.
5. Open a box of low-level (133LL) Gastec® tubes and place several tubes into the water-filled VOA vial. Insert the yellow reagent end of the tubes into the bottom of the VOA vial. Note: Do not place tubes with broken tips in the water bath – heating must be accomplished before breaking the tube tips.
6. Turn on the digital thermometer and place the steel probe into the water-filled VOA vial with the colorimetric tubes.
7. Once the water bath reaches a temperature of approximately 100ºF, the colorimetric tubes and VOA vials containing samples can be heated. *Note: The temperature of the water bath should not exceed 100ºF.*

Heating Samples

1. Place both VOA vials containing the sample into the hot water bath for approximately 1 to 2 minutes.
2. Be sure that the VOA vials are tightly sealed before heating. *Note: When properly heated, the VOA vials should feel warm in the hand – DO NOT OPEN VOA VIALS AFTER HEATING.*

Carbon Filter/Purge Needle Set-up

1. Break both ends of a carbon filter tube using the tip breaker on the piston pump.
2. Connect a carbon filter luer assembly to the carbon filter tube by sliding the open end of the vinyl tubing over the broken end of the carbon filter tube. Note: The carbon filter is re-used for multiple purge cycles.
3. Attach the carbon filter assembly to a purge needle by inserting the carbon filter assembly luer fitting into the purge needle luer fitting.
4. The purge needles are re-used after decontamination. Thoroughly clean and rinse the purge needle between each sample analysis to avoid contaminant carryover.

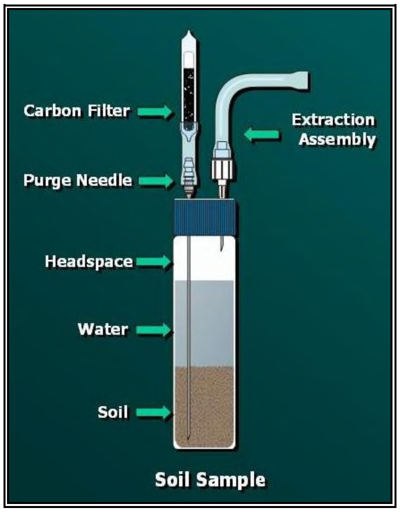
3.0 Sample Collection and Preparation

3.1 Liquid Sample Media

Collect the water or other liquid sample media directly from your sampling device into two 40 ml VOA vials by filling each vial to ~75% capacity (i.e. to about 1-inch below the shoulder of each vial). Tightly secure the caps onto the partially-filled VOA vials. The VOA vials containing the liquid sample to be tested must contain an air-filled headspace to accommodate purging. The caps must be tightened sufficiently to prevent loss of CVOHs during the time between sample collection and analysis (which includes the heating process) and to prevent air leakage during the purging process.

3.2 Solid Sample Media

Place about 1.5 inches of soil (or other solid sample media) into the bottom of each of two VOA vials (i.e. approximately 30 grams in each vial). Immediately after inserting the soil (or other solid sample media) into the two vials, add organic-free or other "clean" water to each VOA vial until they are both ~70 % full (i.e. to approximately 1-inch below the shoulder of each vial). Tightly secure the caps onto the partially-filled VOA vials. Once the caps are secure, shake the VOA vials vigorously for approximately for 5 to 10 seconds to thoroughly mix the soil and water. Additional mixing may be necessary for soil matrices comprised of clay-sized particles. The purpose of the mixing is to transfer any chlorinated compounds suspended in the soil matrix to the water to facilitate more effective purging.



IMPORTANT NOTE: The VOA vials containing the solid sample media and "clean" water must contain an air-filled headspace to accommodate purging. The caps must be tightened sufficiently to prevent loss of CVOHs during the time between sample collection and analysis (which includes the heating process) and to prevent air leakage during the purging process.

3.3 Purpose of the Second VOA Vial

The Color-Tec method is designed for use with two VOA vials (an original and a duplicate) for each sample collected. In certain situations, the duplicate sample may not be used in the performance of the method. However, the duplicate sample should always be collected in the event that it is needed to complete the analysis process. The duplicate sample may be used in either of the following situations:

- When the initial test does not induce a color change in the colorimetric tube, the second VOA vial containing the duplicate sample, may be purged (using the same colorimetric tube) to increase the probability of detecting very low (< 10 µg/L) concentrations.
- When the initial test induces a color change that exceeds the upper limit of the LL tube (a tube reading > 3), the extra VOA vial can be used to analyze the sample using higher range colorimetric tubes (133L or 133M) to tentatively quantify the higher concentration of chlorinated compounds in the sample.

4.0 Sample Analysis Procedure

1. Place both heated VOA vials (original & duplicate sample) into the two VOA holders on the pump-stand.

2. Remove a low-level tube from the hot water bath and wipe it dry.

3. Break both ends of the colorimetric tube using the tip breaker on the piston pump.

4. Insert the colorimetric tube into the pump inlet with the flow arrow (printed on the tube) toward the pump. ***Note:*** *Tube orientation is critical – the yellow reagent end of the tube is inserted in the pump.*

5. Connect a new extraction needle assembly to the colorimetric tube by sliding the open end of the vinyl tubing over the broken end of the colorimetric tube. This step must be completed before inserting the needle into the VOA (Prior to step 6).

6. Remove the protective cap from the extraction needle and insert the needle into the septa of the first VOA vial. ***Note:*** *Be sure that the tip of the extraction needle is positioned within the headspace of the VOA vial (above the water level). Do not insert the extraction needle as far as it will go into the headspace of the VOA vial, but rather only to a point slightly beneath the inside of the septa to reduce the possibility of sample water entering the extraction needle assembly and colorimetric tube during the purging process.*

7. Insert the purge needle (with carbon filter assembly) into the septa of the first VOA vial and push the tip of the needle to the bottom of the VOA vial.
   IMPORTANT NOTE: Do not insert the purge needle before completing steps 5 and 6.

8. Align the 50ml label and red dot on the pump handle with the red dot on the pump shaft.

9. Pull the handle sharply until it locks in the 50ml (half pull) position.

10. Confirm that air is purging through the sample in the VOA vial.

11. Purge for approximately 30 seconds.

12. Check the yellow reagent in the tube for a color-change.

13. If no color-change reaction is visible or if the color reading is less than 1.5, rotate the pump handle ½ turn and pull the handle out to lock in the 100ml position.

14. Continue the 100ml purge until the flow cycle is complete. Note: Flow is complete when the end-of-flow indicator (located on the back of the pump handle) returns to its full brightness.

15. Check the yellow reagent phase in the tube for a color change.

16. If no color-change is visible, remove the extraction needle from the VOA with the vinyl tubing still attached to the low-level tube, rotate the pump handle ¼ turn and push the plunger back into the pump, remove the extraction needle from the first VOA vial and inject it into the septa of the second VOA (duplicate sample), then remove the purge needle from the first VOA vial and inject it into the septa of the second VOA (duplicate sample) - now re-pull the pump handle to lock into the 100ml position.

17. When the second 100ml purge cycle is complete, read and record the results.

For samples containing high concentrations (>150 µg/L) the resulting color-change may exceed the calibrated limit of the low-level tube, requiring the second VOA vial (duplicate sample) to be purged and analyzed by repeating steps 3 through 13 using a medium range (133L) or a high range (133M) tube.

For samples containing low (<5 µg/L) concentrations the color change does not usually begin until 100 CCs of air have purged through the sample. Furthermore, the color change induced at these low concentrations is very slight (below 0.5 on the tube scale) and appears as a slight darkening or light purple hue at the entrance of yellow reagent layer in the LL tube. When the sample contains higher concentrations (>10 µg/L) of chlorinated compounds, the resulting color change is an obvious light to dark purple, which propagates through the yellow reagent layer toward the pump end of the colorimetric tube. The tube reading (Color-Tec response) is obtained by matching the linear extent of the discolored reagent inside the tube to the calibration scale printed on the outside of the tube. Table 1 presents a troubleshooting matrix with causes and solutions potential problems.

Important Procedural Notes:

The disposable extraction needle assembly is intended for one use only. Decontamination and re-use of this part is highly discouraged because of the risk of contaminant carryover from the tubing and other plastic parts which can harbor contaminants from the previous analysis. Purge needles may be reused following decontamination using water and isopropanol.

Carbon filters should be discarded if they become wet from contact with sample water.

Never insert the purge needle into the VOA before the extraction needle assembly has first been connected to the colorimetric tube and inserted into the VOA headspace. If the purge needle is inserted first, the pressure inside the sealed VOA may force sample water up though the purge needle and into the carbon filter. Sample volatiles may be lost if the extraction needle assembly is inserted into the VOA headspace before connecting the tubing to the colorimetric tube.

To prevent clogging of the purge needle when inserting the purge needle into VOA vials containing soil samples, do not immediately push the bottom of the needle through the soil to the bottom of the vial; but rather temporarily position the base of the purge needle in the water above the soil until the pump handle has been pulled to begin air flow through the sample. Once air flow has been initiated, slowly extent the purge needle through the soil to the base of the vial. The air flow from the tip of the purge needle should reduce the potential for clogging as the needle moves through the soil. This procedure is especially helpful when working with clayey soils.

Troubleshooting Guide

Problem	Possible Cause	Solution
Sample does not appear to be purging (bubbling) after the pump handle has been pulled.	Clogged/blocked purge (long) needle.	Use the decontamination syringe to check the purge needle for clogs. If clogged, clean the needle or use a new purge needle.
	Clogged/blocked extraction (short) needle.	Use decontamination syringe to check the extraction needle for clogs. Use decontamination syringe to clean the needle or use a new extraction needle.
	Colorimetric tube is not securely connected to hand pump.	Remove and re-insert the colorimetric tube from the hand pump. If the fit seems loose, replace the hand pump inlet gasket.
	Colorimetric tube is not securely connected to extraction needle tubing.	Check the connection between the extraction needle tubing and the colorimetric tube. If loose, insert the colorimetric tube further into the extraction needle tubing.
	VOA cap is not tightly sealed.	Check the tightness of the VOA cap. Tighten if necessary.
	Colorimetric tube tips were not broken before connecting to hand pump and tubing.	Break both tips of the colorimetric tube before connecting to hand pump and tubing.
	Broken/bad plunger seal in hand pump.	Check the pump seal by holding your finger over the hand pump inlet while pulling the pump handle and lock into the 50cc position. If no vacuum is apparent, open the pump, remove the plunger, replace the plunger seal, and grease the new seal. Re-assemble the pump.
The colorimetric tube shows no reaction after purging a sample that contains chlorinated compounds. (False Negative)	Colorimetric tube is below the optimum operating temperature.	Heat the colorimetric tube to 40°C/104° F before using. It is also recommended to heat the sample. The recommended temperature for tubes and samples when using the Color-Tec Method is 40°C/104° F.
	Colorimetric tube was connected using reversed flow direction.	Use the flow direction arrows to properly align the tube. The purged air must pass through the black oxidizer phase and the white catalyst phase before entering the yellow reagent phase.
	The sample also contains a detectable concentration of xylenes or toluene.	Samples can be tested for the presence of xylenes and toluene using the **Gastec® 122L** colorimetric tube. The detection of chlorinated compounds may be diminished when xylenes or toluene are present in a sample.
The colorimetric tube indicates a reaction after purging a sample that contains no chlorinated compounds. (False Positive)	Chlorinated compounds are present at detectable concentrations the ambient air.	Test the ambient air using an LL tube to determine if chlorinated compounds are present at detectable concentrations. Attach the charcoal filter to the purge needle prior to purging samples.
	HCl vapor is present in the sample VOA or in the ambient air.	Avoid use of HCl in the area where Color-Tec is in use. Use only unpreserved VOAs for samples to be screened with Color-Tec.
	Water vapor has entered the yellow reagent phase of the tube indicating a positive reaction	Avoid purging more that 200 CCs through any sample. Stop purging before condensation inside the tube reaches the end of the black oxidizer phase. Avoid drawing any water from the sample VOA into the colorimetric tube.

5.0 Sample Purging and Detection Methodology

Samples may be purged using 50 cubic centimeters (cc), 100cc, or 200cc purge volumes. These various purge volumes are used in succession to maximize the low-level detection capability and detection range of each tube, thereby reducing the number of tubes needed to tentatively quantify the concentration of total chlorinated compounds in the sample. The pump stand is equipped with two VOA-vial holders to accommodate a second (duplicate) sample to be collected from each sampling location. This duplicate sample (collected and prepared in the same manner as the original sample) serves the following two potential purposes:

1. When purging the initial VOA vial does not induce a color change in the colorimetric tube, the second VOA vial containing the duplicate sample, may be purged (using the same colorimetric tube) to increase the probability of detecting very low (< 10 µg/L) concentrations.
2. When the initial test induces a color change that exceeds the upper limit of the LL tube (a tube reading > 3), the extra VOA vial can be used to analyze the sample using higher range colorimetric tubes (133L or 133M) to tentatively quantify the higher concentration of chlorinated compounds in the sample.

5.1 50cc Purge Volume

Initially, all samples are analyzed using a Gastec® 133-LL tube with a 50cc purge cycle. If the 50cc purge induces a color change reading of 1.5 to 3.0, read the calibration scale value aligned with the stained/unstained interface in the tube and use the pump stroke correction factors provided on Table 1 to determine the correct reading for a 50cc purge volume. If the concentration in the sample exceeds the upper detection limit of the tube (i.e. the color change moves beyond the upper limit of the calibration scale printed on the tube), repeat the analysis using duplicate samples and higher range tubes (133-L, 133-M, and 133-HA) until the color change reaction stops within the calibration scale on the tube. If the color change reaction exceeds the upper limit of the calibration scale of the HA tube, the sample contains a concentration of chlorinated compounds above the upper detection capability of the Color-Tec Method.

5.2 100cc Purge Volume

Following completion of the 50cc purge cycle, if the concentration in the sample has induced a color change in the tube which traveled less than half the distance of the calibrated portion of the reagent phase of the tube (less than a reading of approximately 1.5), pull the pump handle outward and lock it into the 100cc position to complete a full purge cycle. Record the value aligned with the stained/unstained interface on the tube. No correction factor is needed for a 100cc purge.

5.3 200cc Purge Volume

Following completion of the 100cc purge cycle, if the concentration in the sample has induced no color change reaction, remove the purge needle and extraction needle assembly from the VOA vial containing the original sample and insert them into the VOA vial containing the duplicate sample (which has also been pre-heating) and perform another 100cc purge cycle **using the same colorimetric tube**. To perform the transfer to the second vial, remove both needles from the original VOA vial and immediately insert both needles into the septa of the duplicate sample VOA vial. Before re-inserting the pump handle, temporarily remove the colorimetric tube from the tip of the hand pump and re-insert the pump handle completely into the pump while the tube is un-attached. Re-attach the colorimetric tube into the pump tip and pull the pump handle and lock it into the 100cc position. Following the complete second purge cycle, read the calibration scale value aligned with the stained/unstained interface in the tube and use the pump stroke correction factors provided on Table 1 to determine the correct reading for a 200cc purge volume.

Table 1
Purge Volume Correction Factors for 133-Series Tubes

Colorimetric Tube	Purge Volume	Quantity of Pump Pulls	Correction Factor
133-LL	50cc	Half Pull	Tube Reading x 3
133-LL	100cc	Full Pull	Tube Reading x 1
133-LL	200cc	Two Pulls	Tube Reading x 0.5
133-L	50cc	Half Pull	Tube Reading x 3
133-L	100cc	Full Pull	Tube Reading x 1
133-L	200cc	Two Pulls	Tube Reading x 0.5
133-M	50cc	Half Pull	Tube Reading x 2.5
133-M	100cc	Full Pull	Tube Reading x 1
133-M	200cc	Two Pulls	Tube Reading x 0.4
133-HA	50cc	Half Pull	Tube Reading x 3
133-HA	100cc	Full Pull	Tube Reading x 1
133-HA	200cc	Two Pulls	Tube Reading x 0.3∞

6.0 Reading the Tubes

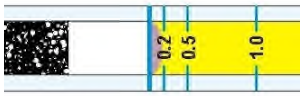
The basic Color-Tec method procedures are simple and intuitive; however, contaminant detection and semi-quantitative values are obtained through visual observation of the colorimetric reaction in the tubes, which is inherently subjective (especially in samples containing very low [<5 µg/L] total CVOHs). These low-level samples induce only a slight color change (i.e. slight darkening or light purple hue) prior to the 0.5ppm line on the tube scale at the entrance of yellow reagent layer in the LL tube. Samples containing concentrations of total chlorinated compounds above 5 µg/L usually induce a more apparent reaction within the LL tube.

6.1 Very Low Concentrations

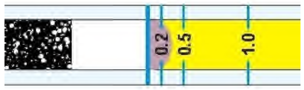
When a sample contains very low concentrations (<10µg/L) of chlorinated compounds, the resulting color change is not immediate or distinct. At these low concentrations the color change does not usually begin until between 100 and 200 CCs of air have purged through the sample into the tube. Furthermore, the color change induced at these low concentrations is very slight (below 0.5 on the tube scale) and appears as a slight darkening or light purple hue at the entrance of yellow reagent layer in the LL tube.

6.2 Low to Medium Concentrations

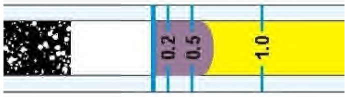
When the sample contains higher concentrations (>10 µg/L) of chlorinated compounds, the resulting color change is an obvious light to dark purple, which propagates through the yellow reagent layer toward the pump end of the colorimetric tube. The detected concentration level is obtained by matching the linear extent of the discolored reagent inside the tube to the calibration scale printed on the outside of the tube.



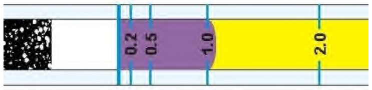
Tube Reading = 0.1
Estimated Concentration = 3 µg/L



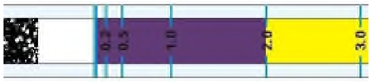
Tube Reading = 0.2
Estimated Concentration = 15 µg/L



Tube Reading = 0.6
Estimated Concentration = 45 µg/L



Tube Reading = 1.0
Estimated Concentration = 70 µg/L



Tube Reading = 2.0
Estimated Concentration = 145 µg/L

6.3 High Concentrations

When the sample contains high concentrations (>100 µg/L) of chlorinated compounds, the color change reaction occurs quickly and usually exceeds the upper detection level of the Gastec® 133LL tube. The higher the concentration of chlorinated compounds in the sample, the faster the color change reaction occurs and the further it propagates through colorimetric tube. Samples containing very high concentrations (>1000 µg/L) of chlorinated compounds, often discolor the entire yellow reagent layer in the LL tube before the pump handle has been fully extended. In these cases, the purging can be discontinued to allow for the current sample bottle to be re-tested using a higher range detector tube. There is no need to continue purging the sample when the detection level of the tube is exceeded. Each subsequently higher range tube (133L, 133M, or 133HA) is used to purge each new duplicate sample in succession until the color change reaction does not exceed the calibration range of the tube being used.

6.4 Recording Tube Readings

It is recommended to record the observed concentration value (tube reading), the range of the colorimetric tube (LL, L, M, or HA) and the final purge volume when logging Color-Tec results. For example, a reading of 2.5 observed on an LL tube using a 100 ml purge should be recorded as **2.5/LL/100**. Purge volume correction factors must be applied for Color-Tec values which were obtained using any purge volume other than 100cc. For example, a reading of 0.2 observed on an LL tube using a 200 ml purge should be recorded as **0.1/LL/200**. A reading of 60 observed on an M tube using a 50 ml purge should be recorded as **150/M/50.**

7.0 Estimating Sample Concentrations (Conversion Table)

The Color-Tec reading (the distance that the color change travels through the tube) is a **relative response** to the amount of chlorinated-compound molecules that have been purged from the sample and directed into the tube. Therefore, the units printed on the tubes are used only to record the **relative response** for each analysis in order to facilitate comparison to laboratory GC/MS methods.

To provide a field-ready estimate of the total chlorinated solvent concentration in liquid and solid samples based on the colorimetric tube reading, The developer of the Color-Tec method created a conversion table (see Table 2) based on statistical comparison of water samples collected from chlorinated solvent sites in which the Color-Tec and GC/MS methods were used to analyze split samples. An estimated concentration may be obtained by matching the Color-Tec tube response to either the *median expected GC/MS concentration* or the *range of expected GC/MS concentrations* provided on the comparison table. The potential range of corresponding analytical values associated with each positive tube reading increases significantly as the sample concentration increases. The estimated concentrations presented on Table 2 represent the central tendency of the comparison data. The actual analytical values obtained by laboratory analysis of split samples may differ substantially from this estimate and may fall outside of the corresponding ranges provided on Table 2.

The expected GC/MS concentrations presented in Table 2 are based on comparison of water sample data only. These conversion values may also be used for soil data; however, the potential range in expected GC/MS concentrations may be increased as a result of the difference in soil volumes used in the two methods and in the inherent heterogeneity of most soil matrices. However, the potential deviation factors included in the *range of expected GC/MS concentrations* column should be sufficient to account for the intrinsic analytical variability of most soil sample results.

THE COLOR-TEC TUBE READING IS NOT THE SAMPLE CONCENTRATION!

The tube reading is a unit-less value which must be compared to laboratory results from split samples in order to yield an estimate of the actual concentration present in the sample. This conversion table provides a reasonable estimate of the expected sample concentration based on the tube reading.

Table 2
Conversion of AQR Color-Tec Readings (Relative Responses) to Expected GC/MS Total Chlorinated Volatile Organic Halocarbon Concentrations

Gastec® Colorimetric Tube	Color-Tec Tube Reading (relative response) (unit-less)	Median Expected GC/MS (Laboratory) Concentration (µg/L or µg/kg)	Range of Expected GC/MS Concentrations (µg/L or µg/kg)	
			Low	High
133-LL	0	3	>0	5
	0.1	7	5	10
	0.2	15	10	20
	0.5	35	25	45
	0.8	55	40	75
	1	70	50	95
	1.5	110	75	140
	2	145	105	190
	2.5	190	130	245
	3	230	160	290
	5	380	260	490
	9	900	630	1,160
133-L	25	2,500	1,250	3,750
	35	4,400	2,200	6,600
	45	7,700	3,850	11,550
	55	15,000	7,500	22,500
	75	17,200	8,600	25,800
133-M	100	21,100	10,500	31,600
	200	46,000	23,000	69,000
	300	85,000	42,500	127,500
133-HA	500	225,500	112,800	338,300
	700	598,300	299,200	897,500
	900	1,587,500	793,800	2,381,300

Notes:
The **Color-Tec Tube Reading** (Color-Tec units) is the value printed on the colorimetric tube at the interface between the reacted and un-reacted reagent (the extent of the color change in the tube for a positive result).

The **Median Expected GC/MS Concentration** is the estimated concentration in micrograms per liter (µg/L) of total chlorinated volatile organic halocarbons (CVOHs) present in the sample for the corresponding Color-Tec tube response.

The **Range of Expected GC/MS Concentrations** is an estimated range of potential concentrations (µg/L or µg/kg) of total chlorinated volatile organic halocarbons (CVOHs) for the for the corresponding Color-Tec tube response.

The **Median Expected GC/MS Concentration** was obtained using statistical comparison of Color-Tec Method data and GC/MS (EPA Method 8260B) data. Comparison data were obtained from 5348 water samples collected from 152 chlorinated solvent (primarily PCE) sites in which the Color-Tec Method was used to analyze the samples in the field and either a laboratory-based or mobile GC/MS was used to analyze split samples.

The **Range of Expected GC/MS Concentrations** reflects the potential deviation in the **Median Expected GC/MS Concentration** based on Color-Tec Method/EPA Method 8260B comparison results. The potential error increases as the concentration increases. The initial deviation factor used for a Color-Tec Reading of zero is +/- 30% and increases to +/- 400% at a Color-Tec Reading of 900 units.

The **Median Expected GC/MS Concentrations** presented in this table are based on comparison of water sample data only. These conversion values may also be used for soil data; however, the potential error or range in expected GC/MS concentrations may be increased as a result in the difference in soil volumes used in the two methods and in the inherent heterogeneity of many soil matrices. The potential deviation factors included in the **Range of Expected GC/MS Concentrations** data should be sufficient to account for the intrinsic analytical variability of most soil sample results.

The expected GC/MS concentrations in this table are provided only to give Color-Tec Method users an approximate concentration for the Color-Tec Tube Response. Actual GC/MS results on split samples may be outside of the stated range for a given Color-Tec Tube Response.

Refer to the **AQR Color-Tec Manual** for detailed information regarding general method principals and potential analytical variables.

8.0 Proposed QA/QC Procedures

As with any analytical method, standard sample preparation and quality assurance/quality control (QA/QC) procedures tailored to the specific project goals should be developed and followed precisely and consistently throughout the sampling and analysis program to insure consistent results and the lowest possible detection levels for all samples analyzed using the Color-Tec method. This section is intended to provide the Color-Tec user with a basic methodology for conducting QA/QC procedures which address various potential operational and procedural issues, such as analytical confidence, method performance, false positives/negatives, replicate accuracy, and contaminant carryover. Users of the Color-Tec method are encouraged to use the information provided in this section to develop project-specific QA/QC and sample handling procedures that insure the level of consistency and accuracy required for the user's sampling program.

8.1 Analytical Confidence and Method Performance

Using Color-Tec to analyze prepared sample spikes containing known concentrations of chlorinated compounds provides confidence that the method procedures are being performed properly performed and may provide a basis for estimating concentrations based on the low-range (133LL) colorimetric tube responses. Spiked sample concentrations should range between 10 µg/L and 200 µg/L to cover the detection range of the low-range (133LL) colorimetric tube. Most analytical laboratories will prepare spiked samples in VOA vials with specified compounds at specified concentrations. Conduct Color-Tec analyses on the spiked samples using the same procedures described in Sections 3 and 4 and record the results in your field log as described in Section 5.3. A 200cc purge using two VOA vials (as described in Section 4.3) may be required to produce a positive Color-Tec reading when testing spiked samples containing 10 µg/L or less of total CVOHs may require a 200cc purge to produce a positive Color-Tec reading.

Performance/confidence testing of the higher range tubes (133L, 133M, and 133HA) using high-concentration spiked samples is unnecessary because the high range tubes are usually not used unless the sample being tested has already exceeded the upper range of the low range tube, thus revealing that the sample being tested contains a sufficient quantity of chlorinated compounds to evoke a positive reaction from the next higher range tube. Given the inherent extreme variability of estimating high concentrations based on tube responses on the high range tubes (133L, 133M, and 133HA), comparison of high concentration (>500 µg/L) spiked samples generally

8.2 Chemical Inhibitors (False Negatives)

The presence of Toluene and Xylenes inhibits/diminishes the ability of the colorimetric tubes to detect CVOHs. At sites where the presence of these compounds is suspected to be present in the soil or water samples, QA procedures may include periodic testing of groundwater or soil samples and ambient air for the presence of toluene and xylenes using a Gastec® Toluene tube (the Toluene tube also detects xylenes). To conduct a test for the presence of compounds which could inhibit the detection of CVOHs use the Toluene (122L) tube to analyze a duplicate soil or water sample using the procedures described in Sections 2 through 4.

8.3 Positive Interference (False Positives)

Chlorinated Volatile Organic Halocarbons. The Gastec® 133-series colorimetric tubes used to perform the Color-Tec method detect all chlorinated volatile organic halocarbons (CVOHs) present in each sample. Thus, individual CVOH compounds cannot be identified/isolated using this method. But rather, each positive tube reading represents the sum total of all CVOH compounds present in the sample as "total CVOHs". This detection of the entire class of compounds is an inherent effect of the colorimetric tube design and thus may not be avoided by any alteration of method procedures.

Water Vapor. A build-up of water vapor in the colorimetric tube in the oxidizer stage (black portion of the tube) and through the catalyst stage (white portion of the tube) can induce a subtle color change similar to that of a low-level positive result if the moisture reaches the reagent stage (yellow portion of the tube). This problem is easily avoided by observing the build-up of condensation inside the tube in the oxidizer stage during purging, and stopping the airflow before the condensation reaches the white catalyst stage. This condition rarely occurs before the maximum required purge volume of 200 CCs is achieved and contaminant presence or absence has been determined.

Hydrogen Chloride Vapor. Hydrogen chloride vapor is the reactant that causes the color change in the yellow reagent used in the PCE colorimetric tubes. The HCl vapor is formed when chlorinated halocarbons pass through the oxidizer and catalyst stages of the tube. Free HCl vapor can also be formed when strong hydrochloric acid comes into contact with air or calcium carbonate. Any source of free hydrogen chloride vapor which enters the colorimetric tube will cause a strong positive reaction. To minimize the risk of false positives from hydrogen chloride vapor, avoid the use of pre-preserved VOAs when using the Color-Tec method. Natural sources of hydrogen chloride vapor are rare.

