FINAL WORK PLAN

Technical Work Plan – Downtown Environmental Assessment Project, Montgomery, Alabama

Prepared for

Alabama Department of Environmental Management by the
Downtown Environmental Alliance

May 2016

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PG Certification

This Work Plan was prepared under the supervision of a Professional Geologist licensed by the Alabama Board of Licensure for Professional Geologists.

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5/2/2016
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Acronyms and Abbreviations

µg/L	micrograms per liter
µg/kg	micrograms per kilogram
µs/cm	microsiemens per centimeter
AEIRG	Alabama Environmental Investigation and Remediation Guidance
ADEM	Alabama Department of Environmental Management
ALDOT	Alabama Department of Transportation
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
Board	Water Works and Sanitary Sewer Board of the City of Montgomery, Alabama
BTEX	benzene, toluene, ethylbenzene, and xylenes
City	City of Montgomery
COC	chemical of concern
COPC	chemical of potential concern
CSM	conceptual site model
DCE	dichloroethene
DEA	Downtown Environmental Alliance
DEAP	Downtown Environmental Assessment Project
DO	dissolved oxygen
DPT	direct-push technology
EAP	Environmental Assessment Project
EI	Environmental Investigation
ELCR	excess lifetime cancer risk
EMC	Environmental Materials Consulting, Inc.
EPA	United States Environmental Protection Agency
FOC	fraction of organic carbon
ft/min	feet per minute
ft/yr	feet per year
FS	feasibility study
HQ	hazard quotient
MCL	maximum contaminant level
mg/L	milligrams per liter
mL/min	milliliters per minute
MNA	monitored natural attenuation
NPL	National Priorities List
NTU	nephelometric turbidity units
ORP	oxidation-reduction potential
PCE	tetrachloroethene
PDB	passive diffusion bag
PID	photoionization detector
ppbv	parts per billion by volume
PRT	post-run tubing
PVC	polyvinyl chloride
PW	public water supply well
RI	Remedial Investigation
RSA	Retirement Systems of Alabama
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan

SVOC	semivolatile organic compound
TCE	trichloroethene
TPC	toxic pollutant criteria
USGS	U.S. Geological Survey
VI	vapor intrusion
VIMS	vapor intrusion monitoring system
VISL	vapor intrusion screening level
VOC	volatile organic compound

SECTION 1

Background and Introduction

This Work Plan is submitted to the Alabama Department of Environmental Management (ADEM) by the Downtown Environmental Alliance (DEA) to further evaluate tetrachloroethene (PCE) in groundwater that was discovered in downtown Montgomery in the early 1990s. In 1991, PCE was detected in former public water supply well PW-9W and also during the construction of the Retirement Systems of Alabama (RSA) Energy Plant in 1993. After several years of investigative activities by ADEM and the City of Montgomery (City), regulatory lead on the site was transferred to the U.S. Environmental Protection Agency (EPA). Additional investigative activities were conducted by EPA and the City through 2012 under EPA's Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) authorities. In a June 2012 letter to EPA, the City requested that the EPA allow it to develop an action plan to address environmental concerns at the site pursuant to establishing a formal agreement to accomplish any necessary environmental investigative and remedial activities under ADEM's regulatory authorities.

The City subsequently developed a group of interested stakeholders in Montgomery (Downtown Environmental Alliance [DEA]) and thereafter prepared an Environmental Action Plan, which was presented to EPA in February 2013. After additional discussions with EPA and further development of the Action Plan, it was finalized and delivered to EPA in March 2014. The Action Plan was approved by EPA in May 2014, along with a commitment from EPA that it would defer regulatory lead of the site to ADEM once an enforceable agreement to complete the site actions was made with the DEA. Subsequently, the *Settlement Agreement for Site Response* (ADEM, 2015) was signed by the DEA and ADEM on September 30, 2015, which outlines the requirements for the DEA to resolve the environmental conditions at the site moving forward.

The DEA currently consists of the following members:

- City of Montgomery—Facilitator
- Alabama Department of Education
- Alabama Department of Transportation (ALDOT)
- Alabama Law Enforcement Agency (formerly Alabama Department of Public Safety)
- The Advertiser Company
- Montgomery County Commission
- Water Works and Sanitary Sewer Board of the City of Montgomery, Alabama (Board)

This Environmental Investigation (EI) Work Plan was developed to meet the objectives outlined in the Environmental Action Plan (CH2M HILL, 2014) and the requirements of Section VIII.B of the *Settlement Agreement for Site Response* (ADEM, 2015). This Work Plan provides a summary and evaluation of existing data and a description of additional data needed to complete the assessment and evaluate potential risks at the site. Additional investigative efforts proposed include groundwater sampling, soil vapor sampling, soil geotechnical testing, and a hydraulic study at Cypress Creek. The data collected will be used to update the conceptual site model (CSM); evaluate current conditions, the interaction between groundwater and surface water, the vapor intrusion (VI) pathway; and assess human health risk.