Free Chlorine. Very high (>20,000 ppm) concentrations of free chlorine can cause a low-level positive reaction in the 133LL colorimetric tube. The conditions necessary for this positive interference rarely occur in groundwater or soil samples.

Contaminant Carryover. It is highly recommended that VOA vials and extraction needle assemblies be discarded following each test. Re-use of these expendable items may cause sufficient carryover of contaminants to cause a false positive result in subsequent samples.

8.4 Ambient Air Interference

Because the Color-Tec method uses ambient air as the purge gas, airborne chlorinated compounds at low concentrations can enter the sample and cause a positive reaction in the detector tube. Conversely, low concentrations of either toluene or xylenes present in the ambient air may enter the colorimetric tube and inhibit/diminish the tube's ability to detect CVOHs. To prevent airborne contaminants from entering the sample and detector tube during sample purging and analysis, the method is used with a carbon pre-filter attached to the purge needle. To determine whether airborne chlorinated contaminants are present, a PCE (133LL) colorimetric tube may be used periodically to test the ambient air at the location where the field testing is being performed. If airborne contaminants are present and the carbon filter is being used, the carbon filters can also be tested periodically using a colorimetric tube to determine if breakthrough is occurring. The ambient air may be similarly tested for the presence of xylenes or toluene using the PCE (133LL) colorimetric tube.

To conduct a test for the presence of chlorinated VOHs in the ambient air, break the tips of a PCE (133LL) or PCE (133LL) colorimetric tube and properly insert it into the hand pump. Pull and lock the pump handle into the 100cc position allowing ambient air to enter the colorimetric tube. *Note: Do not attach an extraction needle assembly to the colorimetric tube while performing this test.* Once the 100cc flow cycle is completed, carefully read the tube and record the results. A positive result indicates the presence of CVOCs in the ambient air at concentrations detectable by Color-Tec which would affect sample results unless the carbon filter assembly is attached to the purge needle (see Section 9). A negative result indicates that CVOCs are not present in the ambient air at concentrations detectable by Color-Tec and therefore will not affect sample results. It is recommended that the carbon filter assembly is used regardless of the ambient air testing results.

8.5 Duplicate Sample Testing Procedure

Duplicate or replicate samples are collected from the same sampling location, at the same time, using the same collection methods, and analyzed using the same procedures as the original samples for the purpose of determining both sampling and analytical method variability. Since a second (duplicate) VOA vial is always collected for the Color-Tec method, a duplicate or replicate analysis may be performed on the second (duplicate) VOA vial any time that a positive result (color change) is evoked by the original sample (first VOA vial) without exceeding the upper limit of the low-level colorimetric tube. In those cases, the duplicate or replicate analysis is simply performed by using a new low-level colorimetric tube to analyze the duplicate sample in the second (unused) VOA vial. If sampling and method variability is low, the result of the duplicate test will be the same or similar to the results obtained from the original test. The relative percent difference (RPD) may be calculated to quantify any variability in the results.

8.6 Collection of Split Samples for Laboratory Analysis

It is recommended that sample splits be collected for laboratory comparison analysis from 5 to 20 percent of the total quantity of samples analyzed using the Color-Tec method. Given a sufficient quantity of split sample pairs and sufficient range of concentration values, the GC/MS-to-Color-Tec comparison data may be used to obtain estimated concentrations for samples in the data set which were analyzed only using the Color-Tec method. This can be achieved using linear regression analysis of the comparison data. Statistical analysis of the comparison data can also be performed to determine site-specific Color-Tec method performance data.

9.0 Safety Precautions

As with the use of any product, it is recommended that the user carefully review all product manuals and Material Safety Data Sheets (MSDS) provided with this product prior to use. Several components of the Color-Tec kit are products obtained from other manufacturers which have manuals including safety precautions. Users of the Color-Tec method should carefully review the manuals and safety precautions and should become familiar with the proper use of all components included in the Color-Tec kit. It is recommended that the procedures involved with the method be incorporated into the user's Site-specific Safety and Health Plan (SSHP). MSDSs for all chemicals provided as part of the Color-Tec kit are available upon request. The following precautions should be considered to reduce potential user safety risks associated with the performance of the Color-Tec method.

Activity	Potential Risk	Precaution
Breaking tube tips	eye injury, dermal puncture	safety glasses
Accidental tube breakage	dermal cuts, exposure to reagent	safety gloves
Use of purge/extraction needles	dermal puncture	use caution
Use of the hot plate	dermal burns, electric shock	limited setting
Use of PCE standards	dermal contact, dermal cuts	safety gloves

Additional Safety Notes:

- Use skin and eye protection while breaking colorimetric and carbon filter tubes;
- The thermostat dial setting of the Corning® Hot Plate should never be set above 5 for any heating purposes required by the Color-Tec method;
- Do not over-fill the water bath pan while heating the samples and tubes;
- Always conduct sample and tube heating activities on a flat, stabile, surface.
- Keep all flammable or combustible materials away from the Corning® Hot Plate during sample and tube heating activities.

- Always use the stainless-steel water-bath pan properly filled with water for heating the samples and tubes – do not heat samples or tubes directly on the surface of the Corning® Hot Plate;
- Do not use any heat source to heat the water-bath, tubes, or samples other than the Corning® Hot Plate provided in the hardware kit.

Disposal of Expendable Materials:

- Re-cap all needles before disposal;
- After re-capping each extraction needle, dispose of the extraction needle assembly while leaving the vinyl tubing attached to the colorimetric tube – Do not attempt to remove the extraction needle assembly from the tip of the colorimetric tube for disposal;
- Dispose of all sharps (needles and broken glassware) in accordance with any and all applicable local and/or federal rules or guidance.
- Dispose of all colorimetric tubes as specified in the Gastec® MSDS and/or in accordance with any and all applicable local and/or federal rules or guidance.
- Dispose of all VOA vials used to contain sample materials in accordance with any and all applicable local and/or federal rules or guidance.

Product Warranty

AQR warrants that the goods sold herein will be free from defects in material and workmanship. This warranty shall be limited to the replacement of defective parts. It is expressly agreed that this warranty shall be in lieu of all warranties of fitness and in lieu of the warrant of merchantability.

EPA Guidance Document References

Using Dynamic Field Activities for On-Site Decision Making
May 2003; OSWER No. 9200.1-40 EPA/540/R03/002; Chapter 5;
http://www.epa.gov/superfund/programs/dfa/download/guidance/40r03002.pdf

Site Characterization Technologies for DNAPL Investigations September 2004; EPA 542-R-04-017;
http://www.clu-in.org/download/char/542r04017.pdf

Understanding Procurement for Sampling and Analytical Services under a Triad Approach June 2005, EPA 542-R-05-022;
http://www.epa.gov/swertio1/download/char/procurement.pdf

Conducting Contamination Assessments at Drycleaning Sites EPA Technology Innovation Program; State Coalition for Remediation of Drycleaners; http://www.drycleancoalition.org/download/assessment.pdf

EPA Triad Implementation References

Using AQR Color-Tec for Source Identification and Delineation
Naval Construction Battalion Center Davisville North Kingstown, RI - 2008 Triad Conference;
http://www.umass.edu/tei/conferences/Triad_PDF/Anderson.pdf

Fast Track to Reducing Conceptual Site Model Uncertainty CH2MHill; Storage Tank Site ST-123 POL Fuel Yard;
http://www.Triadcentral.org/user/includes/dsp_profile.cfm?Project_ID=25

Best Practices in Triad Approach to Characterize TCE, National Laboratory Environmental Sciences Division Argonne, IL;
http://www.triadcentral.org/user/doc/TPP-Hurlburt-BestPractices.pdf

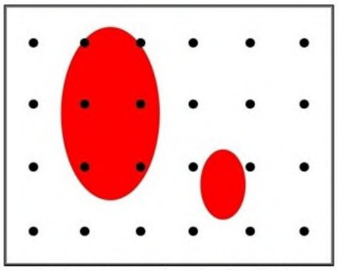
Adaptations to Triad as a Basis for Exit Strategy Development Decision Logic Flow Chart 2006 Triad Poster Session; CH2MHill; http://www.triadcentral.org/user/doc/TPP-Hurlburt-TriadAdaptations.pdf

Successful Triad Implementations at Federal Sites AQR Color-Tec Method locates source areas at Calloway Drum Recycling Site, Auburndale, Florida http://www.triadcentral.org/user/doc/TPP-Callaway-Field_Based_Decision_Approach.pdf

Color-Tec Method Applications

Source Area Identification at chlorinated solvent sites is highly complex given the low solubility of these compounds in water. Chlorinated solvent source zones often persist as suspended residual in unsaturated and saturated subsurface sediments for many decades. Surface water infiltration and groundwater flowing through the source zones slowly dissolves the suspended residual solvent leading to substantial aqueous phase contaminant plumes. Given the high volatility of most chlorinated compounds, residual solvents suspended in the unsaturated soil often leads to significant vapor phase contamination. The Color-Tec method is ideal for locating chlorinated solvent source areas by combining low level detection of all chlorinated compounds with low per sample cost to allow for significant expansion of sampling coverage compared to assessment approaches where only definitive analytical (laboratory) methods are employed to locate source areas. Definitive laboratory analysis provides high analytical accuracy, but sampling quantity is often limited to control costs, resulting in data gaps, sampling uncertainty, and low overall data quality. The low per-sample cost of Color-Tec method offers a 6:1 increase in analysis volume over laboratory methods, allowing for five times the sampling coverage for the same cost.

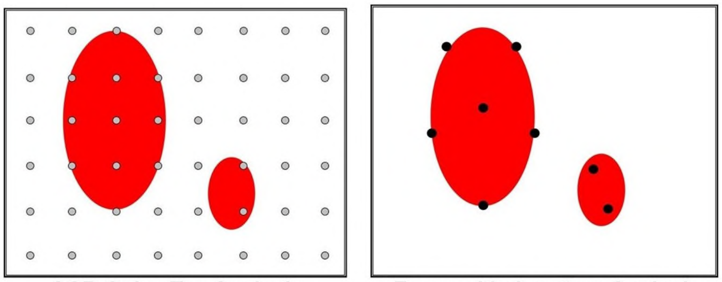
The illustrations below compare the traditional approach of source identification which uses only definitive laboratory analysis, to a collaborative approach which uses a high volume of Color-Tec data combined with a low quantity of definitive laboratory data. This collaborative approach combines high volume/low accuracy with low volume/high accuracy to achieve higher overall data quality than either method alone.



Laboratory Analysis Only
(24 samples at $100 each)

Traditional Approach
(Total Cost = $2,400)

The diagram to the left shows the traditional site investigation scenario in which all samples collected are analyzed using only definitive analytical methods. The red areas represent previously unidentified source areas and black dots represent sampling locations intended to locate and delineate the contaminant plumes. Although this definitive-analysis only approach provides high analytical accuracy, the sampling quantity is often limited in order to control costs, resulting in data gaps, sampling uncertainty, and low overall data quality – and in this example the smaller source area remains undetected.



AQR Color-Tec Analysis
(48 samples at $15 each)

Focused Laboratory Analysis
(8 samples at $100 each)

Collaborative Approach (Total Cost = $1,520)

The two diagrams to the right show an investigation scenario in which a real-time measurement method, such as Color-Tec, is used to increase the overall sampling coverage, resulting in reduced sampling uncertainty and increased overall data quality. In this example, the smaller source area is identified and the Color-Tec data is verified and confirmed by focusing a reduced quantity of definitive, laboratory-based, analysis of split-samples onto the most critical areas of the site. Combining Color-Tec with focused laboratory analysis in this manner provides increased overall data quality and analytical accuracy at significantly lower costs than conventional approaches which rely only on definitive laboratory-based analysis.

Groundwater Profiling is the collection of discrete samples at multiple depths and locations working outward from known source areas to define the lateral and vertical extent of a dissolved groundwater contaminant plume. The technique is used in conjunction with the Color-Tec method at chlorinated solvent sites to allow for immediate decisions regarding subsequent vertical and lateral sampling locations.

Soil Matrix Profiling is similar to groundwater profiling, but uses sampling of the unsaturated soil to define the lateral and vertical extent of the vapor phase contamination.

Groundwater Matrix Profiling (Residual Zone Mapping) is similar to groundwater or soil profiling, but uses sampling of saturated unconsolidated aquifer matrix to define the lateral and vertical extent of suspended residual DNAPL.

Surface Water/Sediment/Pore Water Impact Evaluation is the collection and analysis of sediment, sediment pore water, and surface water to locate and characterize groundwater impacts on surface water.

AQR Color-Tec®

Contact and Ordering Information

- For more information visit http://www.aqrcolor-tec.com/
- For kit orders contact Phil Pecevich at 919-918-7191
  Email: pecevica@bellsouth.net

Equipment and Expendables

- Hardware kit includes piston pump, pump stand, and heating equipment in a Pelican® hard case
- Expendables provided in 20-sample packs
- Expendables for QA/QC tests sold separately
- Cost per sample is $19.95
- Volume discounts available
- Professional technical support is included with every purchase
- Professional in-house or web-based training is available

Hardware Kit

20-Sample Pack

Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

GUIDANCE

Title: **Design and Installation of Monitoring Wells**

Effective Date: February 18, 2008

Number: SESDGUID-101-R0

Authors

Name: Brian Striggow
Title: Environmental Engineer
Signature:
Date: 2-13-08

Approvals

Name: Antonio Quinones
Title: Chief, Enforcement and Investigations Branch
Signature:
Date: 2/13/08

Name: Laura Ackerman
Title: Field Quality Manager, Science and Ecosystem Support Division
Signature: Laura Ackerm
Date: 02|13|08

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Document Control Coordinator.

History	Effective Date
SESDGUID-101-R0, *Design and Installation of Monitoring Wells*, Original Issue	February 18, 2008

TABLE OF CONTENTS

1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when designing and installing permanent and temporary groundwater monitoring wells to be used for collection of groundwater samples.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when designing, constructing and installing groundwater monitoring wells. On the occasion that SESD field personnel determine that any of the procedures described in this section are either inappropriate, inadequate or impractical and that another procedure must be used for any aspect of the design, construction and/or installation of a groundwater monitoring well, the variant procedure will be documented in the field log book, along with a description of the circumstances requiring it's use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the H: drive of the SESD local area network. The Document Control Coordinator is responsible for ensuring the most recent version of the procedure is placed on the H: drive and for maintaining records of review conducted prior to its issuance.

1.4 References

USEPA Region 4 Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), November 2001

USEPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Science and Ecosystem Support Division, Region 4, Athens, GA.

SESD Operating Procedure for Field Sampling Quality Control, SESDPROC-011-Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205- Most Recent Version

SESD Operating Procedure for Field Records and Documentation, SESDPROC-204-Most Recent Version

SESD Operating Procedure for Groundwater Sampling, SESDPROC-301- Most Recent Version

SESD Operating Procedure for Management of Investigation Derived Waste, SESDPROC-202- Most Recent Version

EPA/540/S-95/503, *Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation*

ASTM standard D5092, *Design and Installation of Ground Water Monitoring Wells in Aquifers*

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when constructing and installing groundwater monitoring wells. Refer to the SESD Safety, Health and Environmental Management Program Procedures and Policy (SHEMP) Manual and any pertinent site-specific Health and Safety Plans (HASPs) for guidelines on safety precautions. These guidelines should be used to complement the judgment of an experienced professional. When using this procedure, minimize exposure to potential health hazards through the use of protective clothing, eye wear and gloves. Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate. Section 2.6, Safety Procedures for Drilling Activities, contains detailed and specific safety guidelines that must be followed by Branch personnel when conducting activities related to monitoring well construction and installation.

1.5.2 Procedural Precautions

The following precautions should be considered when constructing and installing groundwater monitoring wells.

- Special care must be taken to minimize or prevent inadvertent cross-contamination between borehole locations. Equipment, tools and well materials must be cleaned and/or decontaminated according to procedures found in SESD Operating Procedure for Field Equipment Cleaning and Decontamination, (SESDPROC-205).
- All field activities are documented in a bound logbook according to the procedures found in SESD Operating Procedure for Field Records and Documentation, (SESDPROC-204).

2 Permanent Monitoring Well Design Considerations

2.1 General

The design and installation of permanent monitoring wells involves drilling into various types of geologic formations that exhibit varying subsurface conditions. Designing and installing permanent monitoring wells in these geologic environments may require several different drilling methods and installation procedures. The selection of drilling methods and installation procedures should be based on field data collected during a hydrogeologic site investigation and/or a search of existing data. Each permanent monitoring well should be designed and installed to function properly throughout the duration of the monitoring program. When designing monitoring wells, the following should be considered:

- Short-and long-term objectives;
- Purpose of the well(s);
- Probable duration of the monitoring program;
- Contaminants likely to be monitored;
- Surface and subsurface geologic conditions;
- Properties of the aquifer(s) to be monitored;
- Well screen placement;
- General site conditions; and
- Potential site health and safety hazards.

In designing permanent monitoring wells, the most reliable, obtainable data should be utilized. Once the data have been assembled and the well design(s) completed, a drilling method(s) must be selected. The preferred drilling methods for installing monitoring wells are those that temporarily case the borehole during drilling and the construction of the well, e.g. hollow-stem augers and sonic methods. However, site conditions or project criteria may not allow using these methods. When this occurs, alternate methods should be selected that will achieve the project objectives. The following discussion of methods and procedures for designing and installing monitoring wells will cover the different aspects of selecting materials and methods, drilling boreholes, and installing monitoring devices.

2.2 Drilling Methods

The following drilling methods may be used to install environmental monitoring wells or collect samples under various subsurface conditions. In all cases the preferred methods are those that case the hole during drilling, i.e. Hollow Stem Augers (HSA) and sonic methods using an override system. Other methods may be used where specific subsurface or project criteria dictate.

2.2.1 Hollow Stem Auger (HSA)

This type of auger consists of a hollow, steel stem or shaft with a continuous, spiraled steel flight, welded onto the exterior. A hollow auger bit, generally with carbide teeth, disturbs soil material when rotated, whereupon the spiral flights transport the cuttings to the surface. This method is best suited in soils that have a tendency to collapse when disturbed. A monitoring well can be installed inside of hollow-stem augers with little or no concern for the caving potential of the soils. If caving sands exist during monitoring well installations, a drilling rig must be used that has enough power to extract the augers from the borehole without having to rotate them. A bottom plug, trap door, or pilot bit assembly can be used at the bottom of the augers to keep out most of the soils and/or water that have a tendency to enter the bottom of the augers during drilling. Potable water (analyzed for contaminants of concern) may be poured into the augers during drilling to equalize pressure so that the inflow of formation materials will be held to a minimum. Water-tight center bits are not acceptable because they create suction when extracted from the augers. This suction forces or pulls cuttings and formation materials into the augers, defeating the purpose of the center plug. Augering without a center plug or pilot bit assembly is permitted, provided that the soil plug, formed in the bottom of the augers, is removed before sampling or installing well casings. Removing the soil plug from the augers can be accomplished by drilling and washing out the plug using a rotary bit, or augering out the plug with a solid-stem auger bit sized to fit inside the hollow-stem auger. Bottom plugs can be used where no soil sampling is conducted during the drilling process. The bottom plug is wedged into the bottom of the auger bit and is knocked out at depth with drill pipe or the weight of the casing and screen assembly. The plug material should be compatible with the screen and casing materials. The use of wood bottom plugs is not acceptable. The type of bottom plug, trap door, or pilot bit assembly proposed for the drilling activity should be approved by a senior field geologist prior to drilling operations. Boreholes can be augered to depths of 150 feet or more (depending on the auger size), but generally boreholes are augered to depths less than 100 feet.

2.2.2 Solid Stem Auger

This type of auger consists of a sealed hollow or solid stem or shaft with a continuous spiraled steel flight welded on the outside of the stem. An auger bit connected to the bottom disturbs soil material when rotated and the helical flights transport cuttings to the surface. At the desired depth the entire auger string is removed to gain access to the bottom of the borehole. This auger method is used in cohesive and semi-cohesive soils that do not have a tendency to collapse when disturbed. Boreholes can be augered to depths of 200 feet or more (depending on the auger size), but generally boreholes are augered to depths less than 100 feet.

Both of the previously discussed auger methods can be used in unconsolidated soils and semi-consolidated (weathered rock) soils, but not in competent rock.

Each method can be employed without introducing foreign materials into the borehole such as water and drilling fluids, minimizing the potential for cross contamination. Minimizing the risk of cross contamination is one of the most important factors to consider when selecting the appropriate drilling method(s) for a project.

2.2.3 Sonic Methods

These methods generally alternately advance concentric hollow drill stems using rotation in conjunction with axial vibration of the drill stem. After each stage of drill stem advancement, the inner string is removed with a core of drill cuttings while the outer ‘override’ string remains to hold the borehole open. The cuttings can be removed nearly intact from the inner casing for examination of the stratigraphy prior to sampling or disposal. Because there are no auger flights to increase the borehole diameter, the quantity of cuttings removed from the hole is minimized as compared to hollow stem augering. With moderate rotation, smearing of the formation materials on the borehole walls is reduced as well. This drilling method is useful in a variety of materials, from flowing sands to heavily consolidated or indurated formations.

In flowing sands, the drill casings can be filled and/or pressurized with potable water to prevent excess entry of formation materials into the drill string. The same QA/QC requirements for sampling of material introduced to the borehole apply as in other drilling methods. Because the amount of water introduced into the borehole can be significant, an approximation of the water used in the drilling process should be logged for use in estimating appropriate well development withdrawal.

Sonic drilling allows a larger diameter temporary casing to be set into a confining layer while drilling proceeds into deeper aquifers. This temporary casing is then removed during the grouting operation. In many cases this will be acceptable technique. However, the level of contamination in the upper aquifer, the importance of the lower aquifers for drinking water uses, the permeability and continuity of the confining layer, and state regulations should be taken into account when specifying this practice as opposed to permanent outer casing placed into the confining unit. Note that when using the temporary casing practice, it is critical that grout be mixed and placed properly as specified elsewhere in this section.

Because the total borehole diameter in sonic drilling is only incrementally larger than the inner casing diameter, particular care should be taken that the well casing is placed in the center of the drill stem while placing the filter pack. Centralizers should be used in most cases to facilitate centering, particularly in the case of deep wells with PVC casing.

2.2.4 Rotary Methods

These methods consist of a drill pipe or drill stem coupled to a drilling bit that rotates and cuts through the soils. The cuttings produced from the rotation of the drilling bit are transported to the surface by drilling fluids which generally consist of water, drilling mud, or air. The water, drilling mud, or air are forced down through the drill pipe, and out through the bottom of the drilling bit. The cuttings are then lifted to the surface between the borehole wall and the drill pipe, (or within a concentric drill stem in reverse rotary). Except in the case of air rotary, the drilling fluid provides a hydrostatic pressure that reduces or prevents borehole collapse. When considering this method, it is important to evaluate the potential for contamination when fluids and/or air are introduced into the borehole.

Due to the introduction of the various circulating fluids, the use of rotary methods requires that the potential for contamination by these fluids be evaluated. Water and mud rotary methods present the possibility of trace contamination of halogenated compounds when municipal water supplies are used as a potable water source. Air rotary drilling can introduce contamination through the use of lubricants or entrained material in the air stream. Unless contaminated formations are cased off, the circulation of drilling fluids presents a danger of cross contamination between formations. In any of the rotary (or sonic) methods, care must be exercised in the selection and use of compounds to prevent galling of drill stem threads.

2.2.4.1 Water Rotary

When using water rotary, potable water (that has been analyzed for contaminants of concern) should be used. If potable water (or a higher quality water) is not available on-site, then potable water will have to be transported to the site or an alternative drilling method will have to be selected. Water does not clog the formation materials, but the suspended drilling fines can be carried into the formation, resulting in a very difficult to develop well. This method is most appropriate for setting isolation casing.

2.2.4.2 Air Rotary

Air rotary drilling uses air as a drilling fluid to entrain cuttings and carry them to the surface. High air velocities, and consequently large air volumes and compressor horsepower are required. “Down-the-hole” (DTH) percussion hammers driven by the air stream can be used with this method to rapidly penetrate bedrock materials. Where a casing through unconsolidated material is required to prevent borehole collapse, it can be driven in conjunction with advancement of the drill stem.

When using air rotary drilling in any zone of potential contamination, the cuttings exiting the borehole must be controlled. This can be done using the dual-tube reverse circulation method where cuttings are carried to the surface inside dual-wall drill pipe and separated with a cyclone separator. An air diverter with hose or pipe carrying cuttings to a waste container is also an acceptable alternative. Allowing cuttings to blow uncontrolled from the borehole is not acceptable.

When using air rotary, the issue of contaminants being introduced into the borehole by the air stream must be addressed. Screw compressor systems should have a coalescing filter system in good working order to capture excess entrained compressor oils. The lubricant to be used with DTH hammers as well as thread lubricants to be used on drill stem should be evaluated for their potential impact on analytical samples.

2.2.4.3 Mud Rotary

Mud rotary is an undesirable drilling method because contamination can be introduced into the borehole from the constituents in the drilling mud, cross contamination can occur along the borehole column, and it is difficult to remove the drilling mud from the borehole after drilling and during well development. The drilling mud can also carry contaminates from a contaminated zone to an uncontaminated zone thereby cross-contaminating the borehole. If mud rotary is selected, only potable water and pure (no additives) bentonite drilling muds should be used. All materials used should have adequate documentation as to manufacturer's recommendations and product constituents. QA/QC samples of drilling muds and potable water should be sampled at a point of discharge from the circulation system to assure that pumps and piping systems are not contributing cross-contamination from previous use.

2.2.5 Other Methods

Other methods such as the cable-tool method, jetting method, and boring (bucket auger) method are available. If these and/or other methods are selected for monitoring well installations, they should be approved by a senior field geologist before field work is initiated.

2.3 Borehole Construction

2.3.1 Annular Space

The borehole or hollow stem auger should be of sufficient diameter so that well construction can proceed without major difficulties. For open boreholes, the annular space should be approximately 2" to allow the uniform deposition of well materials around the screen and riser, and to allow the passage of tremie pipes and well materials without unduly disturbing the borehole wall. For example, a 2" nominal diameter (nom.) casing would require a 6" inside diameter (ID) borehole.

In hollow stem augers and sonic method drill casing, the ID should be of sufficient size to allow the passage of the tremie pipe to be used for well grout placement, as well as free passage of filter sands or bentonite pellets dropped through the auger or casing. In general, 4-1/4" ID should be the minimum size used for placement of 2" nom. casing and 8-1/4" ID for 4" nom. casing. Larger augers should be used where installation difficulties due to geologic conditions or greater depths are anticipated, e.g. larger augers might be required to place a bentonite pellet seal through a long water column.

2.3.2 Over-drilling the Borehole

Sometimes it is necessary to over-drill the borehole in anticipation of material entering the augers during center bit removal or knocking out of the bottom plug. Normally, 3 to 5 feet is sufficient for over-drilling. The borehole can also be over-drilled to allow for an extra space or a "sump" area below the well screen. This "sump" area provides a space to attach a 5 or 10 foot section of well casing to the bottom of the well screen. The extra space or "sump" below the well screen serves as a catch basin or storage area for sediment that flows into the well and drops out of suspension. These "sumps" are added to the well screens when the wells are screened in aquifers that are naturally turbid and will not yield clear formation water (free of visible sediment) even after extensive development. The sediment can then be periodically pumped out of the "sump" preventing the well screen from clogging or "silting up". If the borehole is inadvertently drilled deeper than desired, it can be backfilled to the design depth with bentonite pellets, chips, or the filter sand that is to be used for the filter pack.

2.3.3 Filter Pack Placement

When placing the filter pack into the borehole, a minimum of 6-inches of the filter pack material should be placed under the bottom of the well screen to provide a firm base. Also, the filter pack should extend a minimum of 2-feet above the top of the well screen to allow for settling and to isolate the screened interval from the grouting material. In open boreholes, the filter pack should be placed by the tremie or positive displacement method. Placing the filter pack by pouring the sand into an open drill stem is acceptable with the use hollow stem augers, and other methods where the borehole is temporarily cased down to the filter pack.