1.1 Definition of the DEAP

Based on the discovery of PCE at PW-9W and the RSA Energy Plant, the Downtown Environmental Assessment Project (DEAP) includes the area where PCE was discovered during the construction of the RSA Energy Plant and groundwater surrounding and downgradient from that area. It does not include all urban contaminants from various sources throughout Montgomery (i.e., gas stations). During investigations by EPA, two additional buildings were identified:

- County Annex III Building

- Attorney General's (AG) Building

Based on the locations where PCE was discovered, and data from many investigations in the area, the DEAP boundary is defined as shown on Figure 1-1.

1.2 DEAP Chemicals of Concern

From 1993 to 2012, various environmental sampling has been performed including soil, groundwater, indoor air, soil vapor, surface water, sewer manhole, and tree core sampling to evaluate the nature and extent of the PCE in the project area. Results indicate that chemicals of concern (COCs) in groundwater include PCE and two potential PCE daughter products, trichloroethene (TCE) and cis-1,2-dichloroethene (DCE).

In addition to PCE and TCE, the gasoline-related compounds benzene, toluene, ethylbenzene, and xylenes (BTEX) were identified by EPA as possible COCs; however, the following have been observed from a review of the existing data in the DEAP:

- BTEX was not detected in surface water samples at concentrations exceeding screening levels (see Section 3.2).
- BTEX was not detected in soil samples at concentrations exceeding screening levels (see Section 3.3).
- BTEX was not detected in the most recent groundwater sampling (2010 and 2011) in the DEAP (see Section 2.1.6).
- BTEX was not identified in PW-9W nor as a contaminant in the RSA construction area.
- A comparison of the most recently detected BTEX concentrations in soil vapor (Section 3.4) indicates that BTEX chemicals do not exceed EPA's vapor intrusion screening levels (VISLs).
- BTEX is not associated with the activities which contributed to the definition of the site, i.e., the detection of PCE in the former public water supply well PW-9W, nor in the contaminants found during the construction of the RSA Energy Plant (see Section 2.1.1).

For these reasons, BTEX constituents are not considered a COC for the purposes of this Work Plan.

SECTION 2

Previous Activities and Work Plan Purpose

This section provides a summary of previous investigations and remedial actions, and the purpose and scope of proposed activities.

2.1 History of DEAP Investigations

Numerous investigations have assessed the nature and extent of contamination and potential human health risks associated with the PCE identified in PW-9W and the RSA construction area. The available reports from these investigations are listed in Table 2-1. Data from these reports were reviewed as part of the development of this Work Plan. In addition, results were also available from other assessments and investigations conducted as environmental site assessments for commercial and industrial properties within downtown development projects. These data were used to augment data collected as part of the PCE evaluations to develop a more robust understanding of potential PCE contamination within downtown Montgomery. All available data were compiled into a database and are summarized in Section 3.

2.1.1 ADEM Preliminary Investigations

In 1995, ADEM conducted a Preliminary Assessment of the soil and groundwater around the RSA Energy Plant, which included the installation of four groundwater monitoring wells. The Preliminary Assessment report also summarized previous ADEM investigations, including the Phase I and II investigations conducted in 1993 and 1995, respectively (ADEM, 1996). Groundwater and soil vapor sampling were conducted to assess plume extents, and surface and subsurface hydrology were evaluated via literature review to determine potential impacts to surface water and aquifers within the Montgomery area. No specific sources of the PCE were identified; however, the report identified numerous historical drycleaners in the downtown area. ADEM did not extensively research the possible sources of groundwater plumes contaminated with BTEX, but noted that the sources of two BTEX plumes were considered to be leaking underground storage tanks. As a result of the investigation, ADEM recommended that the site be considered as a candidate for the National Priorities List (NPL).

2.1.2 Downtown Montgomery Sewer Data

In March 1999, CH2M HILL conducted soil, groundwater, and sewer manhole sampling. Soil and groundwater samples were collected from 18 locations adjacent to sewers in downtown Montgomery. Borings were drilled to the water table, at depths ranging from 32 to 70 feet below ground surface (bgs), and sampled every 5 feet for volatile organic compounds (VOCs). Groundwater from each boring and 17 manholes were analyzed for VOCs and semivolatile organic compounds (SVOCs).

The groundwater data from the study indicate that VOCs were present in 14 of the 18 locations, compared to only 9 of the 18 borings reporting VOCs in soil. Seven of the soil borings only reported VOCs at one depth interval. Two soil borings reported VOCs at multiple depth intervals and at higher concentrations, but are located at different study locations indicating limited lateral extent of COCs in soil. The soil data indicate that the VOCs reported in groundwater are not present in soil; rather soil contamination is limited in extent.

Following the soil and groundwater sampling, sewer water samples were collected from manholes. The VOCs detected in the sewers were generally of lower concentrations than reported in groundwater from adjacent borings. As no patterns were observed in the data or from the distribution of VOCs detected, VOCs detected in groundwater appear to be the result of multiple releases.

2.1.3 EPA Remedial Investigation

Between 1999 and 2001, the EPA contracted Black & Veatch to conduct a Remedial Investigation (RI) to evaluate the nature and extent of groundwater contamination due to the PCE discovered in downtown Montgomery (Black & Veatch, 2002). During this investigation, 16 permanent and 16 temporary wells were installed to monitor the vadose zone and the top and bottom of the uppermost aquifer, estimate hydraulic conductivity, and to evaluate the nature and extent of groundwater contamination. Sixty-six subsurface soil samples also were collected to characterize potential source areas. Results of the soil sampling indicated very little contamination; except for the presence of benzo(a)pyrene in one sample, no organic contamination was detected above screening levels. In groundwater, PCE was identified as the most common organic constituent. The RI concluded that DEAP contaminants likely originated from multiple sources within the downtown Montgomery area and the groundwater exposure pathway to residents is incomplete.

To estimate hydraulic conductivity, slug tests were conducted in installed wells. Based on slug test results, EPA estimated hydraulic conductivities of 4.45×10^{-3} feet per minute (ft/min) and 2.48×10^{-3} ft/min in the upper and lower portions of the aquifer, respectively, and associated velocities of 95 feet per year (ft/yr) and 91.6 ft/yr, respectively.

2.1.4 Feasibility Study

Subsequent to the completion of the RI report, the City contracted Malcolm Pirnie to develop a Feasibility Study (FS) for the project area (Malcolm Pirnie, Inc., 2003). Potential remedial options were evaluated for their ability to meet the following generalized remedial action objectives:

- Prevent completion of exposure pathways
  - Prevent migration of impacted groundwater to surface water
  - Prohibit potable use of area groundwater
- Reduce contaminant levels to below risk-based levels
- Prevent human consumption of and inhalation of vapors from contaminated groundwater that would result in unacceptable risk
- Remediate groundwater to meet risk criteria
- Minimize inconvenience to property owners and business from activities related to the installation and implementation of the remedial action

The FS evaluated the following potential remedial options:

- No further action
- No further action with monitored natural attenuation
- In situ chemical oxidation
- Ex situ pumping with advanced oxidation system
- Groundwater pumping to ex situ carbon absorption
- In situ bioremediation

Institutional controls and groundwater monitoring were retained as part of all alternatives. No preferred alternative was identified.

2.1.5 Public Health Assessment Report

In 2004, the Agency for Toxic Substances and Disease Registry (ATSDR, 2004) issued a Public Health Assessment Report for the site. Based on previous studies, the ATSDR compared detected chemicals of potential concern (COPCs) against multiple comparison criteria:

- ATSDR Environmental Media Evaluation Guides
- ATSDR Cancer Risk Guides
- Reference Dose Media Evaluation Guides (computed from the EPA Reference Dose for chronic exposure to a child, assuming pica behavior from soil ingestion)
- EPA Drinking Water Health Advisories (Lifetime)
- EPA Safe Drinking Water Act MCLs

Exposure pathways were evaluated based on available data and the most current (at the time) CSM. Based on those data, potential exposure pathways were not complete. No human health risks associated with drinking the groundwater and no known health effects from industrial use of the groundwater were identified. Soil vapor did not present a risk to human health because of the depth of groundwater (approximately 50 feet bgs). ATSDR noted that because of the quick response by the Board in removing the contaminated well from service and the dilution of any contaminants that may have been present due to blending in the Montgomery water supply system, the site represented “no apparent public health hazard.” The primary concerns of ATSDR were the migration of contamination into nearby aquifers and potential future exposure to contaminated groundwater. Due to depth to groundwater, the report concluded that VI is unlikely at the site.

2.1.6 Groundwater Monitoring

Groundwater sampling was conducted in 2007, 2009, 2010, and 2011 by the City, USGS, and EPA (2010 and 2011), respectively. In 2007, eleven monitoring wells were sampled for VOCs, chromium, lead, and thallium. Wells MWs-03S, -04S, -08S, -11S, and -12S were also sampled for biodegradation indicator parameters (nitrate, sulfate, chloride, and total organic carbon) (Hall, 2007). PCE was detected in the wells where it had been reported previously and at similar concentrations, exceeding the MCL at MWs-02S, -03S, -04S, -08S, and -12S. The report concluded that PCE was not migrating. TCE was only detected in MWs-03S and -04S; it was previously reported in MW-09S. The report indicated concentrations of TCE were decreasing in MW-03S and increasing in MW-04S. Benzene, toluene, and ethylbenzene were not detected in any of the wells (xylenes were not analyzed) (Hall, 2007).