2.3.4 Filter Pack Seal – Bentonite Pellet Seal (Plug)

Bentonite pellets consist of ground, dried bentonite compacted into pellets available in several sizes. Bentonite pellets are compressed to a bulk density of 70-80 lbs/cu.ft. and hydrate to a 30% min. solids material. Where neat cement grouts are to be used, the placement of a bentonite pellet seal above the filter pack is mandatory to prevent the possibility of grout infiltration into the screened interval prior to setting. Bentonite chips or other sealing products should not be substituted in this application. Where bentonite grouts are to be used, the placement of a bentonite pellet seal is optional, but desirable.

Since bentonite pellets begin hydrating rapidly, they can be very difficult to place properly. They are generally placed by pouring slowly into open boreholes, hollow stem augers or sonic drill pipe. In some cases, pellets are placed by tremie pipe and flushed into place with potable water. A tamper can be used to ensure that the material is being placed properly and to rapidly break up any pellet bridging that occurs.

Pellet seals should be designed for a two-foot thickness of dry pellets above the filter pack. Hydration may extend the height of the seal. Where neat cement grouts are to be used, the pellets should be hydrated for eight hours, or the manufacturer's recommended hydration time, whichever is greater. Where the water table is temporarily below the pellet seal, potable (or higher quality) water should be added repeatedly to hydrate the pellets prior to grouting.

2.3.5 Grouting the Annular Space

The annular space between the casing and the borehole wall should be filled with either a 30% solids bentonite grout, a neat cement grout, or a cement/bentonite grout. Each type of grout selected should be evaluated as to its intended use and integrity. Bentonite grouts are preferred unless the application dictates the use of another material.

Bentonite grout shall be a 30% solids pure bentonite grout. Drilling muds are not acceptable for grouting. The grout should be placed into the borehole, by the tremie method, from the top of the bentonite seal to within 2-feet of the ground surface or below the frost line, whichever is the greater depth. The bentonite pellet seal or filter pack should not be disturbed during grout placement, either by the use of a side discharge port on the tremie tube, or by maintaining clearance between the bottom of the tremie tube and the bentonite seal or filter pack. The grout should be allowed to cure for a minimum of 24 hours before the concrete surface pad is installed. The preferred method of achieving proper solids content is by measurement of ingredients per the manufacturer's specifications during mixing with a final check by grout balance after mixing. Bentonite grouts should have a minimum density of 10 lbs/gal to ensure proper gelling and low permeability. The density of the first batch of grout should be measured while mixing to verify proper measurement of ingredients. In addition, the grouting operation should not cease until the bentonite grout flowing out of the borehole has a minimum density of 10 lbs/gal. Estimating the grout density is not acceptable.

Cement grouts are generally dictated where a high level of dissolved solids or a particular dissolved constituent would prevent proper gelling of a bentonite grout. Neat cement grouts (cement without additives) should be mixed using 6 gallons of water per 94-lb bag of Type 1 Portland cement to a density of 15lbs/gal. The addition of bentonite (5 to 10 percent) to the cement grout can be used to delay the "setting" time and may not be needed in all applications. The specific mixtures and other types of cement and/or grout proposed should be evaluated on a case by case basis by a senior field geologist.

2.3.6 Above Ground Riser Pipe and Outer Casing

The well casing, when installed and grouted, should extend above the ground surface a minimum of 2.5 feet. A vent hole should be drilled into the top of the well casing cap to permit pressure equalization, if applicable. An outer protective casing should be installed into the borehole after the annular grout has cured for at least 24 hours. The outer protective casing should be of steel construction with a hinged, locking cap. Generally, outer protective casings used over 2-inch well casings are 4 inches square by 5 feet long. Similarly, protective casings used over 4-inch well casings are 6 inches square and 5 feet long. Other types of protective casing including those constructed of pipe are also acceptable. All protective casings should have sufficient clearance around the inner well casings, so that the outer protective casings will not come into contact with the inner well casings after installation. The protective casings should have a weep hole to allow drainage of accumulated rain or spilled purge water. The weep hole should be approximately 1/4-inch in diameter and drilled into the protective casings just above the top of the concrete surface pad to prevent water from standing inside of the protective casings. Protective casings made of aluminum or other soft metals are normally not acceptable because they are not strong enough to resist tampering. Aluminum protective casing may be used in very corrosive environments such as coastal areas.

Prior to installing the protective casing, the bentonite grout in the borehole annulus is excavated to a depth of approximately two feet. The protective casing is installed by pouring concrete into the borehole on top of the grout. The protective casing is then pushed into the wet concrete and borehole a minimum of 2 feet. Extra concrete may be needed to fill the inside of the protective casing so that the level of the concrete inside of the protective casing is at or above the level of the surface pad. In areas where frost heave of the surface pad is possible, the protective casing should first be pressed into the top surface of the bentonite grout seal and concrete poured around the protective casing. A granular material such as sand or gravel can then be used to fill the space between the riser and protective casing. The use of granular material instead of concrete between the protective casing and riser will also facilitate the future conversion of the well to a flush-mount finish, if required. The protective casing should extend above the ground surface to a height so that the top of the inner well casing is exposed when the protective casing is opened. At each site, all locks on the outer protective casings should be keyed alike.

2.3.7 Concrete Surface Pad

A concrete surface pad should be installed around each well at the same time as the outer protective casing is being installed. The surface pad should be formed around the well casing. Concrete should be placed into the pad forms and into the borehole (on top of the grout) in one operation making a contiguous unit. The size of the concrete surface pad is dependent on the well casing size. If the well casing is 2 inches in diameter, the pad should be 3 feet x 3 feet x 4 inches. If the well casing is 4 inches in diameter, the pad should be 4 feet x 4 feet x 6 inches. Round concrete surface pads are also acceptable. The finished pad should be slightly sloped so that drainage will flow away from the protective casing and off of the pad. A minimum of one inch of the finished pad should be below grade to prevent washing and undermining by soil erosion.

2.3.8 Surface Protection – Bumper Guards

If the monitoring wells are located in a high traffic area, a minimum of three bumper guards consisting of steel pipes 3 to 4 inches in diameter and a minimum 5-foot length should be installed. These bumper guards should be installed to a minimum depth of 2 feet below the ground surface in a concrete footing and extend a minimum of 3 feet above ground surface. Concrete should also be placed into the steel pipe to provide additional strength. Substantial steel rails and/or other steel materials can be used in place of steel pipe. Welding bars between the bumper posts can provide additional strength and protection in high traffic areas, but the protective bumpers should not be connected to the protective casing.

2.4 Construction Techniques

2.4.1 Well Installation

The borehole should be bored, drilled, or augered as close to vertical as possible, and checked with a plumb bob or level. Deviation from plumb should be within 1° per 50ft of depth. Slanted boreholes are undesirable and should be noted in the boring logs and final construction logs. The depth and volume of the borehole, including the over-drilling if applicable, should have been calculated and the appropriate materials procured prior to drilling activities.

The well casings should be secured to the well screen by flush-jointed threads and placed into the borehole and plumbed by the use of centralizers and/or a plumb bob and level. Another method of placing the well screen and casings into the borehole and plumbing them at the same time is to suspend the string of well screen and casings in the borehole by means of a hoist on the drill rig. This wireline method is especially useful if the borehole is deep and a long string of well screen and casings have to be set and plumbed.

No lubricating oils or grease should be used on casing threads. No glue of any type should be used to secure casing joints. Teflon "O" rings can also be used to insure a tight fit and minimize leakage; however, "O" rings made of other materials are not acceptable if the well is going to be sampled for organic compound analyses.

Before the well screen and casings are placed on the bottom of the borehole, at least 6 inches of filter material should be placed at the bottom of the borehole to serve as a firm footing. The string of well screen and casings should then be placed into the borehole and plumbed. Centralizers can be used to plumb a well, but centralizers should be placed so that the placement of the filter pack, bentonite pellet seal, and annular grout will not be hindered. Centralizers placed in the wrong locations can cause bridging during material placement. Monitoring wells less than 50 feet deep generally do not need centralizers. If centralizers are used they should be placed below the well screen and above the bentonite pellet seal. The specific placement intervals should be decided based on site conditions.

When installing the well screen and casings through hollow-stem augers, the augers should be slowly extracted as the filter pack, bentonite pellet seal, and grout are tremied and/or poured into place. The gradual extraction of the augers will allow the materials being placed in the augers to flow out of the bottom of the augers into the borehole. If the augers are not gradually extracted, the materials (sand, pellets, etc.) will accumulate at the bottom of the augers causing potential bridging problems.

After the string of well screen and casing is plumb, the filter pack material should then be placed around the well screen to the designated depth. With cased drilling methods, the sand should be poured into the casing or augers until the lower portion is filled. The casing or augers are then withdrawn, allowing the sand to flow into the evacuated space. With hollow stem augers, sand should always fill the augers 6-12 inches, maintained by pouring the sand while checking the level with a weighted tag line. The filter pack sand in open boreholes should be installed by tremie methods, using water to wash the sand through the pipe to the point of placement.

After the filter pack has been installed, the bentonite pellet seal (if used) should be placed directly on top of the filter pack to an unhydrated thickness of two feet. When installing the seal for use with ~~neat~~ cement grouts, the bentonite pellet seal should be allowed to hydrate a minimum of eight hours or the manufacturer's recommended hydration time, whichever is longer.

After the pellet seal has hydrated for the specified time, the grout should then be pumped by the tremie method into the annular space around the casings. The grout should be allowed to set for a minimum of 24 hours before the surface pad and protective casing are installed.

After the surface pad and protective casing are installed, bumper guards should be installed (if needed). The bumper guards should be placed around the concrete surface pad in a configuration that provides maximum protection to the well. Each piece of steel pipe or approved material should be installed into an 8-to 10-inch diameter hole, to a minimum depth of 2 feet below ground surface, and filled with concrete. As previously stated, the bumper guard should extend above the ground surface a minimum of 3 feet. The total length of each bumper guard should be a minimum of 5 feet.

After the wells have been installed, the outer protective casing should be painted with a highly visible paint. The wells should be permanently marked with the well number, date installed, site name, elevation, etc., either on the cover or an appropriate place that will not be easily damaged and/or vandalized.

If the monitoring wells are installed in a high traffic area such as a parking lot, in a residential yard, or along the side of a road it may be desirable to finish the wells to the ground surface and install water-tight flush mounted traffic and/or man-hole covers. Flush mounted traffic and man-hole covers are designed to extend from the ground surface down into the concrete plug around the well casing. Although flush mounted covers may vary in design, they should have seals that make the unit water-tight when closed and secured. The flush mounted covers should be installed slightly above grade to minimize standing water and promote runoff. Permanent identification markings should be placed on the covers or in the concrete plug around the cover. Expansive sealing plugs should be used to cap the well riser to prevent infiltration of any water that might enter the flush cover.

2.4.2 Double-Cased Wells

Double-cased wells should be constructed when there is reason to believe that interconnection of two aquifers by well construction may cause cross-contamination or when flowing sands make it impossible to install a monitoring well using conventional methods. A highly contaminated surface soil zone may also be cased off so that drilling may continue below the casing with reduced danger of cross contamination. A pilot borehole should be bored through the overburden and/or the contaminated zone into the clay confining layer or bedrock. An outer casing (sometimes called surface or pilot casings) should then be placed into the borehole and sealed with grout. The borehole and outer casing should extend into tight clay a minimum of two feet and into competent bedrock a minimum of 1 foot. The total depths into the clay or bedrock will vary, depending on the plasticity of the clay and the extent of weathering and\or fracturing of the bedrock. The final depths should be approved by a senior field geologist. The size of the outer casing should be of sufficient inside diameter to contain the inner casing, and the 2-inch minimum annular space. In addition, the borehole should be of sufficient size to contain the outer casing and the 2-inch minimum outer annular space, if applicable.

The outer casing should be grouted by the tremie, displacement, grout shoe, or Halliburton method from the bottom to the ground surface. The grout should be pumped into the annular space between the outer casing and the borehole wall. A minimum of 24 hours should be allowed for the grout plug (seal) to cure before attempting to drill through it. The grout mixture used to seal the outer annular space should be either a neat cement, cement/bentonite, cement/sand, or a 30% solids bentonite grout. However, the seal or plug at the bottom of the borehole and outer casing should consist of a Type I portland cement/bentonite or cement/sand mixture. The use of a pure bentonite grout for a bottom plug or seal is not acceptable, because the bentonite grout cures to a gel-like material, and is not rigid enough to withstand the stresses of drilling. When drilling through the seal, care should be taken to avoid cracking, shattering, or washing out the seal. If caving conditions exist so that the outer casing cannot be sufficiently sealed by grouting, the outer casing should be driven into place and a grout seal placed in the bottom of the casing.

2.4.2.1 Bedrock Wells

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

1. The first method is to drill or bore a pilot borehole through the soil overburden into the bedrock. An outer casing is then installed into the borehole by setting it into the bedrock, and grouting it into place as described in the previous section. After the grout has set, the borehole can then be advanced through the grout seal into the bedrock. The preferred method of advancing the borehole into the bedrock is rock coring. Rock coring makes a smooth, round hole through the seal and into the bedrock without cracking and/or shattering the seal. Roller cone bits are used in soft bedrock, but extreme caution should be taken when using a roller cone bit to advance through the grout seal in the bottom of the borehole because excessive water and "down" pressure can cause cracking, eroding (washing), and/or shattering of the seal. Low volume air hammers may be used to advance the borehole, but they have a tendency to shatter the seal because of the hammering action. If the structural integrity of the grout seal is in question, a pressure test can be utilized to check for leaks. A visual test can also be made by examining the cement/concrete core that is collected when the seal is cored with a diamond coring bit. If the seal leaks (detected by pressure testing) and/ or the core is cracked or shattered, or if no core is recovered because of washing, excessive down pressure, etc., the seal is not acceptable. The concern over the structural integrity of the grout seal applies to all double cased wells. Any proposed method of double casing and/or seal testing will be evaluated on its own merits, and will have to be approved by a senior field geologist before and during drilling activities, if

applicable. When the drilling is complete, the finished well will consist of an open borehole from the ground surface to the bottom of the well. There is no inner casing, and the outer surface casing, installed down into bedrock, extends above the ground surface, and also serves as the outer protective casing. If the protective casing becomes cracked or is sheared off at the ground surface, the well is open to direct contamination from the ground surface and will have to be repaired immediately or abandoned. Another limitation to the open rock well is that the entire bedrock interval serves as the monitoring zone. In this situation, it is very difficult or even impossible to monitor a specific zone, because the contaminants being monitored could be diluted to the extent of being non-detectable. The installation of open bedrock wells is generally not acceptable in the Superfund and RCRA programs, because of the uncontrolled monitoring intervals. However, some site conditions might exist, especially in cavernous limestone areas (karst topography) or in areas of highly fractured bedrock, where the installation of the filter pack and its structural integrity are questionable. Under these conditions the design of an open bedrock well may be warranted.

2. The second method of installing a monitoring well into bedrock is to install the outer surface casing and drill the borehole (by an approved method) into bedrock, and then install an inner casing and well screen with the filter pack, bentonite seal, and annular grout. The well is completed with a surface protective casing and concrete pad. This well installation method gives the flexibility of isolating the monitoring zone(s) and minimizing inter-aquifer flow. In addition, it gives structural integrity to the well, especially in unstable areas (steeply dipping shales, etc.) where the bedrock has a tendency to shift or move when disturbed. Omitting the filter pack around the well screen is a general practice in some open rock borehole installations, especially in drinking water and irrigation wells. However, without the filter pack to protect the screened interval, sediment particles from the well installation and/or from the monitoring zone could clog the well screen and/or fill the screened portion of the well rendering it inoperable. Also, the filter pack serves as a barrier between the bentonite seal and the screened interval. Rubber inflatable packers have been used to place the bentonite seal when the filter pack is omitted, but the packers have to remain in the well permanently and, over a period of time, will decompose and possibly contribute contaminants to the monitoring zone.

2.5 Well Construction Materials

2.5.1 Introduction

Well construction materials are chosen based on the goals and objectives of the proposed monitoring program and the geologic conditions at the site(s). In this section, the different types of available materials will be discussed.

2.5.2 Well Screen and Casing Materials

When selecting the materials for well construction, the prime concern should be to select materials that will not contribute foreign constituents, or remove contaminants of concern from the ground water. If the monitoring program is designed to analyze for organic compounds, stainless steel materials are the preferred choice. If the monitoring program calls for the analyses of only inorganic compounds or the contaminants or formation are highly corrosive, then rigid PVC materials meeting National Sanitary Foundation (NSF) Standard 14 type WC (Well Casing) are acceptable. PVC materials may be acceptable for monitoring identified organic compounds in a soluble aqueous phase where incompatibilities are known to not exist. EPA document EPA/540/S-95/503, *Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation* (http://www.epa.gov/ada/-download/issue/napl.pdf) should be used for guidance in this area and in the use of PVC with non-aqueous phase liquids (NAPLs). Another concern is to select materials that will be rugged enough to endure the entire monitoring period. Site conditions will generally dictate the type of materials that can be used. A preliminary field investigation should be conducted to determine the geologic conditions, so that the most suitable materials can be selected. The best grade or highest quality material for that particular application should be selected. Each manufacturer can supply the qualitative data for each grade of material that is being considered. All materials selected for monitoring well installation should be evaluated and approved by a senior field geologist prior to field activities.

Well screen and casing materials generally used in monitoring well construction on RCRA and Superfund sites are listed in order of preference:

1. Stainless Steel (304 or 316)
2. Rigid PVC meeting NSF Standard 14 (type WC)
3. Other (where applicable)

There are other materials used for well screens and casings such as black iron, carbon steel, galvanized steel, and fiberglass, but these materials are not recommended for use in long term monitoring programs at hazardous waste sites, because of their low resistance to chemical attack and potential constituent contribution to the ground water. In cases where a driven casing is used, or a high strength outer casing is needed, carbon steel may be acceptable in non-corrosive aquifers. This outer casing should have threaded connections. Welding casing is not an acceptable practice unless all relevant safety issues have been adequately addressed.

The minimum nominal casing size for most permanent monitoring wells will be 2". Where a complete program of installation, monitoring, and abandonment is being designed, smaller wells may be installed if suitable purging and sampling equipment for the smaller diameter wells can be specified and obtained. The length of well screens in permanent monitoring wells should be long enough to effectively monitor the interval or zone of interest. However, well screens designed for long term monitoring purposes should normally not be less than 5 feet in length. Well screens less than 5 feet long are generally only used in temporary monitoring wells where ground water samples are collected for screening purposes.

2.5.3 Filter Pack Materials

The filter pack materials should consist of clean, rounded to well-rounded, hard, insoluble particles of siliceous composition. The required grain-size distribution or particle sizes of the filter pack materials should be selected based upon a sieve analysis conducted on the soil samples collected from the aquifer materials and/or the formation(s) to be monitored. Filter pack materials should not be accepted unless proper documentation can be furnished as to the composition, grain-size distribution, cleaning procedure, and chemical analysis. If a data search reveals that there is enough existing data to adequately design the well screen and filter pack, then it may not be necessary to conduct a sieve analysis on the formation materials to be monitored. However, all data and design proposals will be evaluated and approved by a senior staff geologist before field activities begin.

2.5.4 Filter Pack and Well Screen Design

The majority of monitoring wells are installed in shallow ground water aquifers that consist of silts, clays, and sands in various combinations. These shallow aquifers are not generally characteristic of aquifers used for drinking water. Therefore, modifications to the procedures used for the design of water well filter packs may be required. In cases where insufficient experience exists with local or similar materials, the filter pack and well screen design should be based on the results of a sieve analysis conducted on soil samples collected from the aquifer or the formation(s) that will be monitored.

In formations consisting primarily of fines (silts and clays), the procedures for water well screen design may result in requirements for filter packs and screen slot sizes that are not available. In those cases the selection of 0.010" screen slots with a 20-40 sand filter pack, or 0.005" screen slots with 100 sand filter pack for very fine formations, will be acceptable practice. Table 6.6.1 provides size specifications for the selection of sand packs for fine formation materials. ASTM standard D5092, *Design and Installation of Ground Water Monitoring Wells in*

Aquifers, may be consulted for further guidance on specifications for sand appropriate for these applications.

Table 6.6.1
Sand Pack Specifications

Screen Opening (in)	Sand Pack Mesh Name	1% Passing Size (d-1) (in)	10% Passing Size (d-10) (in)	30% Passing Size (d-30) (in)	Derived 60% Passing Size (d-60) (in)	Range for Uniformity Coefficient
0.005-0.006	100	.0035 - .0047	.0055 - .0067	.0067 - .0083	.0085 - .0134	1.3 - 2.0
0.010"	20-40	.0098 - .0138	.0157 - .0197	.0197 -.0236	.020 - .0315	1.1 - 1.6

The following procedure should be used in coarser grained formations:

The data from the sieve analysis are plotted on a grain-size distribution graph, and a grain-size distribution curve is generated. From this grain-size distribution curve, the uniformity coefficient (Cu) of the aquifer material is determined. The Cu is the ratio of the 60 percent finer material (d60) to the 10 percent finer material (d10)

$$Cu = (d60/d10)$$

The Cu ratio is a way of grading or rating the uniformity of grain size. For example, a Cu of unity means that the individual grain sizes of the material are nearly all the same, while a Cu with a large number indicates a large range of particle sizes. As a general rule, a Cu of 2.5 or less should be used in designing the filter pack and well screen.

Before designing the filter pack and well screen, the following factors should be considered:

1. Select the well screen slot openings that will retain 90 percent of the filter pack material.

2. The filter pack material should be of the size that minimizes head losses through the pack and also prevents excessive sediment (sand, silt, clay) movement into the well.

3. A filter material of varying grain sizes is not acceptable because the smaller particles fill the spaces between the larger particles thereby reducing the void spaces and increasing resistance to flow. Therefore, filter material of the same grain size and well rounded is preferred.

4. The filter pack design is based on the gradation of the finest aquifer materials being analyzed.

Steps to design a filter pack in aquifers:

1. Construct a grain-size distribution curve, on a grain-size distribution graph, from the sieve analysis of the aquifer materials. The filter pack design (as stated above) is based on the gradation of the finest aquifer materials.

2. Multiply the d30 size from the grain-size distribution graph by a factor of four to nine (Pack-Aquifer ratio). A factor of four is used if the formation is fine-grained and uniform (Cu is less than 3), six if it is coarse-grained and non-uniform, and up to nine if it is highly non-uniform and contains silt. Head losses through filter packs increase as the Pack-Aquifer (P-A) ratios decrease. In order to design a fairly stable filter pack with a minimum head loss, the d30 size should be multiplied by a factor of four.

3. Plot the point from step 2 on the d30 abscissa of a grain-size distribution graph and draw a smooth curve with a uniformity coefficient of approximately 2.5.

4. A curve for the permissible limits of the filter pack is drawn plus or minus 8 per cent of the desired curve with the Cu of 2.5.

5. Select the slot openings for the well screen that will retain 90 per cent or more of the filter pack material.

The specific steps and procedures for sieve analysis and filter pack design can be found in soil mechanics, ground water, and water well design books. The staff geologists and/or engineers should be responsible for the correct design of the monitoring wells and should be able to perform the design procedures.

2.6 Safety Procedures for Drilling Activities

A site health and safety plan should be developed and approved by the Branch Safety Officer or designee prior to any drilling activities, and should be followed during all drilling activities. The driller or designated safety person should be responsible for the safety of the drilling team performing the drilling activities. All personnel conducting drilling activities should be qualified in proper drilling and safety procedures. Before any drilling activity is initiated, utilities should be marked or cleared by the appropriate state or municipal utility protection organization. In developed areas, additional measures should be taken to locate utilities not covered by the utility protection program. Before operating the drill rig, a pilot hole should be dug (with hand equipment) to a depth of three feet to check for undetected utilities or buried objects. Proceed with caution until a safe depth is reached where utilities normally would not be buried. The following safety requirements should be adhered to while performing drilling activities:

1. All drilling personnel should wear safety hats, safety glasses, and steel toed boots. Ear plugs are required and will be provided by the safety officer or driller.

2. Work gloves (cotton, leather, etc.) should be worn when working around or while handling drilling equipment.

3. All personnel directly involved with the drilling rig(s) should know where the kill switch(s) is located in case of emergencies.

4. All personnel should stay clear of the drill rods or augers while in motion, and should not grab or attempt to attach a tool to the drill rods or augers until they have completely stopped rotating. Rod wipers, rather than gloves or bare hands should be used to remove mud, or other material, from drill stem as it is withdrawn from the borehole.

5. Do not hold drill rods or any part of the safety hammer assembly while taking standard penetration tests or while the hammer is being operated.

6. Do not lean against the drill rig or place hands on or near moving parts at the rear of the rig while it is operating.

7. Keep the drilling area clear of any excess debris, tools, or drilling equipment.

8. The driller will direct all drilling activities. No work on the rig or work on the drill site will be conducted outside of the driller’s direction. Overall drill site activities will be in consultation with the site geologist or engineer, if present.

9. Each drill rig will have a first-aid kit and a fire extinguisher located on the rig in a location quickly accessible for emergencies. All drilling personnel will be familiarized with their location.

10. Work clothes will be firm fitting, but comfortable and free of straps, loose ends, strings etc., that might catch on some moving part of the drill rig.

11. Rings, watches, or other jewelry will not be worn while working around the drill rig.

12. The drill rig should not be operated within a minimum distance of 20 feet of overhead electrical power lines and/or buried utilities that might cause a safety hazard. In addition, the drill rig should not be operated while there is lightening in the area of the drilling site. If an electrical storm moves in during drilling activities, the area will be vacated until it is safe to return.

2.7 Well Development

A newly completed monitoring well should not be developed for at least 24 hours after the surface pad and outer protective casing are installed. This will allow sufficient time for the well materials to cure before development procedures are initiated. The main purpose of developing new monitoring wells is to remove the residual materials remaining in the wells after installation has been completed, and to try to re-establish the natural hydraulic flow conditions of the formations which may have been disturbed by well construction, around the immediate vicinity of each well. A new monitoring well should be developed until the column of water in the well is free of visible sediment, and the pH, temperature, turbidity, and specific conductivity have stabilized. In most cases the above requirements can be satisfied; however, in some cases the pH, temperature, and specific conductivity may stabilize but the water remains turbid. In this case the well may still contain well construction materials, such as drilling mud in the form of a mud cake and/or formation soils that have not been washed out of the borehole. Excessive or thick drilling mud can not be flushed out of a borehole with one or two well volumes of flushing. Continuous flushing over a period of several days may be necessary to complete the well development. If the well is pumped to dryness or near dryness, the water table should be allowed to sufficiently recover (to the static water level) before the next development period is initiated. Caution should be taken when using high rate pumps and/or large volume air compressors during well development because excessive high rate pumping and high air pressures can damage or destroy the well screen and filter pack. The onsite geologist should make the decision as to the development completion of each well. All field decisions should be documented in the field log book.

The following development procedures, listed in approximate increasing order of the energy applied to the formation materials, are generally used to develop wells:

1. Bailing
2. Pumping/overpumping
3. Surging
4. Backwashing ("rawhiding")
5. Jetting
6. Compressed air (with appropriate filtering): airlift pumping and air surging

These development procedures can be used, individually or in combination, in order to achieve the most effective well development. In most cases, over-pumping and surging will adequately develop the well without imparting undue forces on the formation or well materials. Except when compressed air is being used for well development, sampling can be initiated as soon as the ground water has re-equilibrated, is free of visible sediment, and the water quality parameters have stabilized. Since site conditions vary, even between wells, a general rule-of-thumb is to wait 24 hours after development to sample a new monitoring well. Wells developed with stressful measures may require as long as a 7-day interval before sampling. In particular, air surge developed wells require 48 hours or longer after development so that the formation can dispel the compressed air and restabilize to pre-well construction conditions. Because of the danger of introducing contaminants with the airstream, the possibility of entraining air in the aquifer, and the violent forces imparted to the formation, air surging is the least desired method of development and should only be used where there is a specific need for the procedure. Air-lift pumping is permissible where an eductor pipe is used and several well volumes of water are removed from the well by other by pumping means after air-lift pumping. The selected development method(s) should be approved by a senior field geologist before any well installation activities are initiated.

2.8 Well Decommisioning (Abandonment)

When a decision is made to decommission (abandon) a monitoring well, the borehole should be sealed in such a manner that the well can not act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers. To properly decommission a well, the preferred method is to completely remove the well casing and screen from the borehole, clean out the borehole, and backfill with a cement or bentonite grout, neat cement, or concrete. In order to comply with state well decommissioning requirements, the appropriate state agency should be notified (if applicable) of monitoring well decommissioning. However, some state requirements are not explicit, so a technically sound well abandonment method should be designed based on the site geology, well casing materials, and general condition of the well(s).