As part of the USGS investigation of the DEAP described in Section 2.1.7, groundwater samples were collected from 13 monitoring wells in 2009 and analyzed for VOCs, and natural attenuation parameters ferrous iron, nitrate, sulfate, and sulfide (USGS, 2011). PCE exceeded the MCL in five wells, MWs-01S, -02S, -04S, -08S, and -12S. TCE only exceeded the MCL in MW-04S. Benzene and toluene were reported at two orders of magnitude or more below MCLs at MW-01S. Benzene was also detected at estimated concentrations in MW-04S and toluene at MW-02S. Ethylbenzene and xylenes results were not included in the report.

In 2010, EPA sampled 13 existing wells for VOCs and metals analyses. PCE was detected in eight wells and exceeded the MCL in five wells (MWs-02S, -04S, -05I, -08S, and -12S). Although TCE was detected in six wells, it was not reported at concentrations above the MCL. BTEX were not detected in any of the samples (EPA, 2010).

EPA sampled the same set of wells again in 2011 for VOCs and metals analyses. Similar results were reported with MCL exceedances of PCE noted in the same wells and no exceedances of TCE reported. As in 2010, PCE was detected in eight wells and TCE in six wells. BTEX were not detected in any of the samples (EPA, 2012a).

2.1.7 USGS Source Investigation

From 2008 to 2010, USGS conducted tree tissue, pore water, and groundwater surveys to determine the nature and extent of the contamination in the downtown Montgomery area (USGS, 2011). The results of these surveys are described below.

From 2008 to 2010, USGS, in cooperation with EPA, conducted a survey that included passive diffusion bag (PDB) sampling of pore water from the hyporheic zone of Cypress Creek, collection of tree cores, and collection of groundwater from 13 monitoring wells, as described in Section 2.1.6. The PDB samplers were deployed in the hyporheic zone during the tree coring event, and the authors report only one sampler resulted in detections (TCE and cis-1,2-dichloroethene [DCE] at PDB1); however, concentrations were not provided in the report. PDB1 was located in the proximity of former public-supply well PW-9W.

Tree tissue survey results indicated elevated levels of TCE within a tree (T64) compared to other tissue sample results. This tree is located at the corner of Washington and South Lawrence Street. Well MW-09S is located near the tree and contains concentrations of TCE that do not exceed the MCL.

2.1.8 Indoor Air and Soil Vapor Surveys

Environmental Materials Consulting, Inc. (EMC) collected Summa and Tedlar air samples from 2010 through 2011 in the County Annex III Building. VOC results were all below regulatory standards and did not indicate a source (EMC, 2010). Five samples collected in February 2011 were analyzed for methane and hydrogen sulfide to assess sewers as a potential source. Results were similar to background concentrations and did not identify the sewer as a source (EMC, 2011).

From April 2011 through August 2012, USGS conducted soil vapor and indoor air surveys near the County Annex III Building and Alabama Attorney General’s (AG’s) Building based on complaints about indoor air quality. Fourteen indoor air and nine soil vapor samples were collected at the County Annex III Building, and eight indoor air and nine soil vapor samples were collected at the Alabama AG’s Building. Samples were collected using a passive sampling technique (Gore® Modules) over a 1-week period in August 2011. EPA concluded that indoor air and subslab results from County Annex III Building and the subbasement of the Alabama AG’s Building were below EPA risk targets and soil vapor results were below screening levels. Based on these results, EPA concluded that mitigation is unwarranted (EPA, 2011). A high efficiency filtration system was installed in the County Annex III Building to address the odor complaints. Carpet in the subbasement of the AG Building was determined to be the cause of the odor in the AG Building and was replaced.

A soil vapor survey was performed in April 2011 by USGS in the parking lot east of the Montgomery Biscuits baseball stadium. Thirteen Gore Modules were installed to evaluate soil vapor responses at the site of the City phytoremediation site. A report of the findings was never provided, but raw data indicates that there is not a substantial mass of PCE in the soil vapor at that location and thus, soil vapor concentrations would be very low.

USGS installed a vapor-intrusion monitoring system (VIMS) adjacent to tree 64. The VIMS allowed for the sampling of soil vapor in 10-foot depth intervals at 10, 20, 30, 40, and 50 feet bgs. Two sampling events occurred: one collecting soil vapor for 24 hours and one for 72 hours. TCE was reported to exceed its VISL in each sample.

2.2 Remedial Activities

In response to the discovery of PCE in Well PW-9W, the Board removed PW-9W from service and abandoned all wells associated with the North Well Field (public water supply wells) except PW-9W, which was retained for environmental testing. This eliminated the potential for consumption of contaminated groundwater. Additionally, the City enacted an ordinance in 2003 to prohibit future well drilling in the downtown area. This reduces the potential for an ingestion exposure pathway to downtown residents and employees.

At this time, there is believed to be only a single industrial groundwater well that is known to exist in or close to the site. The well is located at the bus maintenance facility on North Court Street, where groundwater is periodically used for bus washing. In August 2014, the well was sampled and did not contain detectable concentrations of VOCs. This well will be included as a potential point of exposure during the human health risk assessment.

An emergency removal action was conducted in 1993 by the contractors excavating at the RSA Energy Plant. The remedial action included the removal of contaminated soil and groundwater, and non-aqueous phase liquid (Black & Veatch, 2002). This action eliminated the PCE source area.

In 2011, the City of Montgomery planted clonal cottonwood trees in the greenspace of several parking lots used for the Montgomery Biscuits baseball stadium. Monitoring well MW-08S had shown a slight increasing trend in PCE groundwater concentrations and is located in the southwestern corner of the easternmost parking lot.

2.3 DEAP Purpose and Scope

The purpose of the work proposed in this Work Plan is to:

- Assess the current concentrations and trends of COCs in groundwater.
- Evaluate concentrations in soil vapor where groundwater exceeds EPA residential VISLs.
- Evaluate the potential for vapor intrusion in the vicinity of the current Alabama AG Building and County Annex III Building.
- Evaluate the potential for groundwater to impact surface water in Cypress Creek adjacent to the DEAP.
- Provide sufficient data to assess human health risk for the DEAP.

The scope of field work for this project is detailed in Section 5. The data will be evaluated and results reported as described in Section 6. Upon completion of the investigations, an EI Report will be prepared.

SECTION 3

Evaluation of Existing DEAP Data

All available data from previous sampling events were compiled into a single database and used to develop the DEAP CSM. The locations of the samples collected during these investigations (except tree core data) are shown on Figure 3-1. Concentrations of COCs and BTEX from shallow interval[1] groundwater, soil, and soil vapor samples were compared against default EPA Residential VISLs based on an excess lifetime cancer risk (ELCR) of 1 × 10^{-6} and Hazard Quotient (HQ) of 1. Indoor air data were compared to EPA Residential indoor air Regional Screening Levels (RSLs) based on a ELCR of 1 × 10^{-6} and HQ of 1. Groundwater results from all wells were also compared to EPA MCLs and RSLs based on an ELCR of 1 × 10^{-6} and HQ of 1. Soil results were compared to EPA residential soil RSLs based on an ELCR of 1 × 10^{-6} and HQ of 1. Surface water results were compared to water quality criteria (toxic pollutant criteria [TPC]) per ADEM Admin. Code R. 335-6-10-.07. Tree tissue samples were not compared to screening levels since there are no screening levels for tree tissue. The screening levels for each medium are presented in Table 3-1. The results of the screening are summarized below.

3.1 Groundwater

Figure 3-2 shows the locations of groundwater data used for development of the CSM (presented in Section 4). These data include sampling results from existing groundwater wells, former public water supply well PW-9W, direct-push locations, and temporary wells. The most recent two years of data collected from the monitoring wells shown on Figure 3-2 were compared to screening levels. EPA guidance recommends that data collected within the last year be used so that it is representative of current conditions (EPA, 2015).

3.1.1 COC Concentrations

A review of the COC and BTEX results indicate that only PCE, TCE, and cis-1,2-DCE were detected in groundwater in 2010 and 2011.

- PCE exceeded VISLs in shallow monitoring wells MWs-02S, -04S, -08S, and -12S in 2010 and 2011. PCE exceeded the MCL and latest EPA RSL in the four monitoring wells where the VISL exceedance was observed and in intermediate well MW-05I.
- In 2011, concentrations of TCE decreased in MW-12S to below the VISL and only MWs-04S and -09S exceeded the VISLs. Concentrations of TCE did not exceed the MCL (5 micrograms per liter [µg/L]) in any of the monitoring wells in 2010 or 2011; however, TCE exceeded the latest EPA RSL of 0.49 µg/L in five wells (MWs-04S, 08S, 09S, 12S, and 05I) in 2010 and 2011.
- BTEX was not detected in any of the monitoring wells in 2010 or 2011.
- The most recent results from PW-09W, collected in 2013 and 2014, indicate that none of the COCs exceed screening levels and BTEX was not detected.

3.1.2 Potentiometric Surface

Water levels recorded during the most recent (2011) groundwater sampling event (Table 3-3) were used to develop a potentiometric surface map of the shallow interval (shown on Figure 3-3). The results are consistent with historical flow patterns and indicate that shallow groundwater within the project area generally flows from the southeast to the northwest, towards the Alabama River and Cypress Creek.

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[1] The shallow-most interval of groundwater is the appropriate interval to compare to VISLs, consistent with EPA guidance (2015).

3.2 Surface Water

Surface water samples were collected from Cypress Creek and some of its tributaries in 2006 (four locations) and 2008 (seven locations), as shown on Figure 3-4. The results indicate that although PCE, TCE, and/or toluene were detected at all seven locations during the 2008 sampling event (Table 3-4); laboratory reporting levels were below typical laboratory practical quantitation limits. Sample location 0241998808 is located downgradient from the DEAP; concentrations identified at that location are similar to concentrations identified in samples collected from both upstream and downstream locations, providing no evidence of impacts to surface water from groundwater. None of the surface water samples exceeded TPC.