2.8.1 Decommissioning Procedures

As previously stated the preferred method should be to completely remove the well casing and screen from the borehole. This may be accomplished by augering with a hollow-stem auger over the well casing down to the bottom of the borehole, thereby removing the grout and filter pack materials from the hole. The well casing should then be removed from the hole with the drill rig. The clean borehole can then be backfilled with the appropriate grout material. The backfill material should be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method). This abandonment method can be accomplished on small diameter (1-inch to 4-inch) wells without too much difficulty. With wells having 6-inch or larger diameters, the use of hollow-stem augers for casing removal is very difficult or almost impossible. Instead of trying to ream the borehole with a hollow-stem auger, it is more practical to force a drill stem with a tapered wedge assembly or a solid-stem auger into the well casing and extract it out of the borehole. Wells with little or no grouted annular space and/or sound well casings can be removed in this manner. However, old wells with badly corroded casings and/or thickly grouted annular space have a tendency to twist and/or break-off in the borehole. When this occurs, the well will have to be grouted with the remaining casing left in the borehole. The preferred method in this case should be to pressure grout the borehole by placing the tremie tube to the bottom of the well casing, which will be the well screen or the bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter material and up the inside of the well casing sealing holes and breaks that are present.

A PVC well casing may be more difficult to remove from the borehole than a metal casing, because of its brittleness. If the PVC well casing breaks during removal, the borehole should be cleaned out by using a drag bit or roller cone bit with the wet rotary method to grind the casing into small cuttings that will be flushed out of the borehole by water or drilling mud. Another method is to use a solid-stem auger with a carbide tooth pilot bit to grind the PVC casing into small cuttings that will be brought to the surface on the rotating flights. After the casing materials have been removed from the borehole, the borehole should be cleaned out and pressure grouted with the approved grouting materials.

Where state regulations and conditions permit, it may be permissible to grout the casing in place. This decision should be based on confidence in the original well construction practice, protection of drinking water aquifers, and anticipated future property uses. The pad should be demolished and the area around the casing excavated. The casing should be sawn off at a depth of three feet below ground surface. The screen and riser should be tremie grouted with a 30% solids bentonite grout in the saturated zone. The remaining riser may be grouted with a cement grout for long term resistance to dessication.

3 Temporary Monitoring Well Installation

3.1 Introduction

Five types of temporary monitoring well installation techniques have been demonstrated as acceptable. The type selected for a particular site is dependent upon site conditions. The project leader and site geologist should be prepared to test temporary well installations on site and select the best solution. Temporary wells are cost effective, may be installed quickly, and provide a synoptic picture of ground water quality.

Temporary monitoring well locations are not permanently marked, nor are their elevations normally determined. Sand pack materials may or may not be used, but typically there is no bentonite seal, grout, surface completion, or extensive development (as it normally applies to permanent monitoring wells). Temporary wells are generally installed, purged, sampled, removed, and backfilled in a matter of hours.

Due to the nature of construction, turbidity levels may initially be high. However, these levels may be reduced by low flow purging and sampling techniques as described in Section 7.2.4.

Temporary wells may be left overnight, for sampling the following day, but the well must be secured, both against tampering and against the fall hazard of the open annulus. If the well is not sampled immediately after construction, the well should be purged prior to sampling as specified in SESD Operating Procedure for Groundwater Sampling, SESDPROC-301.

3.2 Data Limitation

Temporary wells described in this section are best used for delineation of contaminant plumes at a point in time, and for some site screening purposes. They are not intended to replace permanent monitoring wells. Temporary wells can be used in conjunction with a mobile laboratory, where quick analytical results can be used to delineate contaminant plumes.

3.3 Temporary Well Materials

Materials used in construction of temporary monitoring wells are the same standard materials used in the construction of permanent monitoring wells. Sand used for the filter pack (if any) should be as specified in Section 2.5.3, Filter Pack Materials. The well screen and casing should be stainless steel for ruggedness and suitability for steam cleaning and solvent rinsing. Other materials may be acceptable, on a case by case basis. Some commercially available temporary well materials, pre-packed riser, screen and filter pack assemblies are available commercially; however, these pre-assembled materials cannot be cleaned. Appropriate QA/QC must be performed to assure there will be no introduction of contamination.

3.4 Temporary Monitoring Well Borehole Construction

Borehole construction for temporary wells is as specified in Section 2.3, using a drill rig. Alternatively, boreholes may be constructed using hand augers or portable powered augers (generally limited to depths of ten feet or less). If a drill rig is used to advance the borehole, the augers must be pulled back the length of the well screen (or removed completely) prior to sampling. When hand augers are used, the borehole is advanced to the desired depth (or to the point where borehole collapse occurs). In situations where borehole collapse occurs, the auger bucket is typically left in the hole at the point of collapse while the temporary well is assembled. When the well is completely assembled, a final auger bucket of material is quickly removed and the well is immediately inserted into the borehole, pushing, as needed, to achieve maximum penetration into the saturated materials.

3.5 Temporary Monitoring Well Types

Five types of monitoring wells which have been shown to be acceptable are presented in the order of increasing difficulty to install and increasing cost:

3.5.1 No Filter Pack

This is the most common temporary well and is very effective in many situations. After the borehole is completed, the casing and screen are simply inserted. This is the least expensive and fastest well to install. This type of well is extremely sensitive to turbidity fluctuations because there is no filter pack. Care should be taken to not disturb the casing during purging and sampling.

3.5.2 Inner Filter Pack

This type differs from the "No Filter Pack" well in that a filter pack is placed inside the screen to a level approximately 6 inches above the well screen. This ensures that all water within the casing has passed through the filter pack. For this type well to function properly, the static water level must be at least 6-12 inches above the filter pack. The screen slots may plug in some clayey environments with this construction method and others that use sand only inside the well screen.

3.5.3 Traditional Filter Pack

For this type of well, the screen and casing are inserted into the borehole, and the sand is poured into the annular space surrounding the screen and casing. Occasionally, it may be difficult to effectively place a filter pack around shallow open boreholes, due to collapse. This method requires more sand than the "inner filter pack" well, increasing material costs. As the filter pack is placed, it mixes with the muddy water in the borehole, which may increase the amount of time needed to purge the well to an acceptable level of turbidity.

3.5.4 Double Filter Pack

The borehole is advanced to the desired depth. As with the "inner filter pack" the well screen is filled with filter pack material and the well screen and casing inserted until the top of the filter pack is at least 6 inches below the water table. Filter pack material is poured into the annular space around the well screen. This type temporary well construction can be effective in aquifers where fine silts or clays predominate. This construction technique takes longer to implement and uses more filter pack material than others previously discussed.

3.5.5 Well-in-a-Well

The borehole is advanced to the desired depth. At this point, a 1-inch well screen and sufficient riser is inserted into a 2-inch well screen with sufficient riser, and centered. Filter pack material is then placed into the annular space surrounding the 1-inch well screen, to approximately 6 inches above the screen. The well is then inserted into the borehole.

This system requires twice as much well screen and riser, with attendant increases in assembly and installation time. The increased amount of well construction materials results in a corresponding increase in decontamination time and costs. The use of pre-packed well screens in this application will require rinse blanks of each batch of screens. Pre-pack Screen assemblies can not be decontaminated for reuse.

3.6 Decommissioning

Temporary well boreholes must be decommissioned after sampling and removal of the screen and riser. Backfilling the holes with cuttings may be acceptable practice for shallow holes in uniform materials with expected low contamination levels. Use of cuttings would not be an acceptable practice if waste materials were encountered or a confining layer was breached. Likewise, where the borehole is adjacent to, or downgradient of contaminated areas, the loose backfilled material could create a highly permeable conduit for contaminant migration. If the borehole will not be backfilled with the soil cuttings for this or other reasons, then SESD Operating Procedure for Management of Investigation Derived Waste, SESDPROC-202, should be referenced regarding disposal of the cuttings as IDW.

4 Temporary Monitoring Well Installation Using the Geoprobe® Screen Point 15/16 Groundwater Sampler

4.1 Introduction

The Geoprobe® Screen Point 15/16 Groundwater Sampler is a discrete interval ground water sampling device that can be pushed to pre-selected sampling depths in saturated, unconsolidated materials. Once the target depth has been reached, the screen is opened and groundwater can be sampled as a temporary monitoring well, which yields a representative, uncompromised sample from that depth. Using knock-out plugs, this method also allows for grouting of the push hole during sample tool retrieval.

The Screen Point® 15 sampler consist of four parts (drive point, screen, sampler sheath and drive head), with an assembled length of 52 inches (1321 mm) and a maximum OD of 1.5 inches (38 mm). When opened, it has an exposed screen length of 41 inches (1041 mm). It is typically pushed using 1.25-inch probe rod. The Screen Point® 16 consists of the same parts and works in the same fashion, the only differences being larger diameter and its use with 1.5” rods.

4.1.1 Assembly of Screen Point® 15/16 Groundwater Sampler

1. Install O-ring on expendable point and firmly seat in the angled end of the sampler sheath.

2. Place a grout plug in the lower end of the screen section. Grout plug material should be chosen with consideration for site specific Data Quality Objectives (DQOs).

3. When using stainless steel screen, place another O-ring* in the groove on the upper end of the screen and slide it into the sampler sheath.

4. Place an O-ring* on the bottom of the drive head and thread into the top of the sampler sheath.

5. The Screen Point® 15/16 Groundwater Sampler is now assembled and ready to push for sample collection.

* It should be noted that O-ring use in steps 3 and 4 are optional.

4.1.2 Installation of Screen Point® 15/16 Groundwater Sampler

1. Attach drive cap to top of sampler and slowly drive it into the ground. Raise the hammer assembly, remove the drive cap and place an O-ring* in the top groove of the drive head. Add a probe rod and continue to push the rod string.

2. Continue to add probe rods until the desired sampling depth is reached.

3. When the desired sampling depth is reached, re-position the probe derrick and position either the casing puller assembly or the rod grip puller over the top of the top probe rod.

4. Thread a screen push adapter on an extension rod and attach sufficient additional extension rods to reach the top of the Screen Point® 15/16 sampler. Add an extension handle to the top of the string of extension rods and run this into the probe rod, resting the screen push adapter on top of the sampler.

5. To expose the screened portion of the sampler, exert downward pressure on the sampler, using the extension rod and push adapter, while pulling the probe rod upward. To expose the entire open portion of the screen, pull the probe rod upward approximately 41 inches.

6. At this point, the Screen Point® 15/16 Groundwater Sampler has been installed as a temporary well and may be sampled using appropriate ground water sampling methodology. If waters levels are less than approximately 25 feet, EIB personnel typically use a peristaltic pump, utilizing low-flow methods, to collect ground water samples from these installations. If water levels are greater than 25 feet, a manual bladder pump, a micro bailer, or other method may have to be utilized to collect the sample (SESD Operating Procedure for Groundwater Sampling, SESDPROC-301-R0) provides detailed descriptions of these techniques and methods).

4.1.3 Special Considerations for Screen Point® 15/16 Installations

Decommissioning (Abandonment)

In many applications, it may be appropriate to grout the abandoned probe hole where a Screen Point® 15/16 sampler was installed. This probe hole decommissioning can be accomplished through two methods which are determined by location and contamination risk. In certain non-critical areas, boreholes may be decommissioned by filling the saturated zone with bentonite pellets and grouting the vadose zone with neat cement poured from the surface or Bentonite pellets properly hydrated in place. Probe holes in areas where poor borehole sealing could present a risk of contaminant migration should be decommissioned by pressure grouting through the probe rod during sampler retrieval. To accomplish this, the grout plug is knocked out of the bottom of the screen using a grout plug push adapter and a grout nozzle is fed through the probe rod, extending just below the bottom of the screen. As the probe rod and sampler are pulled, grout is injected in the open hole below the screen at a rate that just fills the open hole created by the pull. Alternatively, the screen can generally be pulled and the hole re-probed with a tool string to be used for through-the-rod grouting.

Screen Material Selection

Screen selection is also a consideration in sampling with the Screen Point® 15/16 sampler. The screens are available in two materials, stainless steel and PVC. Because of stainless steel's durability, ability to be cleaned and re-used, and overall inertness and compatibility with most contaminants, it is the material typically used during EIB investigations.

Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

OPERATING PROCEDURE

Title: **Field Equipment Cleaning and Decontamination at the FEC**

Effective Date: December 20, 2011	**Number:** SESDPROC-206-R2

Authors

Name: Donald Hunter
Title: Environmental Scientist, Regional Expert
Signature: Donald Hunter Date: 12/16/11

Name: Doug Jager
Title: Environmental Scientist
Signature: K. D. Jager Date: 12/16/11

Approvals

Name: Archie Lee
Title: Chief, Enforcement and Investigations Branch
Signature: Archie Lee Date: 12/19/11

Name: Bill Cosgrove
Title: Chief, Ecological Assessment Branch
Signature: Date: 12/19/11

Name: Bobby Lewis
Title: Field Quality Manager, Science and Ecosystem Support Division
Signature: Date: 12/19/11

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Document Control Coordinator.

History	Effective Date
SESDPROC-206-R2, *Field Equipment Cleaning and Decontamination at the FEC*, replaces SESDPROC-206-R1. **General:** Corrected any typographical, grammatical and/or editorial errors. **Title Page:** Changed the Enforcement and Investigations Branch Chief from Antonio Quinones to Archie Lee. Changed the Field Quality Manager form Laura Ackerman to Bobby Lewis. **Revision History:** Changed Field Quality Manager to Document Control Coordinator. **Section 1.2: A**t the end of the 1st paragraph, added the following statement: Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use. On the 2nd paragraph, removed the last sentence and replaced with new language. The new language clarifies that "Site-specific alterations to these procedures will be approved by the project leader and the SESD Field Quality Manager, and they will be transmitted in writing to FEC personnel." It also clarifies how transmittals/deviations should be documented. **Section 1.3:** Omitted reference to the H: drive. Changed the Field Quality Manager to the Document Control Coordinator. **Section 1.4:** In definitions (first bullet), replaced "soap" with "detergent." Changed all references in the document from "soap" to "detergent." Alphabetized. **Section 1.5:** Updated references. **Section 2.1:** Removed the last sentence from the paragraph related to deviations from the decon procedures (this is now explained in the new language in Section 1. 2). **Section 4:** New Section 4, *Equipment Used for Sample Collection for Perfluorinated Compound Analyses*. All following sections re-numbered. **Section 5.4:** Rewrote #3 to reflect that containers will be rinsed with 10% nitric acid, and not with "at least" 10% nitric acid.	December 20, 2011

Section 5.6: Removed step #3 from the list ("Rinse equipment thoroughly with tap water.") **Section 7.2**: Redi-Flo2® cleaning procedures revised. **Section 7.3:** On the last sentence, removed "drill rig operator." **Section 7.6:** Rewrote #3 to reflect that containers will be rinsed with 10% nitric acid, and not with "at least" 10% nitric acid. **Section 7.10**: Removed the 2nd paragraph related to the mandatory interior and exterior cleaning of vehicles at the conclusion of certain types of field investigations. Replaced with language stating that "Vehicles that become contaminated during the course of the field investigation will be washed (and cleaned on the inside, as appropriate) at the conclusion of each filed trip." Reorganized the remaining paragraphs for clarity.	
SESDPROC-206-R1, *Field Equipment Cleaning and Decontamination at the FEC,* replaces SESDPROC-206-R0. **General** Corrected any typographical, grammatical and/or editorial errors. **Title Page** Changed title for Antonio Quinones from Environmental Investigations Branch to Enforcement and Investigations Branch. Changed Bill Cosgrove's title from Acting Chief to Chief. **Revision History** Changed "SESDPROC-205-R0, Field Equipment Cleaning and Decontamination, Original Issue" to "SESDPROC-206-R0, Field Equipment Cleaning and Decontamination at the FEC, Original Issue." **Section 1.2** Added "the SESD Operating Procedure for Field Equipment Cleaning and Decontamination" before SESDPROC-205. **Section 1.3** Updated information to reflect that the procedure is located on the H: drive of the LAN. Clarified Field Quality Manager (FQM) responsibilities. **Section 1.5** Alphabetized and revised the referencing style for consistency. **Section 1.6.1** Corrected the title of the Safety, Health, and Environmental Management Program Procedures and Policy Manual.	November 1, 2007
SESDPROC-206-R0, *Field Equipment Cleaning and Decontamination at the FEC,* Original Issue	February 05, 2007

TABLE OF CONTENTS

1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when cleaning and decontaminating sampling equipment at the SESD Field Equipment Center (FEC). For the purpose of this procedure, decontamination refers to the removal of contaminants from sampling, drilling and other field equipment to concentrations that do not impact study objectives.

1.2 Scope/Application

Decontamination procedures outlined in this document are intended for use at the FEC for decontaminating sampling and other field equipment. These procedures are not intended to be used in the field. Procedures for use in the field are in found in the SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205. Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use.

Sampling and other field equipment decontaminated in accordance with these procedures will meet the minimum requirements for Data Quality Objective (DQO) Definitive Data Collection. Site-specific alterations to these procedures will be approved by the project leader and the SESD Field Quality Manager, and they will be transmitted in writing to FEC personnel. This transmittal will be documented by the Project Leader in the associated SESD project file for the field investigation. The deviations will also be documented in the Quality Assurance Project Plan (QAPP) prepared for the investigation.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and have been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the SESD Local Area Network (LAN). The Document Control Coordinator (DCC) is responsible for ensuring the most recent version of the procedure is placed on the LAN and for maintaining records of review conducted prior to its issuance.

1.4 Definitions

- Deionized water: Tap water that has been treated by passing through a standard deionizing resin column. At a minimum, the finished water should contain no detectable heavy metals or other inorganic compounds (i.e., at or above analytical detection limits) as defined by a standard inductively coupled Argon Plasma Spectrophotometer (ICP) (or equivalent) scan. Deionized water obtained by other methods is acceptable, as long as it meets the above analytical criteria. Organic-free water may be substituted for deionized water.

- Detergent shall be a standard brand of phosphate-free laboratory detergent such as Luminox®.

- Nitric acid solution (10%) shall be made from reagent-grade nitric acid and deionized water. Nitric acid solutions used to clean equipment cannot be reused.

- Organic-free water: Tap water that has been treated with activated carbon and deionizing units. At a minimum, the finished water must meet the analytical criteria of deionized water and it should contain no detectable pesticides, herbicides, or extractable organic compounds, and no volatile organic compounds above minimum detectable levels as determined by the Region 4 laboratory for a given set of analyses. Organic-free water obtained by other methods is acceptable, as long as it meets the above analytical criteria.

- Solvents (e.g., pesticide-grade isopropanol or other solvents) may be used for a particular investigation if needed. Pesticide-grade acetone or methanol are acceptable. However, it should be noted that if pesticide-grade isopropanol or acetone is used, the detection of acetone in samples collected with solvent rinsed equipment is considered suspect. Pesticide-grade methanol is much more hazardous to use than either pesticide-grade acetone or isopropanol, therefore its use is discouraged. Solvents used to clean equipment cannot be reused.

- Tap water is water from any potable water supply. Deionized water or organic-free water may be substituted for tap water.

1.5 References

SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205, Most Recent Version

US EPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Region 4 SESD, Athens, GA, Most Recent Version

1.6 General Precautions

1.6.1 Safety

Proper safety precautions must be observed when field cleaning or decontaminating dirty sampling equipment. Refer to the SESD Safety, Health and Environmental Management Program (SHEMP) Procedures and Policy Manual and any pertinent site-specific Health and Safety Plans (HASP) for guidelines on safety precautions. These guidelines, however, should only be used to complement the judgment of an experienced professional. Some materials used to implement the decontamination procedures outlined in this procedure are harmful if used improperly. Caution should be exercised and all applicable safety procedures shall be followed. At a minimum, the following precautions shall be taken in the washroom during these operations:

- Safety glasses with splash shields or goggles, gloves and safety boots will be worn during all decontamination operations. A neoprene apron and neoprene gloves are also required during acid rinsing.

- All solvent rinsing operations will be conducted under a fume hood or in the open (never in a closed room).

- No eating, smoking, drinking, chewing, or any hand to mouth contact shall be permitted during decontamination operations.

1.6.2 Procedural Precaution

After decontamination, equipment should be handled only by personnel wearing clean latex gloves to prevent re-contamination.

After the decontaminated equipment is wrapped in aluminum foil and sealed in plastic, the date that the equipment was decontaminated should be written on the plastic. If the equipment was not decontaminated according to this operating procedure, this should also be noted on the plastic. Sampling equipment and or containers must be transported/stored separate from gasoline, oil, grease, solvents, pesticides or any other possible contaminant.

When equipment and containers used to collect samples containing oil, grease, or other hard to remove materials cannot be decontaminated using any of the procedures described in this document, they should be disposed of properly.

2 Introduction to Equipment Cleaning and Decontamination

2.1 General

Procedures included in this operating procedure are intended for use by FEC personnel for decontaminating sampling equipment. Sampling and field equipment decontaminated in accordance with these procedures must meet the minimum requirements for the Data Quality Objectives (DQOs) of the study or investigation.

2.2 Handling Practices and Containers for Decontamination Solutions

Improperly handled decontamination solutions may easily become contaminated. Containers should be constructed of the proper materials to ensure their integrity. Following are the materials to be used for storing the specified decontamination materials:

- Detergent should be kept in clean containers until use. It should be poured directly from the container.

- Solvents should be stored in the unopened original containers until used. Solvents may be applied using the low pressure nitrogen system fitted with a Teflon® nozzle, or by using Teflon® squeeze bottles.

- Tap water may be kept in tanks, squeeze bottles or applied directly from a hose.

- Deionized water should be stored in cleaned containers that can be closed when not being used. It may be applied from squeeze bottles.

- Organic-free water should be stored in cleaned glass, Teflon® or stainless steel containers prior to use. It may be applied using Teflon® squeeze bottles, or directly from the system.

- Nitric acid should be kept in the glass container it is received in, and placed in squeeze bottles prior to application.

2.3 Disposal of Spent Decontamination Solutions

Procedures for safe handling and disposition of spent decontamination solutions, including washwater, rinse water, spent acid solutions, and spent solvents are as follows:

> Washwater/Rinsewater: Waters from equipment decontamination at the FEC may be disposed in the sanitary drain in the washroom. When large equipment (vehicles, augers, etc.) is washed or rinsed outside, it may go onto the ground without recovery.
>
> Nitric Acid: Nitric acid decontamination solutions are to be diluted to a pH greater than 2.0, and flushed down the sanitary drain in the washroom.
>
> Solvent: All solvents used should be captured, properly labeled, and stored on the premises of the FEC until arrangements for proper disposal are made. Used solvents can be classified as either "solvent for recovery" or "solvent for disposal." Solvent for recovery is that which was used at the FEC for decontamination of equipment. Solvent used for decontaminating badly contaminated equipment (e.g., tar removal, etc.) should be designated for disposal. The two groups should be labeled "For Recovery" or "For Disposal" and stored separately at the FEC.

2.4 Initial Processing of Returned Equipment

Field or sampling equipment that needs to be repaired will be identified with a "repair" tag. Any problems encountered with the equipment and specific required repairs shall be noted on this tag, as well as the date and the initials of the investigator. Field equipment or reusable sample containers needing decontamination or repairs will not be stored with clean equipment, sample tubing, or sample containers.

All unused plastic wrapped equipment, containers, and tubing will be examined when the equipment is returned from the field. Any items for which the plastic wrapping is not torn or soiled may be placed back into stock.

3 Sampling Equipment Used for Trace Organic and Inorganic Compounds

Sampling equipment used to collect samples undergoing trace organic and/or inorganic constituent analyses should be thoroughly decontaminated. The following procedures are to be used.

3.1 Standard FEC Decontamination Procedure

1. Wash equipment thoroughly with detergent and hot tap water using a brush or scrub pad to remove any particulate matter or surface film.
2. Rinse equipment thoroughly with hot tap water.
3. Rinse equipment thoroughly with organic-free water.
4. Allow to air dry for at least 24 hours.
5. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and label.

3.2 Procedures for Decontaminating Glass Pans at the FEC

1. Wash equipment thoroughly with detergent and hot tap water using a brush or scrub pad to remove any particulate matter or surface film.
2. Rinse equipment thoroughly with hot tap water.
3. Rinse equipment with 10 percent nitric acid solution. Fresh nitric acid solution should be prepared for each decontamination session.
4. Rinse equipment thoroughly with organic-free water.
5. Allow to air dry for at least 24 hours.
6. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and label.

4 Equipment Used for Sample Collection for Perfluorinated Compound Analyses

4.1 General

Decontamination of equipment used for collection of perfluorinated compound analyses is subject to all the general procedures found in Section 1 of this procedure. Special decontamination procedures, however, are required for perfluorinated compound sampling and decontamination to eliminate the possibility of interference from Teflon®, present as a component in materials used for storage or application of decontamination solutions for SESD's routine decontamination activities. The following procedures, reflecting an absence of Teflon® materials, are to be used.

4.2 Containers for Decontamination Solutions

Improperly handled cleaning solutions may easily become contaminated. Storage and application containers must be constructed of the proper materials to ensure their integrity. Following are acceptable materials used for containing the specified cleaning solutions:

- Detergent must be kept in clean plastic, metal, or glass containers until used. It should be poured directly from the container during use.
- Tap water may be kept in tanks, hand pressure sprayers, squeeze bottles, or applied directly from a hose.
- Deionized water must be stored in clean, glass or plastic containers that can be closed prior to use. It can be applied from plastic squeeze bottles.
- Solvents must be stored in clean, glass or high density polyethylene (HDPE) containers that can be closed prior to use. It can be applied from plastic squeeze/spray bottles provided that containers have been demonstrated to meet the DQO's of the study.

4.3 Decontamination Procedure for Equipment used for Sample Collection for Perfluorinated Compounds (PFCs)

For samples undergoing trace PFCs analyses, the following procedures are to be used for all sampling equipment or components of equipment that come in contact with the sample:

1. Clean with tap water and detergent using a brush, if necessary, to remove particulate matter and surface films. Equipment may be steam cleaned

(detergent and high pressure hot water) as an alternative to brushing. Sampling equipment that is steam cleaned should be placed on racks or saw horses at least two feet above the floor of the decontamination pad. PVC or plastic items should not be steam cleaned.

2. Rinse thoroughly with tap water.

3. Rinse thoroughly with deionized water.

4. Triple rinse with methanol.

5. Place on a clean surface to air-dry.

6. If the equipment is to be stored overnight, it should be covered and secured with clean, unused plastic sheeting.

5 Automatic Wastewater Sampling Equipment

5.1 Automatic Samplers

1. The exterior and accessible interior (excluding the waterproof timing mechanism) portions of the automatic samplers will be washed with detergent and tap water then rinsed with tap water.

2. Desiccant in the flow meters should be checked and replaced, if necessary, each time the equipment is decontaminated.

3. The face of the timing case mechanism will be cleaned with a clean damp cloth.

4. Tubing (sample intake and pump tubing) will be discarded after each use and new Silastic® pump tubing will be installed.

5.2 Distributor Arm

1. Clean with hot tap water, detergent, and a brush.

2. Rinse thoroughly with deionized water.

3. Replace in sampler.

5.3 All Automatic Sampler Headers

1. Disassemble header and using a bottle brush, wash with hot tap water and detergent.

2. Rinse thoroughly with deionized water.

3. Dry thoroughly, then reassemble header and wrap with aluminum foil.

4. Seal in plastic.

5.4 Reusable Composite Sample Containers

1. Wash containers thoroughly with hot tap water and detergent, using a bottle brush to remove particulate matter and surface film.

2. Rinse containers thoroughly with hot tap water.

3. Rinse containers with 10 percent nitric acid.

4. Rinse containers thoroughly with tap water.

5. Rinse containers thoroughly with deionized water.

6. Air dry.

7. Cap with aluminum foil or Teflon® film.

5.5 Glass Sequential Bottles for GC/MS Analyses

1. Rinse with 10 percent nitric acid.

2. Rinse thoroughly with tap water.

3. Wash using detergent, followed by tap and deionized water rinses.

4. Air dry.

5. Replace in covered, automatic sampler base; cover with aluminum foil for storage and mark the base as follows: "Cleaned for organic analyses."

5.6 Reusable Teflon® Composite Mixer Rods

1. Wash equipment thoroughly with detergent and hot tap water using a brush or scrub pad to remove any particulate matter or surface film.

2. Rinse equipment thoroughly with hot tap water.

3. Rinse equipment thoroughly with deionized water.

4. Air dry.

5. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped equipment in plastic and label.

6 Procedures for Tubing

6.1 Silastic® Pump Tubing

The Silastic® pump tubing in the automatic samplers and peristaltic pumps should be replaced after each study. After installation, the exposed ends should be capped with clean, unused aluminum foil.

6.2 Teflon® Sample Tubing

Use only new Teflon® tubing which has been pre-cleaned as follows for the collection of samples for trace organic compound or ICP analyses:

1. Teflon® tubing shall be precut to required lengths – e.g., 10, 15 or 25-foot lengths.

2. Flush interior of tubing with organic-free water.

3. Purge tubing with nitrogen until visibly dry.

4. Coil and wrap tubing in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped tubing in plastic and label.

7 Procedures for Miscellaneous Equipment

7.1 Well Sounders or Tapes

1. Wash with detergent and tap water.
2. Rinse with hot tap water.
3. Rinse with deionized water.
4. Allow to air dry overnight.

7.2 Grundfos Redi-Flo2® Pump

CAUTION – Do not wet the controller. Always disconnect power from the pump when handling the pump body.

Controller Box Decontamination:

1. Wipe the controller box with a damp cloth. Immediately remove any excess water.
2. Let the controller box dry completely.

Pump Decontamination:

1. Remove check valves and adapter fittings and clean separately.
2. Remove intake screen retaining screw and slide screen upward off pump.
3. Inspect electrical cable near pump intake for chafing, breaks, and exposed conductors. If repair is required, perform rudimentary cleaning of pump, reassemble, and tag for repair.
4. Unscrew turbine housing from top of pump and remove turbine assembly from housing. Disassemble turbine assembly and clean all parts as per Section 3.1.
5. Remove bottom plug from motor. Remove the three screws from the bottom of pump and remove the motor bottom and rotor from the motor casing. Tag pump for seal repair if excess grit or dirt in the motor case is present. Wash motor case, rotor, and bottom components as per Section 3.1. (Use only Liquinox® detergent to wash the interior of the motor case).

6. Invert motor housing and slide rotor into housing. Fill motor housing with DI water while jogging rotor up and down to release trapped air. Reassemble bottom of motor housing and tighten screws.

7. Fill motor housing with DI water while continuing to jog rotor up and down. If water leaks out of shaft seal while filling, red-tag motor for seal repair.

8. Reassemble turbine assembly per manufacturer's assembly diagrams and replace intake screen and screw.

9. Perform operational check of pump in plastic bucket of water. Do not touch pump or bucket while pump is connected to controller. Check for visual indication of flow and lack of excessive noise.

10. Connect pump outlet to a test gauge and test the 'deadhead' pressure. If pump fails to achieve 100 psi 'deadhead' pressure, tag pump for turbine repair.

11. Perform final wash of pump by immersing and running pump in containers of detergent, tap water, and organic-free water. Disconnect power and clean pump exterior in detergent and tap water. Final-rinse pump with water over pump and through pump turbine section.

12. Using a brush or scrub pad, clean the electrical cable with detergent and then rinse with tap water and organic free water.

13. Completely air dry.

14. Place the pump in clean plastic bag.

<u>To decontaminate the Redi-Flo2® ball check valve:</u>

1. Remove the ball check valve from the pump head. Check for wear and/or corrosion, and replace as needed. During decontamination, check for free-flow in forward direction and blocking of flow in reverse direction.

2. Using a brush, scrub all components with detergent and tap water.

3. Rinse with organic-free water.

4. Completely air dry.

5. Replace the ball check valve to the Redi-Flo2® pump head.

Note: The deionized or organic-free water within the Redi-Flo2® pump head should be replaced at the FEC after decontamination and prior to storage or re-use.

7.3 Drill Rig, Grout Mixer, and Associated Equipment

Upon return to the FEC, drilling equipment must be cleaned, as follows:

- A thorough interior and exterior cleaning of the drill rig is required at the end of each study. At a minimum, the exterior should be cleaned with a steam jenny.

- If the pump is used to circulate mud rotary drilling fluids or bentontite grout, the pump and tank on the drill rig should be flushed with tap water until clear, and then drained.

- The pump on the grout mixer should be flushed with tap water until clear, then drained.

- The grout mixer should be washed with detergent and tap water. The steam jenny may be used.

Drilling equipment (tools, rods, augers, etc.) shall be decontaminated as follows:

1. Inspect thoroughly. If severe rust, corrosion, paint, or hardened grout is present the equipment may require sandblasting prior to decontamination.

2. Wash with tap water and detergent, using a brush if necessary, to remove particulate matter and surface films. Steam cleaning (high pressure hot water with detergent) may be necessary to remove matter that is difficult to remove with the brush. Drilling equipment that has been steam cleaned should be placed on racks or saw horses at least two feet above ground. Hollow-stem augers, drill rods, and other equipment that is hollow or has passages that transmit water or drilling fluids should be decontaminated on the inside and outside.

3. Rinse thoroughly with tap water.

4. Let completely air dry. Remove and cover with clean, unused plastic and label.

At the direction of the project leader or Quality Assurance Officer, this equipment may be decontaminated as specified in Section 3.1 prior to use.

7.4 Field Analytical Equipment

Field instruments for in-situ water analysis should be wiped with a clean, damp cloth or sponge. The probes on these instruments (pH, conductivity, DO, etc.), should be rinsed with deionized water and air dried.

Any desiccant in these instruments should be checked and replaced, if necessary, each time the equipment is decontaminated.

7.5 Ice Chests and Shipping Containers

Ice chests and reusable containers shall be washed with detergent (interior and exterior) and rinsed with tap water and air dried before storage. If, in the opinion of the field investigators, the container is severely contaminated with concentrated waste or other toxic material, it shall be cleaned as thoroughly as possible, rendered unusable, and properly disposed.

7.6 Organic-Free Water and Deionized Water Storage Containers

NOTE: These containers will be used only for transporting organic-free or deionized water.

1. Wash containers thoroughly (interior and exterior) with hot tap water and detergent, using a bottle brush to remove particulate matter and surface film.
2. Rinse containers thoroughly with hot tap water.
3. Rinse containers with 10 percent nitric acid.
4. Rinse containers thoroughly with tap water.
5. Rinse containers thoroughly with deionized water.
6. Allow to air dry and secure with tightly fitting cap.

When transporting organic-free and deionized water to the field, use only containers cleaned as specified above. Label the container as "organic-free water" or “deionized water” and include the date it was prepared.

7.7 SCBA Facemasks

CAUTION: Facemasks should be inspected for wear or damage. If, after consultation with the Safety Officer, the facemask cannot be repaired, it should be discarded.

1. Wash facemask thoroughly inside and out with hot tap water and detergent. Use only soft brushes. Do not use scouring pads of any type.

2. Rinse facemask thoroughly inside and out with tap water.

3. Hang facemask up until completely dry.

4. Place facemask in plastic bag and return to SCBA case.

APRs are completely dismantled prior to cleaning. Then Steps 1 - 3 for SCBA facemasks are used. When completely dry, the APR is reassembled and placed in a plastic bag.

7.8 Garden Hose

1. Brush exterior with detergent and tap water

2. Rinse with tap water.

3. Flush interior with tap water until clear (minimum of one gallon) and drain.

4. Let completely air dry.

5. Coil and place in clean plastic bag.

7.9 Portable Tanks for Tap Water

1. Scrub interior and exterior with detergent and tap water.

2. Rinse with tap water.

3. Let completely air dry.

4. Close.

7.10 Vehicles

Field investigators are responsible for keeping field vehicles clean by removing trash and other debris. If warranted, based on an evaluation of the type and degree of contamination present, contaminated trash and equipment will be kept separate from ordinary trash and will be properly disposed on-site or upon return.

Vehicles that become contaminated during the course of the field investigation will be washed (and cleaned on the inside, as appropriate) at the conclusion of each filed trip. It will be the responsibility of the field investigators to see that this procedure is followed. This should minimize contamination of equipment or samples due to contamination of vehicles.

8 Preparation of Disposable Sample Containers

8.1 Introduction

No disposable sample container may be reused. All disposable sample containers will be stored in their original packing containers. When packages of uncapped sample containers are opened, they will be placed in new plastic garbage bags and sealed to prevent contamination during storage.

Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

OPERATING PROCEDURE

Title: **Groundwater Sampling**

Effective Date: October 28, 2011
Number: SESDPROC-301-R2

Authors

Name: Donald Hunter
Title: Environmental Scientist, Regional Expert
Signature: Donald Hunter Date: 10/27/11

Approvals

Name: Archie Lee
Title: Chief, Enforcement and Investigations Branch
Signature: Date: 10/27/2011

Name: Bobby Lewis
Title: Field Quality Manager, Science and Ecosystem Support Division
Signature: Date: 10/27/2011

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Document Control Coordinator.

History	Effective Date
SESDPROC-301-R2, *Groundwater Sampling*, replaces SESDPROC-301-R1. **General:** Corrected any typographical, grammatical and/or editorial errors. **Title Page:** Changed Enforcement and Investigations Branch Chief from Antonio Quinones to Archie Lee. Changed Field Quality Manager form Laura Ackerman to Bobby Lewis. **Revision History:** Changed Field Quality Manager to Document Control Coordinator. **Section 1.2:** Added the following statement: Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use. **Section 1.3:** Omitted reference to the H: drive. Changed the Field Quality Manager to the Document Control Coordinator. **Section 1.4:** Updated references. **Section 3:** Section 3 was reorganized and rewritten to include discussions of purging strategies and inclusion of detailed procedures for micro-purging and lack of purging for "no purge" sampling situations. **Section 3.2.1.1.2:** Temperature was removed as a required chemical parameter stabilization criterion.	October 28, 2011
SESDPROC-301-R1, *Groundwater Sampling*, replaces SESDPROC-301-R0. **General** Corrected any typographical, grammatical and/or editorial errors. **Title Page** Changed title for Antonio Quinones from Environmental Investigations Branch to Enforcement and Investigations Branch **Section 1.3** Updated information to reflect that the procedure is located on the H: drive of the LAN. Clarified Field Quality Manager (FQM) responsibilities.	November 1, 2007

Section 1.4 Updated referenced operating procedures due to changes in title names. Alphabetized and revised the referencing style for consistency. **Section 1.5.1** Corrected the title of the Safety, Health, and Environmental Management Program Procedures and Policy Manual. **Section 1.5.2, 4th bullet** Added references to the CFR and IATA's Dangerous Goods Regulations. **Section 2.5** Updated referenced operating procedures due to changes in title names.	
SESDPROC-301-R0, Groundwater Sampling, Original Issue	February 05, 2007

TABLE OF CONTENTS

1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when collecting groundwater samples for field screening or laboratory analysis.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when collecting and handling groundwater samples in the field. On the occasion that SESD field personnel determine that any of the procedures described are either inappropriate, inadequate or impractical and that another procedure must be used to obtain a groundwater sample, the variant procedure will be documented in the field logbook, along with a description of the circumstances requiring its use. Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the SESD Local Area Network (LAN). The Document Control Coordinator (DCC) is responsible for ensuring the most recent version of the procedure is placed on the LAN and for maintaining records of review conducted prior to its issuance.

1.4 References

Columbia Analytical Services, Lab Science News, Passive Diffusion Devices & Polyethylene Diffusion Bag (PDB) Samplers.

International Air Transport Authority (IATA). Dangerous Goods Regulations, Most Recent Version

Puls, Robert W., and Michael J. Barcelona. 1989. Filtration of Ground Water Samples for Metals Analysis. Hazardous Waste and Hazardous Materials 6(4), pp.385-393.
Puls, Robert W., Don A. Clark, and Bert Bledsoe. 1992. Metals in Ground Water: Sampling Artifacts and Reproducibility. Hazardous Waste and Hazardous Materials 9(2), pp. 149-162.
SESD Guidance Document, Design and Installation of Monitoring Wells, SESDGUID-001, Most Recent Version

SESD Operating Procedure for Control of Records, SESDPROC-002, Most Recent Version

SESD Operating Procedure for Sample and Evidence Management, SESDPROC-005, Most Recent Version

SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version

SESD Operating Procedure for Field Sampling Quality Control, SESDPROC-011, Most Recent Version

SESD Operating Procedure for Field pH Measurement, SESDPROC-100, Most Recent Version

SESD Operating Procedure for Field Specific Conductance Measurement, SESDPROC-101, Most Recent Version

SESD Operating Procedure for Field Temperature Measurement, SESDPROC-102, Most Recent Version

SESD Operating Procedure for Field Turbidity Measurement, SESDPROC-103, Most Recent Version

SESD Operating Procedure for Groundwater Level and Well Depth Measurement, SESDPROC-105, Most Recent Version

SESD Operating Procedure for Management of Investigation Derived Waste, SESDROC-202, Most Recent Version

SESD Operating Procedure for Pump Operation, SESDPROC-203, Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205, Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination at the FEC, SESDPROC-206, Most Recent Version

SESD Operating Procedure for Potable Water Supply Sampling, SESDPROC-305, Most Recent Version

The Interstate Technology & Regulatory Council, Technology Overview of Passive Sampler Technologies, Prepared by The Interstate Technology & Regulatory Council Diffusion Sampler Team, March 2006.

United States Environmental Protection Agency (US EPA). 1975. Handbook for Evaluating Water Bacteriological Laboratories. Office of Research and Development (ORD), Municipal Environmental Research Laboratory, Cincinnati, Ohio.

US EPA. 1977. Sampling for Organic Chemicals and Microorganisms in the Subsurface. EPA-600/2-77/176.

US EPA. 1978. Microbiological Methods for Monitoring the Environment, Water and Wastes. ORD, Municipal Environmental Research Laboratory, Cincinnati, Ohio.

US EPA. 1981. "Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples," Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981.

US EPA. 1995. Ground Water Sampling - A Workshop Summary. Proceedings from the Dallas, Texas November 30 – December 2, 1993 Workshop. ORD, Robert S. Kerr Environmental Research Laboratory. EPA/600/R-94/205, January 1995.

US EPA. Analytical Support Branch Laboratory Operations and Quality Assurance Manual. Region 4 SESD, Athens, GA, Most Recent Version

US EPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Region 4 SESD, Athens, GA, Most Recent Version

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when collecting groundwater samples. Refer to the SESD Safety, Health and Environmental Management Program (SHEMP) Procedures and Policy Manual and any pertinent site-specific Health and Safety Plans (HASP) for guidelines on safety precautions. These guidelines should be used to complement the judgment of an experienced professional. Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate.

1.5.2 Procedural Precautions

The following precautions should be considered when collecting groundwater samples.

- Special care must be taken not to contaminate samples. This includes storing samples in a secure location to preclude conditions which could alter the properties of the sample. Samples shall be custody sealed during long-term storage or shipment.
- Always sample from the anticipated cleanest, i.e., least contaminated location, to the most contaminated location. This minimizes the opportunity for cross-contamination to occur during sampling.
- Collected samples must remain in the custody of the sampler or sample custodian until the samples are relinquished to another party.

- If samples are transported by the sampler, they will remain under his/her custody or be secured until they are relinquished.
- Shipped samples shall conform to all U.S. Department of Transportation (DOT) rules of shipment found in Title 49 of the Code of Federal Regulations (49 CFR parts 171 to 179), and/or International Air Transportation Association (IATA) hazardous materials shipping requirements found in the current edition of IATA's Dangerous Goods Regulations.
- Documentation of field sampling is done in a bound logbook.
- Chain-of-custody documents shall be filled out and remain with the samples until custody is relinquished.
- All shipping documents, such as air bills, bills of lading, etc., shall be retained by the project leader and placed in the project files.

2 Special Sampling Considerations

2.1 Volatile Organic Compounds (VOC) Analysis

Groundwater samples for VOC analysis must be collected in 40 ml glass vials with Teflon® septa. The vial may be either preserved with concentrated hydrochloric acid or they may be unpreserved. Preserved samples have a two-week holding time, whereas unpreserved samples have only a seven-day holding time. In the great majority of cases, the preserved vials are used to take advantage of the extended holding time. In some situations, however, it may be necessary to use the unpreserved vials. For example, if the groundwater has a high amount of dissolved limestone, i.e., is highly calcareous, there will most likely be an effervescent reaction between the hydrochloric acid and the water, producing large numbers of fine bubbles. This will render the sample unacceptable. In this case, unpreserved vials should be used and arrangements must be confirmed with the laboratory to ensure that they can accept the unpreserved vials and meet the shorter sample holding times.

The samples should be collected with as little agitation or disturbance as possible. The vial should be filled so that there is a meniscus at the top of the vial and absolutely no bubbles or headspace should be present in the vial after it is capped. After the cap is securely tightened, the vial should be inverted and tapped on the palm of one hand to see if any undetected bubbles are dislodged. If a bubble or bubbles are present, the vial should be topped off using a minimal amount of sample to re-establish the meniscus. Care should be taken not to flush any preservative out of the vial during topping off. If, after topping off and capping the vial, bubbles are still present, a new vial should be obtained and the sample re-collected.

Samples for VOC analysis must be collected using either stainless steel or Teflon® equipment, such as:

- Bailers must be constructed of stainless steel or Teflon®
- RediFlo2® submersible pumps used for sampling should be equipped with Teflon® sample delivery tubing
- Peristaltic pump/vacuum jug assemblies should be outfitted with Teflon® tubing from the water column to the transfer cap, which should also be constructed of Teflon®

2.2 Special Precautions for Trace Contaminant Groundwater Sampling

- A clean pair of new, non-powdered, disposable gloves will be worn each time a different location is sampled and the gloves should be donned immediately prior to sampling. The gloves should not come in contact with the media being sampled and should be changed any time during sample collection when their cleanliness is compromised.
- Sample containers for samples suspected of containing high concentrations of contaminants shall be stored separately.

- Sample collection activities shall proceed progressively from the least suspected contaminated area to the most suspected contaminated area if sampling devices are to be reused. Samples of waste or highly contaminated media must not be placed in the same ice chest as environmental (i.e., containing low contaminant levels) or background samples.
- If possible, one member of the field sampling team should take all the notes and photographs, fill out tags, etc., while the other members collect the samples.
- Clean plastic sheeting will be placed on the ground at each sample location to prevent or minimize contaminating sampling equipment by accidental contact with the ground surface.
- Samplers must use new, verified certified-clean disposable or non-disposable equipment cleaned according to procedures contained in SESD Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205) or SESD Operating Procedure for Field Equipment Cleaning and Decontamination at the FEC (SESDPROC-206) for collection of samples for trace metals or organic compound analyses.

2.3 Sample Handling and Preservation Requirements

1. Groundwater samples will typically be collected from the discharge line of a pump or from a bailer, either from the pour stream of an up-turned bailer or from the stream from a bottom-emptying device. Efforts should be made to reduce the flow from either the pump discharge line or the bailer during sample collection to minimize sample agitation.

2. During sample collection, make sure that the pump discharge line or the bailer does not contact the sample container.

3. Place the sample into appropriate, labeled containers. Samples collected for VOC, acidity and alkalinity analysis must not have any headspace. All other sample containers must be filled with an allowance for ullage.

4. All samples requiring preservation must be preserved as soon as practically possible, ideally immediately at the time of sample collection. If preserved VOC vials are used, these will be preserved with concentrated hydrochloric acid by ASB personnel prior to departure for the field investigation. All other chemical preservatives required for the remaining suite of analytes will be supplied by ASB personnel and will be added to the samples by SESD field personnel or other authorized persons. The adequacy of sample preservation will be checked after the addition of the preservative for all samples except for the samples collected for VOC analysis. If additional preservative is needed, it should be added to achieve adequate preservation. Preservation requirements for groundwater samples are found in the USEPA Region 4 Analytical Support Branch Laboratory Operations and Quality Assurance Manual (ASBLOQAM), Most Recent Version.

2.4 Quality Control

If possible, a control sample should be collected from a location not affected by the possible contaminants of concern and submitted with the other samples. This control sample should be collected as close to the sampled area as possible and from the same water-bearing formation. Equipment blanks should be collected if equipment is field cleaned and re-used on-site or if necessary to document that low-level contaminants were not introduced by pumps, bailers or other sampling equipment.

2.5 Records

Information generated or obtained by SESD personnel will be organized and accounted for in accordance with SESD records management procedures found in SESD Operating Procedure for Control of Records, SESDPROC-002. Field notes, recorded in a bound field logbook, will be generated, as well as chain-of-custody documentation in accordance with SESD Operating Procedure for Logbooks, SESDPROC-010 and SESD Procedure for Sample and Evidence Management, SESDPROC-005.

3 Groundwater Sampling Methods – Purging

3.1 General

Purging is the process of removing stagnant water from a well, immediately prior to sampling, causing its replacement by groundwater from the adjacent formation that is representative of actual aquifer conditions. In order to determine when a well has been adequately purged, field investigators should monitor, at a minimum, the pH, specific conductance and turbidity of the groundwater removed during purging and, in the case of permanent monitoring wells, observe and record the volume of water removed.

There are several purging strategies that may be used, depending on specific conditions encountered for given well sampling situations. When a specific well is characterized, based on the field investigators experience and knowledge, as having fairly typical water levels, depths and purge volumes, as determined according to the procedures in Section 3.2.1, below, SESD will normally use the multiple volume purging procedures and equipment described in Sections 3.2.1 and 3.3 of this procedure for purging the well.

When the traditional multiple volume purge method is considered and it is determined that excessive quantities of IDW would be generated using this method, it may be appropriate, under very limited and specific circumstances, to use an alternate method that reduces the time and amount of purge water to be removed prior to sampling the well. The field project leader will select the alternate method only after careful consideration of the conditions presented by the well and the impact these conditions have on all aspects of the sampling event (time required to sample, quantities of IDW requiring management, etc.).

The alternate purge procedures or sampling strategies available are the "Tubing-in-Screened Interval" method and the MicroPurge or No-Purge methods. These are described and discussed in Sections 3.2.2 and 4.5 of this operating procedure, respectively.

3.2 Purging Methods and Strategies

3.2.1 Traditional Multiple Volume Purge

3.2.1.1 Purging and Purge Adequacy

3.2.1.1.1 Purge Volume Determination

Prior to initiating the purge, the amount of water standing in the water column (water inside the well riser and screen) should be determined, if possible. To do this, the diameter of the well should be determined and the water level and total depth of the well should be measured and recorded. Specific methodology for obtaining these measurements is found in SESD Operating Procedure for Groundwater Level and Well Depth Measurement (SESDPROC-105).

Once this information is obtained, the volume of water to be purged can be determined using one of several methods. One is the equation:

$V = 0.041\ d^2h$

Where: h = depth of water in feet
d = diameter of well in inches
V = volume of water in gallons

Alternatively, the volume of standing water in the well and the volume of three water columns may be determined using a casing volume per foot factor for the appropriate diameter well, similar to that in Table 3.2.1. The water level is subtracted from the total depth, providing the length of the water column. This length is multiplied by the appropriate factor in the Table 3.2.1, corresponding to either the single well volume or the triple well volume, to determine both the single well volume and triple well volumes, in gallons, for the well in question. Other acceptable methods include the use of nomographs or other equations or formulae.

TABLE 3.2.1: WELL CASING DIAMETER VOLUME FACTORS

Casing Diameter (inches)	Gallons/ft, One Water Column	Gallons/ft, Three Water Columns
1	0.04	0.12
2	0.16	0.48
3	0.37	1.11
4	0.65	1.98
5	1.02	3.06
6	1.47	4.41
7	1.99	5.97
8	2.61	7.83
9	3.30	9.90
10	4.08	12.24
11	4.93	14.79
12	5.87	17.61

With respect to volume, an adequate purge is normally achieved when three to five well volumes have been removed. The field notes should reflect the single well volume calculations or determinations, according to one of the above methods, and a reference to the appropriate multiplication of that volume, i.e., a minimum three well volumes, clearly identified as a purge volume goal.

3.2.1.1.2 Chemical Parameter Stabilization Criteria

With respect to the ground water chemistry, an adequate purge is achieved when the pH and specific conductance of the ground water have stabilized and the turbidity has either stabilized or is below 10 Nephelometric Turbidity Units (NTUs) (twice the Primary Drinking Water Standard of 5 NTUs). Although 10 NTUs is normally considered the minimum goal for most ground water sampling objectives, lower turbidity has been shown to be easily achievable in most situations and reasonable attempts should be made to achieve these lower levels. (Note: Because groundwater temperature is subject to rapid changes when collected for parameter measurement, its usefulness is subject to question for the purpose of determining parameter stability. As such, it has been removed from the list of parameters used for stability determination. Even though temperature is not used to determine stability during well purging, it is still advisable to record the sample temperature, along with the other groundwater chemistry parameters during well purging, as it may be needed to interpret other chemical parameter results in some situations.)

Stabilization occurs when, for at least three consecutive measurements, the pH remains constant within 0.1 Standard Unit (SU) and specific conductance varies no more than approximately 5 percent. Other parameters, such as dissolved oxygen (DO), may also be used as a purge adequacy parameter. Normal goals for DO are 0.2 mg/L or 10% saturation, whichever is greater. DO measurements must be conducted using either a flow-through cell or an over-topping cell to minimize or reduce any oxygenation of the sample during measurement. Oxidation Reduction Potential (ORP) should not be used as a purge stabilization parameter but may be measured during purging to obtain the measurement of record for ORP for the sampling event.

There are no set criteria for establishing how many total sets of measurements are adequate to document stability of parameters. If the calculated purge volume is small, the measurements should be taken frequently enough to provide a sufficient number of measurements to evaluate stability. If the purge volume is large, measurements taken every 15 minutes, for example, may be sufficient. See the SESD Operating Procedures for Field pH Measurement (SESDPROC-100), Field Specific Conductance Measurement (SESDPROC-101), Field Temperature Measurement (SESDPROC-102), Field Turbidity Measurement (SESDPROC-103), Field Measurement of Dissolved Oxygen (SESDPROC-106) and Field Measurement of Oxidation-Reduction Potential (SESDPROC-113) for procedures for conducting these measurements.

If, after three well volumes have been removed, the chemical parameters have not stabilized according to the above criteria, additional well volumes (up to five well volumes), should be removed. If the parameters have not stabilized within five volumes, it is at the discretion of the project leader whether or not to collect a sample or to continue purging. If, after five well volumes, pH and conductivity have stabilized and the turbidity is still decreasing and approaching an acceptable level, additional purging should be considered to obtain the best sample possible, with respect to turbidity. The conditions of sampling should be noted in the field log.

3.2.1.1.3 Purge Adequacy Considerations

In some situations, even with slow purge rates, a well may be pumped or bailed dry (evacuated). In these situations, this generally constitutes an adequate purge and the well can be sampled following sufficient recovery (enough volume to allow filling of all sample containers). ***It is not necessary that the well be evacuated three times before it is sampled***. The pH, specific conductance, temperature, and turbidity should be measured and recorded, during collection of the sample from the recovered volume, as the measurements of record for the sampling event.

For wells with slow recovery, attempts should be made to avoid purging them to dryness. This can be accomplished, for example, by slowing the purge rate. As water enters a well that has been purged to dryness, it may cascade down the sand pack and/or the well screen, stripping volatile organic constituents that may be present and/or introducing soil fines into the water column.

It is particularly important that wells be sampled as soon as possible after purging. If adequate volume is available immediately upon completion of purging, the well must be sampled immediately. If not, sampling should occur as soon as adequate volume has recovered. If possible, sampling of wells which have a slow recovery should be scheduled so that they can be purged and sampled in the same day, after adequate volume has recovered. Wells of this type should, unless it is unavoidable, not be purged at the end of one day and sampled the following day.

3.2.2 “Tubing-in-Screened-Interval” Method

The “Tubing-in-Screen” method, sometimes referred to as the “Low Flow” method, is used primarily when calculated purge volumes for the traditional purging method are excessive and present issues related to timely completion of the project and/or management of investigation derived waste.

3.2.2.1 Purge Criteria

3.2.2.1.1 Placement of Pump Tubing or Intake

The peristaltic pump tubing or intake point of the submersible pump is placed in the approximate mid-portion of the screened interval of the well. By definition, this method cannot be applied for purging with a bailer.

3.2.2.1.2 Conditions of Pumping

Prior to initiation of pumping, a properly decontaminated well sounder should be lowered into the well being sampled to monitor the static water level prior to and during the purging process. Ideally, there should be only a slight and stable drawdown of the water column after pumping begins. If this condition cannot be met, then one of the other methods should be employed.

3.2.2.1.3 Stability of Chemical Parameters

As with the traditional purging method described in Section 3.2.1, it is important that all chemical parameters be stable as defined in Section 3.2.1.1 prior to sampling.