3.3 Soil

Based on available reports, soil samples were collected during at least 16 separate events from 1993 to 2010 at the locations shown on Figure 3-5. Data are available for 276 soil samples collected from 71 unique sample locations summarized in Table 3-5. Results of these investigations indicate a lack of residual soil mass as follows:

- Samples collected during early investigations of soil near the RSA Energy Plant were not analyzed for all VOCs; however, results indicate that PCE in soil was limited to the excavation area and generally found at depth.
- A more extensive study conducted around the sewer system in downtown Montgomery 1999 indicated that COCs were detected in only half of the borings sampled; only one concentration of ethylbenzene exceeded the RSL at CH2-SB15 (25 to 27 feet bgs) (Table 3-5).
- The EPA RI (Black & Veatch, 2002) reported very little contamination; during the RI, only benzo(a)pyrene in one sample was detected at levels above screening levels.

Historical soil sampling results do not indicate a residual source.

3.4 Soil Vapor

Soil vapor sampling was conducted from 2010 to 2012 at 47 locations within the DEAP, as shown on Figures 3-6 and 3-7. The soil vapor results were compared to EPA residential VISLs. Only TCE exceeded the VISL at all five depths for both VIMS sampling events, with concentrations generally increasing with depth (Table 3-6). No soil vapor exceedances were reported from samples collected adjacent to the County Annex III Building, the Alabama AG's Building, the Wallace Building, and the Folsom Building.

The soil vapor screening survey conducted in 2011 was performed at the phytoremediation test site located at the parking lots for the Montgomery Biscuits baseball stadium. The results were presented as a total mass, rather than a concentration; thus, there are no screening levels for comparison. The samples were collected very near the location of monitoring well MW-08S, which has shown a slight increasing trend in PCE concentration in the groundwater. Because only a small mass of PCE was present in a few of the Gore sorber modules, it is expected that the soil vapor concentrations would be very low.

3.5 Indoor Air

Sixty-three indoor air samples were collected at the County Annex III Building and the Alabama AG's Building (Figure 3-7) using various sampling methods including Gore-sorber technology, Tedlar bags, and Summa canisters. Samples were analyzed for VOCs.

In the County Annex III Building, only PCE (4 samples), TCE (1 sample), benzene (1 sample) and ethylbenzene (29 samples) were detected at concentrations exceeding RSLs (Table 3-7). All of these compounds are common indoor air contaminants and do not correlate with results from the soil vapor samples collected adjacent to the building. The County installed a high efficiency air filtration system in the Annex III building. No additional indoor air quality complaints have been received.

In the Alabama AG's Building, none of the compounds detected exceeded the RSLs (Table 3-7). Testing of emissions from carpet installed in the subbasement verified that the carpet was the source of chemicals reported by the Gore-sorber method. The carpet was reacting with the moisture and pH of the concrete slab in the subbasement. The carpet squares were removed, the concrete floor sealed, and a new rolled carpet (without vinyl backing) was installed. No additional odor complaints have been received.

3.6 Tree Core

In August 2008, tree core samples were collected from 69 trees in and around downtown Montgomery, and in native vegetation growing in the riparian zones of the Alabama River and Cypress Creek. TCE was detected in 24 of the trees sampled, PCE in 7 of the trees, and cis-1,2-DCE in 2 of the trees. The highest concentration of TCE was reported in T64 located near monitoring well MW-09S; however, groundwater at MW-09S indicates only low levels of TCE (3.5 µg/L in 2010). The tree tissue results do not correlate with groundwater concentrations as indicated by the elevated TCE reported in T64 (68,650 parts per billion by volume [ppbv]) and low TCE concentration at MW-09S. In addition, TCE was not detected in adjacent trees T63 and T62, indicating a sporadic spatial distribution that is inconsistent with a groundwater plume.

3.7 Conclusions and Data Usability

Groundwater, soil, and surface water analytical data are considered to be of sufficient quality for use in developing the CSM and proposed sampling approach. The results of the evaluation indicate that groundwater contains low concentrations of PCE, TCE and cis-1,2-DCE. BTEX was not detected in groundwater samples from wells within the DEAP during the last two monitoring events (2010 and 2011), and only benzene and toluene were detected in 2009 at low concentrations below screening levels. (Note that laboratory detection limits in 2009 were below typical laboratory limits).

Groundwater flow is towards the Alabama River and Cypress Creek. Because of the detections of COCs at most sampling locations in Cypress Creek, and particularly upstream of the DEAP, sampling of the Creek is not recommended to assess potential impacts from the plume. Rather, additional evaluation of the interaction between groundwater and Cypress Creek are proposed to assess the potential for DEAP groundwater to impact Cypress Creek.

Soil sampling results indicate that there is no residual mass within the DEAP vadose zone. No additional sampling of soil is proposed in this Work Plan.

The soil vapor and indoor air data were evaluated as screening level data only. Additional soil vapor samples are proposed to further evaluate the potential for vapor intrusion.