3.3 Equipment Considerations for Purging

Monitoring well purging is accomplished by using in-place plumbing and dedicated pumps or by using portable pumps/equipment when dedicated systems are not present. The equipment utilized by Branch personnel will usually consist of peristaltic pumps and variable speed electric submersible pumps, but may also include bladder pumps or inertial pumps. The pump of choice is usually a function of the well diameter, the depth to water, the depth of the well and the amount of water that is to be removed during purging. Whenever the head difference between the sampling location and the water level is less than the limit of suction and the volume to be removed is reasonably small, a peristaltic pump should be used for purging. For wells where the water level is below the limit of suction (approximately 25’ to 30’, and/or where there is a large volume of water to be purged, the variable speed electric submersible pump would be the pump of choice. SESD Operating Procedure for Pump Operation (SESDPROC-203) contains the use and operating instructions for all pumps commonly used during SESD ground water investigations.

Bailers may also be used for purging in appropriate situations, however, their use is discouraged. Bailers tend to disturb any sediment that may be present in the well, creating or increasing sample turbidity. Bailers, if improperly used, may also strip volatile organic compounds from the water column being sampled. If a bailer is used, it should be a closed-top Teflon® bailer.

3.3.1 Wells Without Plumbing or In-Place Pumps

For permanent monitoring wells, the depth to water (water level) and depth of the well (total depth) should be determined before purging. Caution should be exercised during this procedure to prevent cross-contamination between wells. This is a critical concern when samples for trace organic compounds or metals analyses are collected. See SESD Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205**)** for cleaning procedures for well sounders. After cleaning, the well sounding device should be protected to keep it clean until its next use.

3.3.1.1 Purging with Pumps

3.3.1.1.1 Peristaltic Pumps

The following step-by-step procedures describe the process of purging with a peristaltic pump:

1. Cut a length of standard-cleaned (SESD Operating Procedure for Field Equipment Cleaning and Decontamination at the FEC (SESDPROC-206) Teflon® tubing, equal to the well depth plus an additional five to ten feet. Enough tubing is needed to run from the ground surface up to the top of the well casing and back down to the bottom of the well. This will allow for operation of the pump at all possible water level conditions in the well.

2. Place one end of the tubing into the vacuum side of the peristaltic pump head. Proper sizing of the Teflon® and Silastic® or Tygon® tubing should allow for a snug fit of the Teflon® tubing inside the flexible tubing mounted in the pump head.

3. Run a short section of tubing (does not have to be Teflon®) from the discharge side of the pump head to a graduated bucket.

4. Place the free end of the Teflon® tubing into the well until the end of the tubing is just below the surface of the water column.

5. Secure the Teflon® tubing to the well casing or other secure object using electrician's tape or other suitable means. This will prevent the tubing from being lost in the well should the tubing detach from the pump head.

6. Turn on the pump to produce a vacuum on the well side of the pump head and begin the purge. Observe pump direction to ensure that a vacuum is being applied to the purge line. If the purge line is being pressurized, either switch the tubing at the pump head or reverse the polarity of the cables on the pump or on the battery.

7. If the pumping rate exceeds the recovery rate of the well, continue to lower the tubing into the well, as needed, until the drawdown stabilizes or the well is evacuated to dryness. If the pump is a variable speed peristaltic pump, and the water level in the well is being drawn down, reduce the speed of the pump in an attempt to stabilize the drawdown. If the well can be purged without evacuating the well to dryness, a sample with greater integrity can be obtained.

8. For wells which are not evacuated to dryness, particularly those with recovery rates equal to or very nearly equal to the purge rate, there may not be a complete exchange and removal of stagnant water in that portion of the water column above the tubing intake. For this reason, it is important that the tubing intake be placed in the very uppermost portion of the water column while purging. Standard field measurements should frequently be taken during this process to verify adequacy of the purge and readiness for sampling, as described in Section 3.

3.3.1.1.2 Submersible Pumps

When a submersible pump is used for well purging, the pump itself is lowered into the water column. The pump must be cleaned as specified in SESD Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205).

The pump/hose assembly used in purging should be lowered into the top of the standing water column and not deep into the column. This is done so that the purging will "pull" water from the formation into the screened area of the well and up through the casing so that the entire static volume can be removed. If the pump is placed deep into the water column, the water above the pump may not be removed, and the subsequent samples, particularly if collected with a bailer, may not be representative of the aquifer conditions. It is recommended that the pump not be lowered more than three to five feet into the water column. If the recovery rate of the well is faster than the pump rate and no observable draw down occurs, the pump should be raised until the intake is within one foot of the top of the water column for the duration of purging. If the pump rate exceeds the recovery rate of the well, the pump will have to be lowered, as needed, to accommodate the drawdown. After the pump is removed from the well, the hose and the pump should be cleaned as outlined in SESD Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205).

3.3.1.2 Purging with Bailers

Standard-cleaned (SESD Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205) or SESD Operating Procedure for Field Equipment Cleaning and Decontamination at the FEC (SESDPROC-206) closed-top Teflon® bailers with Teflon® coated stainless steel leaders and new nylon rope are lowered into the top of the water column, allowed to fill, and removed. It is critical that bailers be slowly and gently immersed into the top of the water column, particularly during final stages of purging, to minimize turbidity and disturbance of volatile organic constituents. The use of bailers for purging and sampling is discouraged because the correct technique is highly operator dependent and improper use may result in an unrepresentative sample.

3.3.2 Wells With In-Place Plumbing

Wells with in-place plumbing are commonly found at municipal water treatment plants, industrial water supplies, private residences, etc. Many permanent monitoring wells at active facilities are also equipped with dedicated, in-place pumps. The objective of purging wells with in-place pumps is the same as with monitoring wells without in-place pumps, i.e., to ultimately collect a ground water sample representative of aquifer conditions. Among the types of wells identified in this section, two different approaches are necessary.

A permanent monitoring well with an in-place pump should, in all respects, be treated like a monitoring well without a pump. One limitation is that in most cases the in-place pump is “hard” mounted, that is, the pump is suspended in the well at a pre-selected depth and cannot be moved up or down during purging and sampling. In these cases, well volumes are calculated, parameters are measured and the well is sampled from the pump discharge, after volume removal and parameter conditions have been met.

In the case of the other types of wells, i.e., municipal, industrial and residential supply wells, however, not enough is generally known about the construction aspects of the wells to apply the same criteria as used for monitoring wells, i.e., 3 to 5 well volumes. The volume to be purged in these situations, therefore, depends on several factors: whether the pumps are running continuously or intermittently and whether or not any storage/pressure tanks are located between the sampling point and the pump. The following considerations and procedures should be followed when purging wells with in-place plumbing under the conditions described.

3.3.2.1 Continuously Running Pumps

If the pump runs more or less continuously, no purge (other than opening a valve and allowing it to flush for a few minutes) is necessary. If a storage tank is present, a spigot, valve or other sampling point should be located between the pump and the storage tank. If not, locate the valve closest to the tank. Measurements of pH, specific conductance, temperature, and turbidity are recorded at the time of sampling.

3.3.2.2 Intermittently or Infrequently Running Pumps

If the pump runs intermittently or infrequently, best judgment should be utilized to remove enough water from the plumbing to flush standing water from the piping and any storage tanks that might be present. Generally, under these conditions, 15 to 30 minutes will be adequate. Measurements of pH, specific conductance, temperature and turbidity should be made and recorded at intervals during the purge and the final measurements made at the time of sampling should be considered the measurements of record for the event.

3.3.3 Temporary Monitoring Wells

3.3.3.1 General Considerations

Procedures used to purge temporary ground water monitoring wells differ from permanent wells because temporary wells are installed for immediate sample acquisition. Wells of this type may include standard well screen and riser placed in boreholes created by hand augering, power augering, or by drilling. They may also consist of a rigid rod and screen that is pushed, driven, or hammered into place to the desired sampling interval, such as a direct push Wellpoint®, a Geoprobe® Screen Point 15/16 sampler or a Hydropunch® sampler. As such, the efforts to remove several volumes of water to replace stagnant water do not necessarily apply because stagnant water is not present. It is important to note, however, that the longer a temporary well is in place and not sampled, the more stagnant the water column becomes and the more appropriate it becomes to apply, to the extent possible, standard permanent monitoring well purging criteria to it to re-achieve aquifer conditions.

In cases where the temporary well is to be sampled immediately after installation, purging is conducted primarily to mitigate the impacts of installation. In most cases, temporary well installation procedures disturb the existing aquifer conditions, resulting primarily in increased turbidity. Therefore, the goal of purging is to reduce the turbidity and remove the volume of water in the area directly impacted by the installation procedure. Low turbidity conditions in these types of wells that are completed within the limit of suction are typically and routinely achieved by the use of low-flow/low stress purging techniques using variable speed peristaltic pumps.

3.3.3.2 Purging When Water Level Is Within Limit of Suction

In situations where the elevation of the top of the water column is within the limit of suction (no greater than about 25 feet head difference between the pump and the water level), a variable speed peristaltic pump may be used to purge temporary wells. Enough tubing is deployed to reach the bottom of the temporary well screen. At the onset of purging, the tubing is slowly lowered to the bottom of the screen and is used to remove any formation material which may have entered the well screen during installation. This is critical to ensuring rapid achievement of low turbidity conditions. After the formation material is removed from the bottom of the screen, the tubing is slowly raised through the water column to near the top of the column. The tubing can be held at this level to determine if the pump rate is drawing down the water level in the well. If the water level remains the same, secure the tubing at the surface to maintain this pumping level.

If drawdown is observed on initiation of pumping, reduce the pump speed and attempt to match the drawdown of the well. Sustained pumping at these slow rates will usually result in a relatively clear, low turbidity sample. If the drawdown stabilizes, maintain that level, however, if it continues to lower, "chase" the water column until the well is evacuated. In this case, the recovered water column may be relatively free of turbidity and can be sampled. It may take several episodes of recovery to provide enough volume for a complete sample.

3.3.3.3 Purging When Water Level Is Greater Than Limit of Suction

In situations where the elevation of the water table is greater than the limit of suction, peristaltic pumps cannot be used to purge temporary wells. If the temporary well is a ScreenPoint15® sampler with small diameter probe rod riser, the only practical choices for water removal are a small diameter bailer, a small diameter bladder pump or an inertial pump. If the well is to be used strictly for VOC screening, it may be acceptable to use the bailer to bail as much sediment from the well as possible prior to sampling. If metals are the analytes of concern, the bladder pump is the best choice for lowering the turbidity of the water column prior to sampling, followed next by the inertial pump. For larger diameter temporary wells, two-inch diameter or greater, bailers and the Grundfos® RediFlo2 may be used although excessive silt or other “fines” may present problems with the operation of the pump.

3.3.3.4 Considerations for Direct Push Groundwater Sampling

With many of the direct push sampling techniques, purging is either not practical or possible, therefore, no purging is conducted. The sampling device is simply pushed or driven to the desired depth and opened and the sample is collected and retrieved. As a result, some samples collected in this way may not be satisfactory or acceptable for certain analyses, i.e., the subject procedure may yield a turbid sample that is not appropriate for metals analyses.

3.4 Field Care of Purging Equipment

New plastic sheeting should be placed on the ground surface around the well casing to prevent contamination of the pumps, hoses, ropes, etc., in the event they accidentally come into contact with the ground surface or, for some reason, they need to be placed on the ground during the purging event. It is preferable that hoses used in purging that come into contact with the ground water be kept on a spool or contained in a large wash tub lined with plastic sheeting, both during transportation and during field use, to further minimize contamination by the transporting vehicle or the ground surface.

Careful consideration shall be given to using submersible pumps to purge wells which are excessively contaminated with oily compounds, because it may be difficult to adequately decontaminate severely contaminated pumps under field conditions. When wells of this type are encountered, alternative purging methods, such as bailers, should be considered.

3.5 Investigation Derived Waste

Purging generates quantities of purge water or investigation derived waste (IDW), the disposition of which must be considered. See SESD Operating Procedure for Management of Investigation Derived Waste (SESDPROC-202) for guidance on management or disposal of this waste.

4 Groundwater Sampling Methods – Sampling

4.1 General

Sampling is the process of obtaining, containerizing, and preserving (if required) a ground water sample after the purging process is complete. Non-dedicated pumps for sample collection generally should not be used. Many pumps are made of materials such as brass, plastic, rubber, or other elastomeric products which may cause chemical interferences with the sample. Their principle of operation may also render them unacceptable as a sample collection device. It is recognized that there are situations, such as industrial or municipal supply wells or private residential wells, where a well may be equipped with a dedicated pump from which a sample would not normally be collected. Discretion should always be used in obtaining a sample.

4.2 Sampling Wells With In-Place Plumbing

Samples should be collected following purging from a valve or cold water tap as near to the well as possible, preferably prior to any storage/pressure tanks or physical/chemical treatment system that might be present. Remove any hose that may be present before sample collection and reduce the flow to a low level to minimize sample disturbance, particularly with respect to volatile organic constituents. Samples should be collected directly into the appropriate containers as specified in the ASBLOQAM. It may be necessary to use a secondary container, such as a clean 8 oz. or similar size sample jar or a stainless steel scoop, to obtain and transfer samples from spigots with low ground clearance. Also, refer to the discussion in the SESD Operating Procedure for Potable Water Supply Sampling (SESDPROC-305), Sec. 4.2, Potable Water Samples Collected from Wells with In-Place Plumbing**.** Potable well measurements for pH, specific conductance and turbidity, and possibly temperature, if warranted, should be recorded at the time of sample collection.

4.3 Sampling Wells Without Plumbing, Within the Limit of Suction

4.3.1 Equipment Available

The pump of choice for sampling ground water within the limit of suction is the variable-speed peristaltic pump. Its use is described in the following sections. Other acceptable alternatives that may be used under these conditions are the RediFlo2® electric submersible pump (with Teflon® tubing) and a closed-top Teflon® bailer.

4.3.1.1 Peristaltic Pump, Direct from Pump Head Tubing

Samples for some constituents, primarily inorganic analytes such as metals and cyanide, may be collected directly from the pump head tubing. This method is acceptable under the following conditions:

- The pump head tubing must be changed between sampling locations;

- The pump head tubing must be either be certified clean according to SESD's internal quality control program described in Section 3.2 of the SESD Operating Procedure for Field Sampling Quality Control (SESDPROC-011) or
- An equipment rinsate blank is collected by pumping de-ionized water through a piece of the tubing.

4.3.1.2 Peristaltic Pump/Vacuum jug

It is not acceptable to collect samples for organic compound analyses through the flexible tubing used in the pump head. When collecting samples for organic compound analyses it is necessary to use a vacuum container, placed between the pump and the well for sample collection. The following step-by-step procedures describe the process of sampling with a peristaltic pump and vacuum jug (see note following these procedures for collection of VOC samples):

1. Disconnect the purge tubing from the pump. Make sure the tubing is securely attached to the protective casing or other secure object.

2. Insert the tubing into one of the ferrule nut fittings of a Teflon® vacuum container transfer cap assembly.

3. Place a suitable length of Teflon® tubing between the remaining transfer cap assembly ferrule nut fitting and the vacuum side of the flexible tubing in the peristaltic pump head. Securely hand-tighten both fittings.

4. Turn the pump on. Water should begin to collect in the transfer container (typically a 1-liter sample container) within a few minutes. If water does not begin to flow into the container within several minutes, check the transfer cap fittings and make sure the assembly is tightly attached to the container. It may be necessary to tighten the ferrule nuts with a wrench or pliers to achieve a vacuum in the system, particularly when approaching the maximum head difference between the pump and water table (limit of suction).

5. When the transfer container is nearly full, turn off the pump, remove the transfer cap assembly, and pour the sample into the appropriate containers. Because the 1-liter containers used by the Branch are rinsed with nitric acid during cleaning, they cannot be used for collecting samples to be analyzed for nitrogen sensitive parameters.

6. If additional sample volume is needed, replace the transfer cap assembly, turn the pump on, and collect additional volume. The use of Teflon® valves or ball check devices to retain the water column in the sample delivery tubing during the transfer phase, when large volumes of sample are required, is acceptable. These devices, however, must be constructed so that they may be completely disassembled and cleaned according to the procedures in SESD

Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205).

7. When sampling is completed, all Teflon® tubing should be discarded.

   NOTE: Samples for volatile organic compound analyses cannot be collected using this method. If samples for VOC analyses are required, they must be collected with a Teflon® or stainless steel bailer or by other approved methods, such as the "soda straw" method. The "soda straw" method involves allowing the tubing to fill, by either lowering it into the water column (A) or by filling it via suction applied by the pump head (B). If method (A) is used, the tubing is removed from the well after filling and the captured sample is allowed to drain into the sample vial. If method (B) is used, after running the pump and filling the tubing with sample, the pump speed is reduced and the direction reversed to push the sample out of the tubing into the vials. Avoid completely emptying the tubing when filling the sample vials when using method (B) to prevent introducing water that was in contact with the flexible pump head tubing. Either method is repeated, as necessary, until all vials are filled.

4.3.1.3 RediFlo2® Electric Submersible Pump (with Teflon® Tubing)

After purging has been accomplished with RediFlo2® electric submersible pump, the sample may be obtained directly from the pump discharge, provided that Teflon® tubing was used for the sample delivery line. The discharge rate of the pump should be reduced during volatile organic compound sample collection to minimize sample disturbance. Note, if the RediFlo2® electric submersible pump is used for sampling, the pump must undergo a full external and internal cleaning. In addition, pump rinsate blanks must be collected, at the appropriate frequency, to demonstrate that the pump has been adequately cleaned between wells.

4.3.1.4 Bailers

New bailer rope should be attached to the bailer via a Teflon® coated stainless steel wire. (If a bailer was used to purge the well, it may also be used to sample the well and new bailer rope is not required between purging and sampling). The bailer should be gently immersed in the top of the water column until just filled. At this point, the bailer should be slowly removed and the contents emptied into the appropriate sample containers.

4.4 Sampling Wells without Plumbing, Exceeding the Limit of Suction

All methods described previously in Section 4.3.2.1.3, RediFlo2® Electric Submersible Pumps, and Section 4.3.2.1.4, Bailers, are suitable sample methods where the water table is too deep to consider the use of a peristaltic pump for sampling.

4.5 Micro-Purge or No Purge Sampling Procedures

The Micro-Purge or No Purge sampling procedures are usually employed when it necessary to keep purge volumes to an absolute minimum. Among the Micro-Purge or No Purge procedures that might be employed are:

- Low pump rate sampling with peristaltic or submersible pumps (typical Micro-Purge sampling),
- HydraSleeve^{TM} or
- Passive diffusion bag (PDB) sampling

The use of these procedures is acceptable only when the site hydrogeology is well understood, with respect to the hydraulic conductivity of geologic materials within the well screen interval. The underlying assumption, when employing these procedures, is that the formation in which the well is screened has a high hydraulic conductivity ($K>10^{-5}$ cm/sec, for example), resulting in a state of equilibrium existing between the water standing in the screened interval and the formation water in which the well is screened. In this situation, the well is considered to be in a perpetually "purged" state and purging is not required.

These procedures are generally impractical for SESD to implement because of the general lack of hydrogeologic information for the sampled wells and the real necessity, in some cases, that the pumps be pre-deployed to overcome issues related to turbidity resulting from pump placement prior to sampling.

4.5.1 Sampling with Pumps

The peristaltic pump tubing or intake point of the submersible pump is placed in the approximate mid-portion of the screened interval of the well or other interval selected by the field team leader. If turbidity and its impact on metals analyses are a concern, a period of time sufficient should be allowed to mitigate effects of pump or tubing placement. After it has been determined that sampling may proceed, the pump is turned on and operated at a rate that does not cause significant drawdown of the water column, as measured using a water level sounder. During sampling, sufficient water to supply enough volume for the analytes of concern and the purge parameters is pumped. Purging should continue until purge parameters stabilize, generally three consecutive stable sets of readings, before samples are collected.

4.5.2 HydraSleeves^{TM}

HydraSleeeves^{TM} are grab sampling devices that are deployed in a closed configuration then opened in the desired interval for sample collection. The following is a summary of its operation:

1. Sampler placement - Reusable weight is attached and the HydraSleeve^{TM} is lowered and placed at the desired position in the well screen. In-situ water pressure keeps the reed valve closed, preventing water from entering the sampler. Well is allowed to return to equilibrium.

2. Sample collection - The reed valve opens to allow filling when the sampler is moved upward faster than 1 foot per second, either in one continuous upward pull or by cycling the sampler up and down to sample a shorter interval. There is no change in water level, and only minimal agitation during collection.

3. Sample retrieval - When the flexible sleeve is full, the reed valve closes and the sampler can be recovered without entry of extraneous overlying fluids. Samples are removed by puncturing the sleeve with the pointed discharge tube and draining the contents into containers for sampling or field measurement.

4.5.3 Passive Diffusion Bags

Passive diffusion bag (PDB) samplers are bags comprised of low-density polyethylene (LDPE) plastic and containing analyte-free water, preferably with no headspace. The bags are deployed, with stainless steel weights, to the desired sample interval and are allowed to equilibrate with the water at the point of deployment in the well. A deployment period of a minimum of 14 days is recommended to ensure equilibration prior to removal.

After 14 days, the bags and opened with a puncture device or other cutting implement and the contents transferred to containers for sampling or field measurement.

4.5.4 General Considerations for Micro-Purge or No-Purge Sampling

When using the Micro-Purge method, it may be advisable to deploy the tubing or pump in advance of sample collection. Introducing the tubing or pump into the screened interval is likely to dislodge sediment and other fines that have settled or bridged on the well screen material and the gravel pack media behind the screen. If sampling is conducted immediately, turbidity issues may render this method impractical from a parameter stability standpoint.

HydraSleevesTM and PDBs must be evaluated for appropriateness for analytes of concern.

4.6 Sample Preservation

After sample collection, all samples requiring preservation must be preserved as soon as practical. Consult the ASBLOQAM for the correct preservative for the particular analytes of interest. All samples preserved using a pH adjustment (except VOCs) must be checked, using pH strips, to ensure that they were adequately preserved. This is done by pouring a small volume of sample over the strip. Do not place the strip in the sample. Samples requiring reduced temperature storage should be placed on ice immediately.

4.7 Special Sample Collection Procedures

4.7.1 Trace Organic Compounds and Metals

Special sample handling procedures should be instituted when trace contaminant samples are being collected. All sampling equipment, including pumps, bailers, water level measurement equipment, etc., which comes into contact with the water in the well must be cleaned in accordance with the cleaning procedures described in the SESD Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205 or SESD Operating Procedure for Field Equipment Cleaning and Decontamination at the FEC (SESDPROC-206). Pumps should not be used for sampling unless the interior and exterior portions of the pump and the discharge hoses are thoroughly cleaned. Blank samples should be collected to determine the adequacy of cleaning prior to collection of any sample using a pump other than a peristaltic pump.

4.7.2 Order of Sampling with Respect to Analytes

In many situations when sampling permanent or temporary monitoring wells, an adequate purge, with respect to turbidity, is often difficult to achieve. Removal and insertion of equipment after the purge and prior to actual sampling may negate the low turbidities achieved during purging and elevate turbidity back to unacceptable levels. For this reason, it is important that special efforts be used to minimize any disturbance of the water column after purging and to collect the aliquot for metals first. Therefore, the preferred order of sampling is metals first, followed by other inorganic analytes, extractable organic compounds and volatile organic compounds.

4.7.3 Filtering

As a standard practice, ground water samples will not be filtered for routine analysis. Filtering will usually only be performed to determine the fraction of major ions and trace metals passing the filter and used for flow system analysis and for the purpose of geochemical speciation modeling. Filtration is not allowed to correct for improperly designed or constructed monitoring wells, inappropriate sampling methods, or poor sampling technique.

When samples are collected for routine analyses and are filtered, both filtered and non-filtered samples will be submitted for analyses. Samples for organic compounds analysis should not be filtered. Prior to filtration of the ground water sample for any reason other than geochemical speciation modeling, the following criteria must be demonstrated to justify the use of filtered samples for inorganic analysis:

1. The monitoring wells, whether temporary or permanent, have been constructed and developed in accordance with the SESD Guidance Document, Design and Installation of Monitoring Wells (SESDGUID-001).

2. The ground water samples were collected using sampling techniques in accordance with this section, and the ground water samples were analyzed in accordance with USEPA approved methods.

3. Efforts have been undertaken to minimize any persistent sample turbidity problems. These efforts may consist of the following:

   - Redevelopment or re-installation of permanent ground water monitoring wells.
   - Implementation of low flow/low stress purging and sampling techniques.

4. Turbidity measurements should be taken during purging and sampling to demonstrate stabilization or lack thereof. These measurements should be documented in the field notes. If the ground water sample appears to have either a chemically-induced elevated turbidity, such as would occur with precipitate formation, or a naturally elevated colloid or fine, particulate-related turbidity, filtration will not be allowed.

If filtration is necessary for purposes of geochemical modeling or other **pre-approved** cases, the following procedures are suggested:

1. Accomplish in-line filtration through the use of disposable, high capacity filter cartridges (barrel-type) or membrane filters in an in-line filter apparatus. The high capacity, barrel-type filter is preferred due to the higher surface area associated with this configuration. If a membrane filter is utilized, a minimum diameter of 142 mm is suggested.

2. Use a 5 µm pore-size filter for the purpose of determining the colloidal constituent concentrations. A 0.1 µm pore-size filter should be used to remove most non-dissolved particles.

3. Rinse the cartridge or barrel-type filter with 500 milliliters of the solute (groundwater to be sampled) prior to collection of sample. If a membrane filter is used, rinse with 100 milliliters of solute prior to sample collection.

Potential differences could result from variations in filtration procedures used to process water samples for the determination of trace element concentrations. A number of factors associated with filtration can substantially alter "dissolved" trace element concentrations; these include filter pore size, filter type, filter diameter, filtration method, volume of sample processed, suspended sediment concentration, suspended sediment grain-size distribution, concentration of colloids and colloidally-associated trace elements, and concentration of organic matter. Therefore, consistency is critical in the comparison of short-term and long-term results. Further guidance on filtration may be obtained from the following: 1) Metals in Ground Water: Sampling Artifacts and Reproducibility; 2) Filtration of Ground Water Samples for Metals Analysis; and 3) Ground Water Sampling - A Workshop Summary. See Section 1.4, References, for complete citation for these documents.

Bacterial Sampling

Whenever wells (normally potable wells) are sampled for bacteriological parameters, care must be taken to ensure the sterility of all sampling equipment and all other equipment entering the well. Further information regarding bacteriological sampling is available in the following: 1) Sampling for Organic Chemicals and Microorganisms in the Subsurface; 2) Handbook for Evaluating Water Bacteriological Laboratories; and 3) Microbiological Methods for Monitoring the Environment, Water and Wastes. See Section 1.4, References, for complete citation for these documents.

4.8 Specific Sampling Equipment Quality Assurance Techniques

All equipment used to collect ground water samples shall be cleaned as outlined in the SESD Operating Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205) or SESD Operating Procedure for Field Equipment Cleaning and Decontamination at the FEC (SESDPROC-206) and repaired, if necessary, before being stored at the conclusion of field studies. Cleaning procedures utilized in the field or field repairs shall be thoroughly documented in field records.

4.9 Auxiliary Data Collection

During ground water sample collection, it is important to record a variety of ground water related data. Included in the category of auxiliary data are water levels measured according to the SESD Operating Procedure for Groundwater Level and Well Depth Measurement (SESDPROC-105), well volume determinations (Section 3.1.1, Purging and Purge Adequacy), pumping rates during purging (see below), and occasionally, drillers or boring logs. This information should be documented in the field records.

4.9.1 Well Pumping Rate – Bucket/Stop Watch Method

The pumping rate for a pump can be determined by collecting the discharge from the pump in a bucket of known volume and timing how long it takes to fill the bucket. The pumping rate should be in gallons per minute. This method shall be used primarily with pumps with a constant pump rate, such as gasoline-powered or electric submersible pumps. Care should be taken when using this method with some battery-powered pumps. As the batteries' charge decreases, the pump rate also decreases so that pumping rate calculations using initial, high pump rates may be erroneously high. If this method is used with battery-powered pumps, the rate should be re-checked frequently to ensure accuracy of the pumping rate calculations.

Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

OPERATING PROCEDURE

Title: **Packing, Marking, Labeling and Shipping of Environmental and Waste Samples**

Effective Date: April 20, 2011	**Number:** SESDPROC-209-R2

Authors

Name: Art Masters
Title: Environmental Scientist, Regional Expert
Signature: Date: 4/14/11

Approvals

Name: Archie Lee
Title: Chief, Enforcement and Investigations Branch
Signature: Date: 4/14/11

Name: Bill Cosgrove
Title: Chief, Ecological Assessment Branch
Signature: Date: 4/14/11

Name: Liza Montalvo
Title: Field Quality Manager, Science and Ecosystem Support Division
Signature: Date: 4/14/11

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Document Control Coordinator.

History	Effective Date
SESDPROC-209-R2, *Packing, Marking, Labeling and Shipping of Environmental and Waste Samples*, replaces SESDPROC-209-R1. **Title Page:** Changed EIB Branch Chief from Antonio Quinones to Archie Lee. Changed Field Quality Manager from Laura Ackerman to Liza Montalvo. **Revision History:** Previous versions of the document will be maintained by the Document Control Coordinator (DCC). Changed from Field Quality Manager to DCC. **Section 1.2:** Added the following statement: Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use. **Section 1.3:** Changed requirement so that the DCC is responsible for ensuring the most recent version of the procedure is placed on the SESD LAN and for maintaining records of review conducted prior to its issuance. Deleted reference to the H: drive. **Section 3, fifth paragraph**: On item #2 on the list, replaced "be sure" with "ensure that." On item #3, deleted the last sentence that stated that only "Up to three VOA vials may be packed in one Whirl-Pak container or bag." Deleted outdated item #4 referencing shipment of VOA vials in metal cans. On items #5 and #6, removed references to vermiculite in favor of generic "absorbent material."	April 20, 2011
SESDPROC-209-R1, *Packing, Marking, Labeling and Shipping of Environmental and Waste Samples*, replaces SESDPROC-209-R0. **General** Corrected any typographical, grammatical and/or editorial errors. **Title Page** Changed title for Antonio Quinones from Environmental Investigations Branch to Enforcement and Investigations Branch. Changed Bill Cosgrove's title from Acting Chief to Chief.	November 1, 2007

Section 1.3 Updated information to reflect that the procedure is located on the H: drive of the LAN. Clarified Field Quality Manager (FQM) responsibilities. **Section 1.4** Alphabetized and revised the referencing style for consistency. Added reference to the SHEMP Procedures and Policy Manual. **Section 1.5.1** Corrected the title of the Safety, Health, and Environmental Management Program Procedures and Policy Manual.	
SESDPROC-209-R0, Packing, Marking, Labeling and Shipping of Environmental and Waste Samples, Original Issue	February 05, 2007

TABLE OF CONTENTS

1 General Information

1.1 Purpose

Regulations for packing, marking, labeling, and shipping of dangerous goods by air transport are promulgated by Department of Transportation under 49 CFR, Subchapter C, Hazardous Materials Regulations, and the International Air Transport Authority (IATA), which is equivalent to United Nations International Civil Aviation Organization (UN/ICAO). Transportation of hazardous materials (dangerous goods) by EPA personnel is covered by EPA Order 1000. This document describes general and specific procedures, methods and considerations to be used and observed by SESD field investigators when packing, marking, labeling and shipping environmental and waste samples to ensure that all shipments are in compliance with the above regulations and guidance.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when packing, marking, labeling, and shipping environmental samples and dangerous goods by air transport. Samples collected during field investigations or in response to a hazardous materials incident must be classified prior to shipment, as either environmental or hazardous materials (dangerous goods) samples.

In general, environmental samples include drinking water, most groundwater and ambient surface water, soil, sediment, treated municipal and industrial wastewater effluent, biological specimens, or any samples not expected to be contaminated with high levels of hazardous materials. Samples collected from process wastewater streams, drums, bulk storage tanks, soil, sediment, or water samples from areas suspected of being highly contaminated may require shipment as dangerous goods.

Government employees transporting samples or hazardous materials (i.e., preservatives or waste samples) in government vehicles are not subject to the requirements of this section in accordance with 49 CFR 171.1(d)(5). EPA contractors, however, are not covered by this exemption and may not transport these materials without full compliance with 49 CFR.

Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and have been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the SESD local area network (LAN). The Document Control Coordinator (DCC) is responsible for ensuring the most recent version of the procedure is placed on the LAN and for maintaining records of review conducted prior to its issuance.

1.4 References

International Air Transport Authority (IATA). Dangerous Goods Regulations, Most Recent Version.

Title 40 Code of Federal Regulations (CFR), Pt. 136.3, Identification of Test Procedures, July 1, 2001. See Table II, Footnote 3.

Title 49 CFR, Pt. 171.1(d)(5), Applicability of Hazardous Materials Regulations (HMR) to Persons and Functions.

United States Department of Transportation (US DOT). 2003. Letter from Edward T. Mazzullo, Director, Office of Hazardous Materials Standards, to Henry L. Longest II, Acting Assistant Administrator, USEPA, Ref No. 02-0093, February 13, 2003.

US Environmental Protection Agency (US EPA) Order 1000.18, February 16, 1979.

US EPA. 1981. "Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples," Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981.

US EPA. 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. Region 4 Science and Ecosystem Support Division (SESD), Athens, GA.

US EPA. Analytical Support Branch Laboratory Operations and Quality Assurance Manual. Region 4 SESD, Athens, GA, Most Recent Version.

US EPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Region 4 SESD, Athens, GA, Most Recent Version.

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when packing, marking, labeling, and shipping environmental or waste samples. Refer to the SESD Safety, Health and Environmental Management Program (SHEMP) Procedures and Policy Manual and any pertinent site-specific Health and Safety Plans (HASPs) for guidelines on safety precautions. These guidelines, however, should only be used to complement the judgment of an experienced professional.

2 Shipment of Dangerous Goods

The project leader is responsible for determining if samples collected during a specific field investigation meet the definitions for dangerous goods. If a sample is collected of a material that is listed in the Dangerous Goods List, Section 4.2, IATA, then that sample must be identified, packaged, marked, labeled, and shipped according to the instructions given for that material. If the composition of the collected sample(s) is unknown, and the project leader knows or suspects that it is a regulated material (dangerous goods), the sample may not be offered for air transport. If the composition and properties of the waste sample or highly contaminated soil, sediment, or water sample are unknown, or only partially known, the sample may not be offered for air transport.

In addition, the shipment of pre-preserved sample containers or bottles of preservatives (e.g., NaOH pellets, HCL, etc.) which are designated as dangerous goods by IATA is regulated. Shipment of nitric acid is strictly regulated. Consult the IATA Dangerous Goods Regulations for guidance. ***Dangerous goods must not be offered for air transport by any personnel except SESD's dangerous goods shipment designee or other personnel trained and certified by IATA in dangerous goods shipment.***

3 Shipment of Environmental Samples

Guidance for the shipment of environmental laboratory samples by personnel is provided in a memorandum dated March 6, 1981, subject "Final National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Laboratory Samples". By this memorandum, the shipment of the following unpreserved samples is not regulated:

- Drinking water
- Treated effluent
- Biological specimens
- Sediment
- Water treatment plant sludge
- POTW sludge

In addition, the shipment of the following preserved samples is not regulated, provided the amount of preservative used does not exceed the amounts found in 40 CFR 136.3 or the USEPA Region 4 Analytical Support Branch Laboratory Operations and Quality Assurance Manual (ASBLOQAM), Most Recent Version. This provision is also discussed in correspondence between DOT and EPA (Department of Transportation, Letter from Edward T. Mazzullo, Director, Office of Hazardous Materials Standards, to Henry L. Longest II, Acting Assistant Administrator, USEPA, Ref No.: 02-0093, February 13, 2003). It is the shippers' (individual signing the air waybill) responsibility to ensure that proper amounts of preservative are used:

- Drinking water
- Ambient water
- Treated effluent
- Biological specimens
- Sediment
- Wastewater treatment plant sludge
- Water treatment plant sludge

Samples determined by the project leader to be in these categories are to be shipped using the following protocol, developed jointly between USEPA, OSHA, and DOT. This procedure is documented in the "Final National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Environmental Laboratory Samples."

Untreated wastewater and sludge from Publicly Owned Treatment Works (POTWs) are considered to be "diagnostic specimens" (not environmental laboratory samples). However, because they are not considered to be etiologic agents (infectious) they are not restricted and may be shipped using the procedures outlined below.

Environmental samples should be packed prior to shipment by air using the following procedures:

1. Allow sufficient headspace (ullage) in all bottles (except VOA containers with a septum seal) to compensate for any pressure and temperature changes (approximately 10 percent of the volume of the container).

2. Ensure that the lids on all bottles are tight (will not leak).

3. Place bottles in separate and appropriately sized polyethylene bags and seal the bags. If available, the use of Whirl-Pak bags is preferable, if unavailable seal regular bags with tape (plastic electrical tape).

4. Select a sturdy cooler in good repair. Secure and tape the drain plug with fiber or duct tape inside and outside. Line the cooler with a large heavy duty plastic bag.

5. Place cushioning/absorbent material in the bottom of the cooler and then place the containers in the cooler with sufficient space to allow for the addition of cushioning between the containers.

6. Put "blue ice" (or ice that has been "double bagged" in heavy duty polyethylene bags and properly sealed) on top of and/or between the containers. Fill all remaining space between the containers with absorbent material.

7. Securely fasten the top of the large garbage bag with tape (preferably plastic electrical tape).

8. Place the Chain-of-Custody Record or the CLP Traffic Report Form (if applicable) into a plastic bag, and tape the bag to the inner side of the cooler lid.

9. Close the cooler and securely tape (preferably with fiber tape) the top of the cooler shut. Chain-of-custody seals should be affixed to the top and sides of the cooler within the securing tape so that the cooler cannot be opened without breaking the seal.

Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

OPERATING PROCEDURE

Title: **Potable Water Supply Sampling**

Effective Date: November 1, 2007 **Number:** SESDPROC-305-R1

Authors

Name: Maria Labrador
Title: Environmental Engineer
Signature: M Labrador Date: 11/2/07

Approvals

Name: Antonio Quinones
Title: Chief, Enforcement and Investigations Branch
Signature: Date: 11/02/07

Name: Laura Ackerman
Title: Field Quality Manager, Science and Ecosystem Support Division
Signature: Laura Acker Date: 11/01/07

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Field Quality Manager.

History	Effective Date
SESDPROC-305-R1, *Potable Water Sampling*, replaces SESDPROC-305-R0 **General** Updated referenced operating procedures due to changes in title names and/or to reflect most recent version. **Title Page** Changed title for Antonio Quinones from Environmental Investigations Branch to Enforcement and Investigations Branch **Section 1.3** Updated information to reflect that the procedure is located on the H: drive of the LAN. Clarified Field Quality Manager (FQM) responsibilities. **Section 1.4** Alphabetized and revised the referencing style for consistency. **Section 1.5.1** Corrected the title of the Safety, Health, and Environmental Management Program Procedures and Policy Manual.	November 1, 2007
SESDPROC-305-R0, Potable Water Supply Sampling, Original Issue	February 05, 2007

TABLE OF CONTENTS

Contents

1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when collecting potable water supply samples for field screening or laboratory analysis.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when collecting and handling potable water supply samples in the field. On the occasion that SESD field personnel determine that any of the procedures described in this section are inappropriate, inadequate or impractical and that another procedure must be used to obtain a potable water supply sample, the variant procedure will be documented in the field log book, along with a description of the circumstances requiring its use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the H: drive of the SESD local area network. The Field Quality Manager (FQM) is responsible for ensuring the most recent version of the procedure is placed on the H: drive and for maintaining records of review conducted prior to its issuance.

1.4 References

International Air Transport Authority (IATA). Dangerous Goods Regulations, Most Recent Version

Puls, Robert W., and Michael J. Barcelona. Filtration of Ground Water Samples for Metals Analysis. *Hazardous Waste and Hazardous Materials* 6(4): 385-393 (1989).

Puls, Robert W., Don A. Clark, and Bert Bledsoe. Metals in Ground Water: Sampling Artifacts and Reproducibility. *Hazardous Waste and Hazardous Materials* 9(2): 149-162 (1992).

SESD Operating Procedure for Control of Records, SESDPROC-002, Most Recent Version

SESD Operating Procedure for Equipment Inventory and Management, SESDPROC-104, Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205, Most Recent Version

SESD Operating Procedure for Field pH Measurements, SESDPROC-100, Most Recent Version

SESD Operating Procedure for Field Sampling Quality Control, SESDPROC-011, Most Recent Version

SESD Operating Procedure for Field Specific Conductance Measurements, SESDPROC-101, Most Recent Version

SESD Operating Procedure for Field Temperature Measurements, SESDPROC-102, Most Recent Version

SESD Operating Procedure for Field Turbidity Measurements, SESDPROC-103, Most Recent Version

SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version

SESD Operating Procedure for Management of Investigation Derived Waste, SESDPROC-202, Most Recent Version

SESD Operating Procedure for Packaging, Marking, Labeling and Shipping of Environmental and Waste Samples, SESDPROC-209, Most Recent Version

SESD Operating Procedure for Sample and Evidence Management, SESDPROC-005, Most Recent Version

US EPA. 1975. Handbook for Evaluating Water Bacteriological Laboratories. Office of Research and Development (ORD), Municipal Environmental Research Laboratory. Cincinnati, Ohio.

US EPA. 1977. Sampling for Organic Chemicals and Microorganisms in the Subsurface, EPA-600/2-77-176

US EPA. 1978. Microbiological Methods for Monitoring the Environment, Water and Wastes, ORD, Environmental Monitoring and Support Laboratory. Cincinnati, Ohio

US EPA. 1995. Ground Water Sampling - A Workshop Summary. Proceedings from the Dallas, Texas November 30 - December 2, 1993 Workshop. Office of Research and Development Robert S. Kerr Environmental Research Laboratory. EPA/600/R-94/205.

US EPA. 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. Region 4 Science and Ecosystem Support Division (SESD), Athens, GA

US EPA. Analytical Support Branch Laboratory Operations and Quality Assurance Manual. Region 4 SESD, Athens, GA, Most Recent Version

US EPA. April 13, 1981. Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples. Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273)

US EPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Region 4 SESD, Athens, GA, Most Recent Version

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when collecting potable water supply samples. Refer to the SESD Safety, Health and Environmental Management Program (SHEMP) Procedures and Policy Manual and any pertinent site-specific Health and Safety Plans (HASP) for guidelines on safety precautions. These guidelines should be used to complement the judgment of an experienced professional. Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate.

1.5.2 Procedural Precautions

The following precautions should be considered when collecting potable water supply samples.

- Special care must be taken not to contaminate samples. This includes storing samples in a secure location to preclude conditions which could alter the properties of the sample. Samples shall be custody sealed during long-term storage or shipment.
- Always sample from the anticipated cleanest, i.e., least contaminated location, to the most contaminated location. This minimizes the opportunity for cross-contamination to occur during sampling.
- Collected samples must remain in the custody of the sampler or sample custodian until the samples are relinquished to another party.
- If samples are transported by the sampler, they will remain under his/her custody or be secured until they are relinquished.
- Shipped samples shall conform to all U.S. Department of Transportation (DOT) and/or International Air Transportation Association (IATA) hazardous materials shipping requirements.

- Documentation of field sampling is done in a bound logbook.
- Chain-of-custody documents shall be filled out and remain with the samples until custody is relinquished.
- All shipping documents, such as air bills, bills of lading, etc., shall be retained by the project leader and stored in a secure place.

2 Special Sampling Considerations

2.1 Volatile Organic Compounds (VOC) Analysis

Potable water supply samples for VOC analysis must be collected in 40 ml glass vials with Teflon® septa. The vials may be either preserved with concentrated hydrochloric acid or they may be unpreserved. Preserved samples have a two week holding time, whereas unpreserved samples have only a seven day holding time. In the great majority of cases, the preserved vials are used to take advantage of the extended holding time. In some situations however, it may be necessary to use the unpreserved vials. For example, if the potable water supply has a high amount of dissolved limestone, i.e., is highly calcareous, there will most likely be an effervescent reaction between the hydrochloric acid and the water, producing large numbers of fine bubbles. This will render the sample unacceptable. In this case, unpreserved vials should be used and arrangements must be confirmed with the laboratory to ensure that they can accept the unpreserved vials and meet the shorter sample holding times.

The samples should be collected with as little agitation or disturbance as possible. The vial should be filled so that there is a meniscus at the top of the vial and absolutely no bubbles or headspace should be present in the vial after it is capped. After the cap is securely tightened, the vial should be inverted and tapped on the palm of one hand to see if any undetected bubbles are dislodged. If a bubble or bubbles are present, the vial should be topped off using a minimal amount of sample to re-establish the meniscus. Care should be taken not to flush any preservative out of the vial during topping off. If, after topping off and capping the vial, bubbles are still present, a new vial should be obtained and the sample re-collected.

2.2 Special Precautions for Trace Contaminant Potable Water Supply Sampling

- A clean pair of new, non-powdered, disposable gloves will be worn each time a different location is sampled and the gloves should be donned immediately prior to sampling. The gloves should not come in contact with the media being sampled and should be changed any time during sample collection when their cleanliness is compromised.
- Sample containers for samples suspected of containing high concentrations of contaminants shall be stored separately.
- Sample collection activities shall proceed progressively from the least suspected contaminated area to the most suspected contaminated area if sampling devices are to be reused. Samples of waste or highly contaminated media must not be placed in the same ice chest as environmental (i.e., containing low contaminant levels) or background samples.
- If possible, one member of the field sampling team should take all the notes and photographs, fill out tags, etc., while the other members collect the samples.
- Samplers must use new, verified certified-clean disposable or non-disposable equipment cleaned according to procedures contained in SESD Operating

Procedure for Field Equipment Cleaning and Decontamination (SESDPROC-205) for collection of samples for trace metals or organic compound analyses.

2.3 Sample Handling and Preservation Requirements

The following procedures should be followed when collecting samples from potable water supplies:

1. Potable water supply samples will typically be collected from a tap or spigot located at or near the well head or pump house and before the water supply is introduced into any storage tanks or treatment units. Efforts should be made to reduce the flow from either the tap or spigot during sample collection to minimize sample agitation.
2. During sample collection, make sure that the tap or spigot does not contact the sample container.
3. Place the sample into appropriate, labeled containers. Samples collected for VOC analysis must not have any headspace (see Section 2.1, Volatile Organic Compound Analysis). All other sample containers must be filled with an allowance for ullage.
4. All samples requiring preservation must be preserved as soon as practically possible, ideally immediately at the time of sample collection. If preserved VOC vials are used, these will be preserved with concentrated hydrochloric acid by Analytical Support Branch (ASB) personnel prior to departure for the field investigation. All other chemical preservatives required for the remaining suite of analytes will be supplied by ASB personnel and will be added to the samples by SESD field personnel or other authorized persons. The adequacy of sample preservation will be checked after the addition of the preservative for all samples except for the samples collected for VOC analysis. Additional preservative should be added to achieve adequate preservation. Preservation requirements for groundwater samples are found in the USEPA Region 4 Analytical Support Branch Laboratory Operations and Quality Assurance Manual (ASBLOQAM), Most Recent Version.

2.4 Quality Control

Equipment blanks should be collected if equipment is field cleaned and re-used on-site or if necessary to document that low-level contaminants were not introduced by any sampling equipment.

2.5 Records

Information generated or obtained by SESD personnel will be organized and accounted for in accordance with SESD records management procedures found in the SESD Operating Procedure for Control of Records (SESDPROC-002). Field notes, recorded in a bound field logbook, will be generated, as well as chain-of-custody documentation in accordance with the SESD Operating Procedure for Sample and Evidence Management (SESDPROC-005) and SESD Operating Procedure Logbooks (SESDPROC-010).

3 Potable Water Supply Sampling – Sample Site Selection

3.1 General

The following should be considered when choosing the location to collect a potable water sample:

- Taps selected for sample collection should be supplied with water from a service pipe connected directly to a water main in the segment of interest.

- Whenever possible, choose the tap closest to the water source, and prior to the water lines entering the residence, office, building, etc., and also prior to any holding or pressurization tanks.

- The sampling tap must be protected from exterior contamination associated with being too close to a sink bottom or to the ground. Contaminated water or soil from the faucet exterior may enter the bottle during the collection procedure since it is difficult to place a bottle under a low tap without grazing the neck interior against the outside faucet surface. If the tap is too close to the ground for direct collection into the appropriate container, it is acceptable to use a smaller container to transfer sample to a larger container. The smaller container should be made of glass or stainless steel, and should be decontaminated to the same standards as the larger container.

- Leaking taps that allow water to discharge from around the valve stem handle and down the outside of the faucet, or taps in which water tends to run up on the outside of the lip, are to be avoided as sampling locations.

- Disconnect any hoses, filters, or aerators attached to the tap before sampling. These devices can harbor a bacterial population if they are not routinely cleaned or replaced when worn or cracked.

- Taps where the water flow is not constant should be avoided because temporary fluctuation in line pressure may cause clumps of microbial growth that are lodged in a pipe section or faucet connection to break loose. A smooth flowing water stream at moderate pressure without splashing should be used. The sample should be collected without changing the water flow. It may be appropriate to reduce the flow for the volatile organic compounds aliquot to minimize sample agitation.

Occasionally, samples are collected to determine the contribution of system-related variables (e.g., transmission pipes, water coolers, water heaters, holding tanks, pressurization tanks, etc.) to the quality of potable water supplies. In these cases, it may be necessary to ensure that the water source has not been used for a specific time interval (e.g., over a weekend or a three- or four-day holiday period). Sample collection may consist of collecting a sample of the initial flush, collecting a sample after several

minutes, and collecting another sample after the system being investigated has been completely purged.

When sampling for bacterial content, the sample container should not be rinsed before use due to possible contamination of the sample container or removal of the thiosulfate dechlorinating agent (if used). When filling any sample container, care should be taken that splashing drops of water from the ground or sink do not enter into either the bottle or cap.

When sampling at a water treatment plant, samples are often collected from the raw water supply and the treated water after chlorination.

Obtain the name(s) of the resident or water supply owner/operator, the resident's exact mailing address, and the resident's home and work telephone numbers. The information is required so that the residents or water supply owner/operators can be informed of the results of the sampling program.

4 Potable Water Supply Sampling Methods - Purging

4.1 General

4.1.1 Purging and Purge Adequacy

Purging is the process of removing stagnant water immediately prior to sampling. In order to determine when an adequate purge has occurred, field investigators should monitor the pH, specific conductance, temperature, and turbidity of the water removed during purging. For potable water supply sampling it is recommended to purge the system for at least 15 minutes when possible.

An adequate purge is achieved when the pH, specific conductance, and temperature of the potable water have stabilized and the turbidity has either stabilized or is below 10 Nephelometric Turbidity Units (NTUs) (twice the Primary Drinking Water Standard of 5 NTUs). Although 10 NTUs is normally considered the minimum goal for most water sampling objectives, lower turbidity has been shown to be easily achievable in most situations and reasonable attempts should be made to achieve these lower levels. Stabilization occurs when, for at least three consecutive measurements, the pH remains constant within 0.1 Standard Unit (SU), specific conductance varies no more than approximately 10 percent, and the temperature is constant. There are no set criteria establishing how many total sets of measurements are adequate to document stability of parameters.

If, after 15 minutes, the in situ chemical parameters have not stabilized according to the above criteria, additional water can be removed. If the parameters have not stabilized after 15 minutes, it is at the discretion of the project leader whether or not to collect a sample or to continue purging.

4.2 Potable Water Samples Collected from Wells with In-Place Plumbing

Wells with in-place plumbing are commonly found at municipal water treatment plants, industrial water supplies, private residences, etc. The objective of purging wells with in-place pumps is the same as with monitoring wells without in-place pumps, i.e., to ultimately collect a water sample representative of aquifer conditions. Among the types of wells identified in this section, two different approaches are necessary.

A permanent well with an in-place pump should, in all respects, be treated like a well without a pump. One limitation is that in most cases the in-place pump is “hard” mounted, that is, the pump is suspended in the well at a pre-selected depth and cannot be moved up or down during purging and sampling. In these cases, well volumes are removed, parameters are measured and the well is sampled from the pump discharge, after volume removal and parameter conditions have been met.

In the case of the other types of wells, i.e., municipal, industrial and residential supply wells, however, not enough is generally known about the construction aspects of the wells to apply the same criteria as used for monitoring wells, i.e., 3 to 5 well volumes. The volume to be purged in these situations, therefore, depends on several factors: whether the pumps are running continuously or intermittently and whether or not any storage/pressure tanks are located between the sampling point and the pump. The following considerations and procedures should be followed when purging wells with in-place plumbing under the conditions described.

4.2.1 Continuously Running Pumps

If the pump runs more or less continuously, no purge (other than opening a valve and allowing it to flush for a few minutes) is necessary. If a storage tank is present, a spigot, valve or other sampling point should be located between the pump and the storage tank. If not, locate the valve closest to the tank. Measurements of pH, specific conductance, temperature, and turbidity are recorded at the time of sampling.

4.2.2 Intermittently or Infrequently Running Pumps

If the pump runs intermittently or infrequently, best judgment should be utilized to remove enough water from the plumbing to flush standing water from the piping and any storage tanks that might be present. Generally, under these conditions, 15 to 30 minutes will be adequate. Measurements of pH, specific conductance, temperature and turbidity should be made and recorded at intervals during the purge and the final measurements made at the time of sampling should be considered the measurements of record for the event.

4.3 Investigation Derived Waste

Purging generates quantities of purge water or investigation derived waste (IDW), the disposition of which must be considered. See SESD Operating Procedure for Management of Investigation Derived Waste (SESDPROC-202) for guidance on management or disposal of this waste.

5 Potable Water Supply Sampling Methods – Sampling

5.1 General

Sampling is the process of obtaining, containerizing, and preserving (if required) a potable water supply water sample after the purging process is complete. It is recognized that there are situations, such as industrial or municipal supply wells or private residential wells, where a well may be equipped with a dedicated pump from which a sample would not normally be collected. Discretion should always be used in obtaining a sample.

5.2 Collecting Samples from In-Place Plumbing

Samples should be collected following purging from a valve or cold water tap as near to the well as possible, preferably prior to any storage/pressure tanks or physical/chemical treatment system that might be present. Remove any hose that may be present before sample collection and reduce the flow to a low level to minimize sample disturbance, particularly with respect to volatile organic constituents. Samples should be collected directly into the appropriate containers (see the ASBLOQAM for a list of containers). It may be necessary to use a secondary container, such as a clean 8 oz. or similar size sample jar or a stainless steel scoop, to obtain and transfer samples from spigots with low ground clearance. All measurements for pH, specific conductance, temperature, and turbidity should be recorded at the time of sample collection.

1. Ideally, the sample should be collected from a tap or spigot located at or near the well head or pump house and before the water supply is introduced into any storage tanks or treatment units. If the sample must be collected at a point in the water line beyond pressurization or holding tank, a sufficient volume of water should be purged to provide a complete exchange of fresh water into the tank and at the location where the sample is collected. If the sample is collected from a tap or spigot located just before a storage tank, spigots located inside the building or structure should be turned on to prevent any backflow from the storage tank to the sample tap or spigot. It is generally advisable to open several taps during the purge to ensure a rapid and complete exchange of water in the tanks.

2. Purge the system for at least 15 minutes when possible. During the purge period, obtain at least three sets of readings as follows: after purging for several minutes, measure the pH, specific conductivity, temperature and turbidity of the water. Continue to measure these parameters to assess for stabilization.

3. After three sets of readings have been obtained, samples may be collected. If stabilization has not occurred after the 15-minute purge period, it is at the discretion of the project leader to collect the sample or continue purging and monitoring the parameters. This would depend on the condition of the system and the specific objectives of the investigation.

5.3 Sample Preservation

After sample collection, all samples requiring preservation must be preserved as soon as practical. Consult the ASBLOQAM for the correct preservative for the particular analytes of interest. All samples preserved using a pH adjustment (except VOCs) must be checked, using pH strips, to ensure that they were adequately preserved. This is done by pouring a small volume of sample over the strip. Do not place the strip in the sample. Samples requiring reduced temperature storage should be placed on ice immediately.

5.4 Special Sample Collection Procedures

5.4.1 Trace Organic Compounds and Metals

Special sample handling procedures should be instituted when trace contaminant samples are being collected. All sampling equipment which comes into contact with the water must be cleaned in accordance with the cleaning procedures described in SESD Operating Procedure for Field Equipment Cleaning and Decontamination, (SESDPROC-205).

5.4.2 Filtering

As a standard practice, potable water samples will not be filtered for routine analysis. Filtering will usually only be performed to determine the fraction of major ions and trace metals passing the filter and used for flow system analysis and for the purpose of geochemical speciation modeling. Filtration is not allowed to correct for improperly designed or constructed wells, inappropriate sampling methods, or poor sampling technique.