The tree tissue sampling results were evaluated as screening level data. The results did not correlate to groundwater concentrations or reveal a spatial distribution pattern that would indicate that the data are representative of a groundwater plume, thus further tree tissue sampling is not recommended. Groundwater and soil vapor concentrations will be used to further evaluate the site.

SECTION 4

Conceptual Site Model

The CSM has been developed using the historical investigation results summarized in Sections 2 and 3, and is represented on Figure 4-1.

4.1 Site Geology/Hydrogeology

The geology beneath the DEAP consist of a thin soil layer on top of quaternary terrace deposits comprised of medium to coarse-grained sand, with interbedded clay and gravel lenses. Underlying these recent terrace deposits are Cretaceous sediments of the Eutaw, Gordo, and Coker formations. The Eutaw formation is an aquifer unit characterized by two thick layers of marine sands separated by a thin layer of marine clay (USGS, 1987). The terrace deposits and Eutaw formation are combined to comprise the shallow aquifer. The Gordo and Coker aquifers consist of an estimated 500 feet of interbedded clay, sand, and gravel above crystalline bedrock.

The shallow aquifer is unconfined and 120 to 150 feet thick underneath the DEAP, but a localized low permeability zone may exist from approximately 35 to 50 feet bgs (ADEM, 1995). Groundwater is typically encountered from approximately 30 to 45 feet bgs and generally flows west-northwest. Based upon slug tests, hydraulic conductivity in the shallow aquifer has been estimated between 2.48×10^{-3} ft/min and 4.45×10^{-3} ft/min (Black & Veatch, 2002). The shallow aquifer is underlain by a low-permeability sandy clay unit that effectively separates it from the underlying Gordo and Coker formations.

4.2 Source Areas

Impacted soil, groundwater, and non-aqueous phase liquid was removed from the RSA Energy Plant construction area during the 1993 emergency removal action. The RSA Energy Plant received regulatory closure and therefore is understood not to be a likely continuing source for PCE contamination in downtown Montgomery. In addition, the historical investigation results indicate that little to no residual mass is present in soils and that the presence of groundwater contamination is likely due to multiple historical releases within downtown Montgomery.

4.3 Plume Extents

The two plumes shown on Figure 4-1 were delineated based on the historical data and compared to the MCL as this value is lower than the latest RSL. In particular, Figure 4-1 shows whether PCE was not detected (green locations), detected below the MCL (yellow locations), or detected at concentrations greater than the MCL (red locations). Plume boundaries are drawn based on locations that exceed criteria with the exception of MW-04S. Five sample locations north of and including MW-09S define a boundary between the PCE plume at the RSA building and MW-04S; because no PCE was identified in this area, concentrations of PCE at MW-04S are not associated with the DEAP.

The southern plume includes the RSA building area because of the discovery of PCE. The northern extent of that plume area is limited because PCE was not detected in MW-07I until 2009, 8 years after installation. PCE has been detected in MW-08S since it was first sampled in 2000. The data from these two wells indicate that these plumes are not connected. This plume is bound to the south by MW-10S and to the east by a sample adjacent to a parking deck owned by the State of Alabama (Figure 4-1).

The plume that extends from MW-08S is delineated to the east, southwest, and north by one-time samples that were collected during historical investigations. To the northwest, it is bound by Cypress Creek.

4.4 Evaluation of Potential Exposure Pathways

A 2004 evaluation of available data conducted by ATSDR concluded that no residential or municipal wells still in use were known to be contaminated with PCE or TCE. ATSDR also concluded that there was no known exposure via the air pathway, but did note a potential for VI (ATSDR, 2004). All public water supply wells were closed in 1991 following initial detection of the PCE. The North Well Field was replaced with a new well field far from downtown, in southern Montgomery County. The wells in the North Well Field were permanently abandoned (casing pulled and well grouted) in 2011. PW-9W was retained for environmental testing purposes only.

This study will evaluate the current and future potential for exposure to COCs in groundwater and soil vapor. As stated in Section 2.2, the industrial groundwater well will be included as a potential point of exposure during the human health risk assessment. Additionally, the interaction between groundwater and surface water at Cypress Creek will be evaluated.

SECTION 5

Proposed Environmental Investigation

The proposed site investigation includes three components:

- Collecting groundwater samples from existing monitoring wells and a piezometer to be constructed near Cypress Creek.
- Collecting soil vapor samples near monitoring wells that exceed VISLs and near the County Annex III Building and the north wing of the Alabama AG's Building
- Evaluating the groundwater to surface water interaction at Cypress Creek adjacent to the DEAP.

Field activities will be conducted by qualified personnel working under a project-specific Sampling and Analysis Plan (SAP in Appendix A) and a project-specific Health and Safety Plan.