When samples are collected for routine analyses and are filtered, both filtered and non-filtered samples will be submitted for analyses. Samples for organic compounds analysis should not be filtered. Prior to filtration of the water sample for any reason other than geochemical speciation modeling, the following criteria must be demonstrated to justify the use of filtered samples for inorganic analysis:

1. The water samples were collected using sampling techniques in accordance with this section, and the water samples were analyzed in accordance with USEPA approved methods.

2. Efforts have been undertaken to minimize any persistent sample turbidity problems.

3. Turbidity measurements should be taken during purging and sampling to demonstrate stabilization or lack thereof. These measurements should be documented in the field notes. If the water sample appears to have either a chemically-induced elevated turbidity, such as would occur with precipitate

formation, or a naturally elevated colloid or fine, particulate-related turbidity, filtration will not be allowed.

If filtration is necessary for purposes of geochemical modeling or other **pre-approved** cases, the following procedures are suggested:

1. Accomplish in-line filtration through the use of disposable, high capacity filter cartridges (barrel-type) or membrane filters in an in-line filter apparatus. The high capacity, barrel-type filter is preferred due to the higher surface area associated with this configuration. If a membrane filter is utilized, a minimum diameter of 142 mm is suggested.

2. Use a 5 µm pore-size filter for the purpose of determining the colloidal constituent concentrations. A 0.1 µm pore-size filter should be used to remove most non-dissolved particles.

3. Rinse the cartridge or barrel-type filter with 500 milliliters of the solute (potable water to be sampled) prior to collection of sample. If a membrane filter is used, rinse with 100 milliliters of solute prior to sample collection.

Potential differences could result from variations in filtration procedures used to process water samples for the determination of trace element concentrations. A number of factors associated with filtration can substantially alter "dissolved" trace element concentrations; these include filter pore size, filter type, filter diameter, filtration method, volume of sample processed, suspended sediment concentration, suspended sediment grain-size distribution, concentration of colloids and colloidal-associated trace elements, and concentration of organic matter. Therefore, consistency is critical in the comparison of short-term and long-term results. Further guidance on filtration may be obtained from the following: 1) Metals in Ground Water: Sampling Artifacts and Reproducibility; 2) Filtration of Ground Water Samples for Metals Analysis; and 3) Ground Water Sampling - A Workshop Summary

Bacterial Sampling

Whenever wells (normally potable wells) are sampled for bacteriological parameters, care must be taken to ensure the sterility of all sampling equipment and all other equipment entering the well. Further information regarding bacteriological sampling is available in the following: 1) Sampling for Organic Chemicals and Microorganisms in the Subsurface; 2) Handbook for Evaluating Water Bacteriological Laboratories; and 3) Microbiological Methods for Monitoring the Environment, Water and Wastes.

5.5 Specific Sampling Equipment Quality Assurance Techniques

All equipment used to collect potable water samples shall be cleaned as outlined in the SESD Operating Procedure for Field Equipment Cleaning and Decontamination

(SESDPROC-205) and repaired, if necessary, before being stored at the conclusion of field studies. Cleaning procedures utilized in the field or field repairs shall be thoroughly documented in field records.

5.6 Auxiliary Data Collection

During potable water sample collection, it may be necessary to record additional sampling data, such as flow rates, etc. This information should be documented in the field records.

Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

OPERATING PROCEDURE

Title: **Surface Water Sampling**

Effective Date: November 1, 2007

Number: SESDPROC-201-R1

Authors

Name: Joe Compton
Title: Life Scientist
Signature: Joe Compton
Date: 11/7/07

Name: Laura Ackerman
Title: Environmental Engineer
Signature: Laura Acker
Date: 11|02|07

Approvals

Name: Antonio Quinones
Title: Chief, Enforcement and Investigations Branch
Signature:
Date: 11/02/07

Name: Bill Cosgrove
Title: Chief, Ecological Assessment Branch
Signature:
Date: 11/2/07

Name: Laura Ackerman
Title: Field Quality Manager, Science and Ecosystem Support Division
Signature: Laura Acker
Date: 11|02|07

Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Field Quality Manager.

History	Effective Date
SESDPROC-201-R1, *Surface Water Sampling*, replaces SESDPROC-201-R0. **General** Corrected any typographical, grammatical and/or editorial errors. **Title Page** Changed title for Antonio Quinones from Environmental Investigations Branch to Enforcement and Investigations Branch. Changed Bill Cosgrove's title from Acting Chief to Chief. **Section 1.3** Updated information to reflect that the procedure is located on the H: drive of the LAN. Clarified Field Quality Manager (FQM) responsibilities. **Section 1.4** Updated referenced operating procedures due to changes in title names. Alphabetized and revised the referencing style for consistency. Added two references (49 CFR and SESDPROC-206). **Section 1.5.1** Corrected the title of the Safety, Health, and Environmental Management Program Procedures and Policy Manual. **Section 1.5.2, 4th bullet** Added references to the CFR and IATA's Dangerous Goods Regulations. **Section 2.2, 5th bullet** Added reference to SESDPROC-206. **Section 2.5** Updated referenced operating procedures due to changes in title names.	November 1, 2007
SESDPROC-201-R0, *Surface Water Sampling*, Original Issue	February 05, 2007

TABLE OF CONTENTS

Contents

1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when collecting surface water samples for field screening or laboratory analysis.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when collecting and handling surface water samples in the field. On the occasion that SESD field personnel determine that any of the procedures described in this section are either inappropriate, inadequate or impractical and that another procedure must be used to obtain a surface water sample, the variant procedure will be documented in the field log book, along with a description of the circumstances requiring its use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and have been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the H: drive of the SESD local area network. The Field Quality Manager (FQM) is responsible for ensuring the most recent version of the procedure is placed on the H: drive and for maintaining records of review conducted prior to its issuance.

1.4 References

International Air Transport Authority (IATA). Dangerous Goods Regulations, Most Recent Version

SESD Operating Procedure for Control of Records, SESDPROC-002, Most Recent Version

SESD Operating Procedure for Sample and Evidence Management, SESDPROC-005, Most Recent Version

SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version

SESD Operating Procedure for Field Sampling Quality Control, SESDPROC-011, Most Recent Version

SESD Operating Procedure for Field pH Measurement, SESDPROC-100, Most Recent Version

SESD Operating Procedure for Field Specific Conductance Measurement, SESDPROC-101, Most Recent Version

SESD Operating Procedure for Field Turbidity Measurement, SESDPROC-103, Most Recent Version

SESD Operating Procedure for Equipment Inventory and Management, SESDPROC-108, Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205, Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination at the FEC, SESDPROC-206, Most Recent Version

SESD Operating Procedure for Packaging, Marking, Labeling and Shipping of Environmental and Waste Samples, SESDPROC-209, Most Recent Version

Title 49 Code of Federal Regulations, Pts. 171 to 179, Most Recent Version

United States Environmental Protection Agency (US EPA). 1981. "Final Regulation Package for Compliance with DOT Regulations in the Shipment of Environmental Laboratory Samples," Memo from David Weitzman, Work Group Chairman, Office of Occupational Health and Safety (PM-273), April 13, 1981.

US EPA. 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. Region 4 Science and Ecosystem Support Division (SESD), Athens, GA

US EPA. Analytical Support Branch Laboratory Operations and Quality Assurance Manual. Region 4 SESD, Athens, GA, Most Recent Version

US EPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Region 4 SESD, Athens, GA, Most Recent Version

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when collecting surface water samples. Refer to the SESD Safety, Health and Environmental Management Program (SHEMP) Procedures and Policy Manual and any pertinent site-specific Health and Safety Plans (HASP) for guidelines on safety precautions. These guidelines should be used to complement the judgment of an experienced professional. Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate.

1.5.2 Procedural Precautions

The following precautions should be considered when collecting surface water samples.

- Special care must be taken not to contaminate samples. This includes storing samples in a secure location to preclude conditions which could alter the properties of the sample. Samples shall be custody sealed during long-term storage or shipment.
- Collected samples are in the custody of the sampler or sample custodian until the samples are relinquished to another party.
- If samples are transported by the sampler, they will remain under his/her custody or be secured until they are relinquished.
- Shipped samples shall conform to all U.S. Department of Transportation (DOT) rules of shipment found in Title 49 of the Code of Federal Regulations (49 CFR parts 171 to 179), and/or International Air Transportation Association (IATA) hazardous materials shipping requirements found in the current edition of IATA's Dangerous Goods Regulations.
- Documentation of field sampling is done in a bound logbook.
- Chain-of-custody documents shall be filled out and remain with the samples until custody is relinquished.
- All shipping documents, such as air bills, bills of lading, etc., shall be retained by the project leader and stored in a secure place.

2 Special Sampling Considerations

2.1 Volatile Organic Compounds (VOC) Analysis

Surface water samples for VOC analysis must be collected in 40 ml glass vials with Teflon® septa. The vial may be either preserved with concentrated hydrochloric acid or they may be unpreserved. Preserved samples have a two week holding time, whereas, unpreserved samples have only a seven day holding time. In the great majority of cases, the preserved vials are used to take advantage of the extended holding time. In some situations, however, it may be necessary to use the unpreserved vials. For example, if the surface water sample contains a high concentration of dissolved calcium carbonate, there may be an effervescent reaction between the hydrochloric acid and the water, producing large numbers of fine bubbles. This will render the sample unacceptable. In this case, unpreserved vials should be used and arrangements must be confirmed with the laboratory to ensure that they can accept the unpreserved vials and meet the shorter sample holding times.

The samples should be collected with as little agitation or disturbance as possible. The vial should be filled so that there is a reverse or convex meniscus at the top of the vial and absolutely no bubbles or headspace should be present in the vial after it is capped. After the cap is securely tightened, the vial should be inverted and tapped on the palm of one hand to see if any undetected bubbles are dislodged. If a bubble or bubbles are present, the vial should be topped off using a minimal amount of sample to re-establish the meniscus. Care should be taken not to flush any preservative out of the vial during topping off. If, after topping off and capping the vial, bubbles are still present, a new vial should be obtained and the sample re-collected.

Samples for VOC analysis must be collected using either stainless steel or Teflon® equipment.

2.2 Special Precautions for Trace Contaminant Surface Water Sampling

- A clean pair of new, non-powdered, disposable gloves will be worn each time a different location is sampled and the gloves should be donned immediately prior to sampling. The gloves should not come in contact with the media being sampled and should be changed any time during sample collection when their cleanliness is compromised.
- Sample containers for samples suspected of containing high concentrations of contaminants shall be stored separately.
- All background or control samples shall be collected and placed in separate ice chests or shipping containers. Sample collection activities shall proceed progressively from the least suspected contaminated area to the most suspected contaminated area. Samples of waste or highly contaminated media must not be placed in the same ice chest as

environmental (i.e., containing low contaminant levels) or background samples.

- If possible, one member of the field sampling team should take all the notes and photographs, fill out tags, etc., while the other members collect the samples.
- Samplers must use new, verified and certified-clean disposable or non-disposable equipment cleaned according to procedures contained in SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205, or SESD Operating Procedure for Field Cleaning and Decontamination at the FEC, SESDPROC-206, for collection of samples for trace metals or organic compound analyses.

2.3 Sample Handling and Preservation Requirements

1. Surface water samples will typically be collected either by directly filling the container from the surface water body being sampled or by decanting the water from a collection device such as a stainless steel scoop or other device.
2. During sample collection, if transferring the sample from a collection device, make sure that the device does not come in contact with the sample containers.
3. Place the sample into appropriate, labeled containers. Samples collected for VOC analysis must not have any headspace (see Section 2.1, Volatile Organic Compound Analysis). All other sample containers must be filled with an allowance for ullage.
4. All samples requiring preservation must be preserved as soon as practically possible, ideally immediately at the time of sample collection. If preserved VOC vials are used, these will be preserved with concentrated hydrochloric acid by ASB personnel prior to departure for the field investigation. All other chemical preservatives required for the remaining suite of analytes will be supplied by ASB personnel and will be added to the samples by SESD field personnel or other authorized persons. The adequacy of sample preservation will be checked after the addition of the preservative for all samples, except for the samples collected for VOC analysis. If it is determined that a sample is not adequately preserved, additional preservative should be added to achieve adequate preservation. Preservation requirements for surface water samples are found in the USEPA Region 4 Analytical Support Branch Laboratory Operations and Quality Assurance Manual (ASBLOQAM), Most Recent Version.
5. All samples preserved using a pH adjustment (except VOCs) must be checked, using pH strips, to ensure that they were adequately preserved. This is done by pouring a small volume of sample over the strip. Do not place the strip in the sample. Samples requiring reduced temperature storage should be placed on ice immediately.

2.4 Quality Control

If possible, a control sample should be collected from a location not affected by the possible contaminants of concern and submitted with the other samples. In streams or other bodies of moving water, the control sample should be collected upstream of the sampled area. For impounded bodies of water, particularly small lakes or ponds, it may be difficult or inappropriate to obtain an unbiased control from the same body of water from which the samples are collected. In these cases, it may be appropriate to collect a background sample from a similar impoundment located near the sampled body of water if there is a reasonable certainty that the background location has not been impacted. Equipment blanks should be collected if equipment is field cleaned and re-used on-site or if necessary to document that low-level contaminants were not introduced by pumps, bailers or other sampling equipment.

2.5 Records

Information generated or obtained by SESD personnel will be organized and accounted for in accordance with SESD records management procedures found in SESD Operating Procedure for Control of Records, SESDPROC-002. Field notes, recorded in a bound field logbook, will be generated, as well as chain-of-custody documentation in accordance with SESD Operating Procedure for Logbooks, SESDPROC-010 and SESD Operating Procedure for Sample and Evidence Management, SESDPROC-005.

3 General Considerations

3.1 General

The surface water sampling techniques and equipment described in the following Sections 4, 5 and 6 of this procedure document are designed to minimize effects on the chemical and physical integrity of the sample. If the procedures in this section are followed, a representative sample of the surface water should be obtained.

3.2 Equipment Selection Considerations

The physical location of the investigator when collecting a sample may dictate the equipment to be used. If surface water samples are required, direct dipping of the sample container into the stream is desirable. Collecting samples in this manner is possible when sampling from accessible locations such as stream banks or by wading or from low platforms, such as small boats or piers. Wading or streamside sampling from banks, however, may cause the re-suspension of bottom deposits and bias the sample. Wading is acceptable if the stream has a noticeable current (is not impounded), and the samples are collected while facing upstream. If the stream is too deep to wade, or if the sample must be collected from more than one water depth, or if the sample must be collected from an elevated platform (bridge, pier, etc.), supplemental sampling equipment must be used.

To collect a surface water sample from a water body or other surface water conveyance, a variety of methods can be used:

- Dipping Using Sample Container
- Scoops
- Peristaltic Pumps
- Submersible Pumps
- Discrete Depth Samplers
- Bailers
- Buckets

Regardless of the method used, precautions should be taken to insure that the sample collected is representative of the water body or conveyance. These methods are discussed in the following sections.

4 Dipping Using Sample Container

A sample may be collected directly into the sample container when the surface water source is accessible by wading or other means. The sampler should face upstream if there is a current and collect the sample without disturbing the bottom sediment. The surface water sample should always be collected prior to the collection of a sediment sample at the same location. The sampler should be careful not to displace the preservative from a pre-preserved sample container, such as the 40-ml VOC vial.

5 Scoops

Stainless steel scoops provide a means of collecting surface water samples from surface water bodies that are too deep to access by wading. They have a limited reach of about eight feet and if samples from distances too far to access using this method are needed, a mobile platform, such as a boat may be required.

Stainless steel scoops are useful for reaching out into a body of water to collect a surface water sample. The scoop may be used directly to collect and transfer a surface water sample to the sample container, or it may be attached to an extension in order to access the selected sampling location.

6 Peristaltic Pumps

Another device that can be effectively used to sample a water column, such as a shallow pond or stream, is the peristaltic pump/vacuum jug system. The peristaltic pump can be used to collect a water sample from any depth if the pump is located at or near the surface water elevation. There is no suction limit for these applications. The use of a metal conduit to which the tubing is attached, allows for the collection of a vertical sample (to about a 25 foot depth) which is representative of the water column. The tubing intake is positioned in the water column at the desired depth by means of the conduit. Using this method, discrete samples may be collected by positioning the tubing intake at one depth or a vertical composite may be collected by moving the tubing intake at a constant rate vertically up and down the water column over the interval to be composited.

Samples for VOC analysis cannot be collected directly from the peristaltic pump discharge or from the vacuum jug. If a peristaltic pump is used for sample collection and VOC analysis is required, the VOC sample must be collected using one of the "soda straw" variations. Ideally, the tubing intake will be placed at the depth from which the sample is to be collected and the pump will be ran for several minutes to fill the tubing with water representative of that interval. After several minutes, the pump is turned off and the tubing string is retrieved. The pump speed is then reduced to a slow pumping rate and the pump direction is reversed. After turning the pump back on, the sample stream is collected into the VOC vials as it is pushed from the tubing by the pump. Care must be taken to prevent any water that was in contact with the silastic pump head tubing from being incorporated into the sample.

7 Discrete Depth Samplers

When discrete samples are desired from a specific depth, and the parameters to be measured do not require a Teflon®-coated sampler, a standard Kemmerer or Van Dorn sampler may be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the ends of the sampler open while being lowered in a vertical position, thus allowing free passage of water through the cylinder. The Van Dorn sampler is plastic and is lowered in a horizontal position. In each case, a messenger is sent down a rope when the sampler is at the designated depth, to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill respective sample containers. With a rubber tube attached to the valve, dissolved oxygen sample bottles can be properly filled by allowing an overflow of the water being collected. With multiple depth samples, care should be taken not to disturb the bottom sediment, thus biasing the sample.

When metals and organic compounds parameters are of concern, then a double-check valve, stainless steel bailer or Kemmerer sampler should be used to collect the sample.

8 Bailers

Teflon® bailers may also be used for surface water sampling if the study objectives do not necessitate a sample from a discrete interval in the water column. A closed-top bailer with a bottom check-valve is sufficient for many studies. As the bailer is lowered through the water column, water is continually displaced through the bailer until the desired depth is reached, at which point the bailer is retrieved. This technique may not be successful where strong currents are found.

9 Buckets

A plastic bucket can be used to collect samples for measurement of water quality parameters such as pH, temperature, and conductivity. Samples collected for analysis of classical water quality parameters including but not limited to ammonia, nitrate-nitrite, phosphorus, and total organic carbon may also be collected with a bucket. Typically, a bucket is used to collect a sample when the water depth is too great for wading, it is not possible to deploy a boat, or access is not possible (excessive vegetation or steep embankments) and the water column is well mixed. The water body is usually accessed from a bridge. The bucket is normally lowered by rope over the side of the bridge. Upon retrieval, the water is poured into the appropriate sample containers

Caution should be exercised whenever working from a bridge. Appropriate measures should be taken to insure the safety of sampling personnel from traffic hazards.

10 Submersible Pumps

Submersible pumps can be used to collect surface water samples directly into a sample container. The constituents of interest should be taken into consideration when choosing the type of submersible pump and tubing to be used. If trace contaminant sampling of extractable organic compounds and/or inorganic analytes will be conducted, the submersible pump and all of its components should be constructed of inert materials such as stainless steel and Teflon®. The tubing should also be constructed of Teflon®. If re-using the same pump between sample locations, the pump should be decontaminated using SESD Operating Procedure for Field Equipment Cleaning and Decontamination, (SESDPROC-205). New tubing should be used at each sample location.

If the samples will be analyzed for classical parameters such as ammonia, nitrate-nitrite, phosphorus, or total organic carbon, the pump and tubing may be constructed of components other than stainless steel and Teflon®. The same pump and tubing may be re-used at each sampling station after rinsing with deionized water and then purging several volumes of sample water through the pump and tubing prior to filling the sample containers.

Either a grab or composite sample can be collected using a submersible pump. A composite sample can be collected by raising and lowering the pump throughout the water column. If a composite sample is collected, it may be necessary to pump the sample into a compositing vessel for mixing prior to dispensing into the sample containers. If a compositing vessel is required, it should be constructed of materials compatible with the constituents of concern and decontaminated between sample stations according to appropriate procedures, again depending on the constituents of concern.

11 Automatic Samplers

Where unattended sampling is required (e.g., storm-event sampling, time-of-travel studies) an automatic sampler may be used. The automatic sampling device may be used to collect grab samples based on time, in-stream flow or water level or used to collect composite samples as dictated by the study data needs. The automatic sampling device should be calibrated prior to deployment to insure the proper volume is collected. The manufacturer's instruction manual should be consulted for automatic sampler operation.

12 Trace-Level Mercury Sampling

In order to prevent contamination during sample collection, Region 4 has developed this sampling procedure for trace-level mercury analysis (< 1 part per trillion). This procedure is based on EPA Method 1669.

A vacuum chamber assembly is utilized to collect surface water samples for trace-level mercury analyses. The vacuum chamber assembly consists of the following: 1) an airtight acrylic, cylindrical chamber with an o-ring sealed lid to hold the sample bottle, 2) a Teflon® sample tubing that connects to a centered Teflon® compression fitting on top of the chamber. The other end of the tubing passes through a rigid Teflon® pole for stability and has a modified magnetic screen holder at the intake, and a hand vacuum pump. The chamber is designed to hold a 2-liter sample bottle; however, smaller sample containers may be utilized with a spacer inserted into the chamber. A two inch square of 100 µm Nitex® screen is used on the magnetic screen holder at the intake to prevent large pieces of debris from entering the sample. The screen does not prevent the passage of particulate organic matter which is often prevalent in surface water. The vacuum chamber has a second off-center compression fitting with a 4 inch piece of Teflon® tubing inserted in the fitting. A piece of clear Tygon® tubing approximately 18-24 inches long is placed over the small piece of Teflon®. The Teflon® adds stability to the tubing and keeps it from crimping. The Tygon® is attached to the hand pump and the chamber with electrical tape. The Nitex® screen intake is inserted into the water to be sampled and a vacuum is pulled on the chamber by means of the hand vacuum pump, thus drawing a water sample into a sample container placed directly beneath the intake tubing within the chamber.

Teflon® bottles or 300-Series glass bottles with single use Teflon®-lined caps may be used for sample collection. All sample containers used for collection of trace-level mercury water samples must be pre-cleaned in a laboratory as described in EPA Method 1631. Teflon® containers should also be etched on the outside of the bottle with a unique identification number for QA purposes. All bottles for trace-level sampling must be double bagged in re-sealable bags. Water samples collected for total, inorganic, methyl or ethyl mercury analyses are pumped into appropriately cleaned bottles. Preservation should be done in a clean room laboratory that has been specifically prepared for the preparation of trace level samples (positive pressure ventilation, sticky floor mats, etc.). Preservation must occur within 48 hours of sample collection, sooner if possible. Region 4 utilizes laboratory preservation of trace-level mercury samples in order to minimize the potential for contamination, and if split samples are required, they must be split in a trace-level clean room laboratory.

The following quality assurance/quality control (QA/QC) samples are collected in conjunction with low-level mercury samples:

- bottle blanks
- equipment blanks

- air deposition blanks
- trip blanks
- duplicates, and
- splits

A bottle blank is prepared in the lab with reagent-grade water to insure the cleanliness of the bottles prior to use in the field. After decontamination of the Teflon® tubing by pumping and discarding several sample container volumes of reagent-grade water through the tubing, (using the same amount of water used for sample collection in the field) an equipment blank sample is collected into an appropriately pre-cleaned sample container. Equipment blanks are collected at the beginning of each field trip and at the end of each day. The bottle blank and the equipment blank do not go out into the field and are preserved at the end of the day with the regular field samples.

Air deposition blanks are collected to determine if airborne mercury is present at the time of sample collection. The air deposition blanks consist of a pre-cleaned mercury sample container, filled with reagent-grade water by the laboratory that prepared the containers, and is shipped with the containers to the field. The air deposition blank is uncapped using "clean hands"/ "dirty hands" procedures (see below) and set near the sampling location throughout the duration of the mercury sample collection for that particular station. Once the mercury sample is collected, the air deposition blank is recapped and handled and processed with the other mercury samples. One air deposition blank is collected each day by each field crew unless atmospheric conditions or site conditions warrant additional blanks.

Trip blanks are utilized to determine if any contaminants of interest to the study are potentially introduced to the samples during storage and transport to the laboratory. Trip blanks are prepared by the laboratory which supplies the mercury sample containers. The trip blanks consist of cleaned bottles which are filled with reagent-grade water by the laboratory and shipped with the other clean sample containers. A dark plastic bag is placed in each cooler that will hold the trace-level water samples. One trip blank is placed in each trace-level cooler of samples and returned to the laboratory with the ambient trace-level water samples. All trace-level samples should be kept in the dark until they are preserved. The trip blanks are never opened in the field. Trip blanks are preserved in the clean room.

Duplicate samples are discrete samples collected at the same site and time to measure variability of collected samples and to assess sample collection consistency. Sample splits are aliquots of a minimum 500 ml poured from a single ambient sample. They must be split in a trace-level clean room laboratory.

In order to prevent cross contamination in samples analyzed for trace-level mercury in ambient surface waters, clean sampling protocols must be employed throughout the sampling effort. For each sampling event, one sampling team member is designated as "clean hands" and one as "dirty hands" (see below). All operations involving contact with the sample bottle and transfer of the sample from the sample collection device to the sample bottle are handled by the individual designated as "clean hands". "Dirty hands" is responsible for preparation of the sampling device (except the sample container) and for all other activities that do not involve direct contact with the sample.

Prior to sample collection with the vacuum chamber assembly, the Teflon® line is cleaned at each station by rinsing with ambient water as follows: A 2-liter poly bottle is placed into the chamber and filled half full with ambient water. The bottle is swirled to rinse it and the water is discarded downstream of sampling area. The same 2-liter poly bottle can be used at each station. Additional cleaning measures are not recommended as long as the chamber assembly is only used to collect ambient surface water samples. Detergent washes and acid rinses are not conducted due to potential mercury contamination from these solutions. If applicable, samples for other analyses can be collected in a poly bottle with the vacuum chamber assembly but should be collected before the trace-level sample as an additional means of flushing the sampling line prior to collection of the trace-level samples. It is not necessary to implement the "clean hands"/ "dirty hands" method for collection of non-mercury samples, but latex or vinyl gloves should be worn when any samples are collected.

Following are procedures for cleaning the vacuum chamber tubing and collection of ancillary water quality samples, if applicable:

1. Carefully approach the sampling station from downstream and downwind if possible.

2. While wearing latex or vinyl gloves, place an uncapped 2-liter poly bottle into the chamber and secure the chamber lid by attaching the spring-loaded clamps.

3. Place a new square of 100 µm Nitex® screen in the magnetic screen holder. Place the intake beneath the surface of the water (mid-depth or six inches, which ever is less) and hold firmly in place. Care should be taken not to disturb sediment particles in very shallow waters (< 4 inches deep).

4. Squeeze the hand pump until liquid starts to fill the bottle in the chamber. When the bottle is approximately half full, release the vacuum on the chamber, remove the bottle, swirl the contents and discard the water downstream. Repeat this rinse. If ancillary water quality samples are to be collected, return the 2-liter poly bottle to the chamber and pump the required volume of water to fill the appropriate ancillary sample containers. Remove the 2-liter bottle from the chamber and cap. Fill the ancillary sample bottles upon completion of the mercury sample collection.

Water samples for trace level mercury analyses should be collected immediately after the ancillary water samples have been collected according to the following procedures:

1. “Clean hands” should put on a pair of latex or vinyl gloves, then a pair of shoulder length polyethylene gloves.

2. “Dirty hands” should put on a pair of latex or vinyl gloves, retrieve the double bagged trace level sample bottle from the cooler, and open the outer bag. “Clean hands” should open the inner bag and remove the pre-cleaned Teflon® or glass bottle.

3. “Dirty hands” should open the lid on the chamber. “Clean hands” should place the sample bottle in the chamber, remove the bottle top and place it inside the chamber with the bottle.

4. “Dirty hands” should close and secure the chamber lid and using the hand pump, fill the container. The sample container should be filled to overflowing. “Dirty hands” should then release the vacuum and open the lid on the chamber.

5. “Clean hands” should place the top on the sample bottle, remove it from the chamber and place it in the inner bag and seal the bag. “Dirty hands” should seal the outer bag and place the sample in the black bag in the dark cooler. Only coolers dedicated to storage and transport of trace-level mercury samples should be used.