5.1 Groundwater Sampling

Groundwater samples will be collected from 13 existing monitoring wells (Table 5-1). In addition, after installation, the temporary piezometer proposed to assess surface water/groundwater interaction at Cypress Creek (TMPZ-1 on Figure 5-1) will be sampled. Samples will be analyzed for COCs, as summarized in Table 5-1. This groundwater sampling event should be conducted during the summer, when the potential for volatilization is highest to conservatively assess soil vapor concentrations (Section 5.2). Samples will be collected in accordance with the Alabama Environmental Investigation and Remediation Guidance (AEIRG) and the site specific SAP in Appendix A.

5.2 Soil Vapor Sampling

Site-wide soil vapor sample locations will be selected based on current groundwater concentrations. Soil vapor sampling will be performed where COCs are present in shallow groundwater at concentrations exceeding EPA residential VISLs (adjusted for site-specific groundwater temperature). Temporary dual-depth soil vapor probes will be installed and sampled near each shallow groundwater monitoring well where COC concentrations exceed one or more VISLs. Groundwater from eight shallow monitoring wells and one shallow piezometer (Table 5-1) will be sampled as discussed in Section 5.1. A soil core will be collected at each proposed soil vapor sampling location to determine the depth to groundwater. Geotechnical sampling will be performed at three locations, as discussed in Section 5.3.

Initially, the shallower depth, 6 to 8 feet bgs, which is the approximate basement slab depth, will be sampled. The deeper depth probe will then be installed in a separate hole. Each of the borings will be at least 5 feet away from the monitoring well and each other. The deeper depth probe will be within several feet of the groundwater table as determined from the soil core, which ranges from approximately 25 to 60 feet bgs throughout the site.

Area-specific soil vapor samples will be collected around the County Annex III Building and north wing of the Alabama AG's Building. Temporary exterior subslab soil vapor probes (or vapor pins) will be installed and sampled at four locations surrounding the County Annex III Building (one on each side of the building) and three locations around the northern wing of the Alabama AG's Building (one on each side of the wing).

Additionally, soil vapor samples will be collected from two depths, 10 feet and 50 feet, of the existing VIMS located across Washington Avenue from the County Annex III Building.

The soil vapor probes will be installed, sampled, and abandoned in accordance with the AEIRG and the site specific SAP. The soil vapor samples will be collected in the vadose zone above the capillary fringe and analyzed for COCs as summarized in Table 5-1.

5.3 Geotechnical Sampling

Geotechnical samples will be collected from the vadose zone using Shelby Tubes. The samples will be co-located at three locations where soil vapor samples will be collected. Geotechnical samples will be collected using a direct push technology (DPT) drilling rig. One Shelby Tube will be collected at each lithologic unit identified in the boring based on available boring logs. The samples will be collected for analysis of dry bulk density, total porosity, saturated porosity, and fraction of organic carbon (FOC) (Table 5-1). These samples will be used to evaluate the site-specific potential for soil vapor attenuation in the vadose zone and the variability of geotechnical parameters in the subsurface.

5.4 Hydraulic Study at Cypress Creek

The interaction between groundwater and the reach of Cypress Creek adjacent to the DEAP will be analyzed over two time periods (spring and summer) to assess changes due to seasonal fluctuations. A temporary creek gauge will be installed within Cypress Creek and in a temporary piezometer, TMPZ-1 (Figure 5-1). The relationship between the Creek and groundwater levels at any given time will provide information as to whether groundwater is flowing into the creek (gaining reach) or surface water is flowing out of the Creek into the underlying aquifer (losing reach). To evaluate seasonal changes within Cypress Creek, LevelTroll transducers will be deployed in the temporary creek gauge and the temporary piezometer during both a spring and summer period. The first study period will begin within approximately 30 days of approval of this Work Plan (ideally in April when precipitation is typically higher). The second study period will be conducted during the summer (ideally in August or September when precipitation is usually low). The piezometer will be installed in accordance with the AEIRG and the site specific SAP. A professional land surveyor will be contracted to survey the top of the creek gauge, the bottom of the creek at the gauge, and the top of casing of the temporary piezometer.

SECTION 6

Results Evaluation

6.1 Data Evaluation and Screening

When all three components of the investigation are concluded, the data will be evaluated as outlined below.

6.1.1 Groundwater Data Evaluation and Screening

Groundwater analytical results will be compared to EPA MCLs and RSLs. Historical data available at the monitored locations then will be plotted versus time (time series charts) to assess concentration trends.

The time series charts will also be used to assess natural attenuation of the plume. Lines of evidence used to demonstrate that natural attenuation is effective in reducing COC concentrations will include the use of historical data to demonstrate stable or decreasing concentration trends with time and distance. The time series charts will be used to evaluate whether trends are increasing, stable, or declining. Field parameters, dissolved oxygen (DO) and oxidation-reduction potential (ORP), may be used to assess whether aquifer conditions are suited to degradation of the COCs.

6.1.2 Vapor Intrusion Data Evaluation

Soil vapor data will be compared to the most recent version of EPA's residential VISLs based on a target ELCR of $1 \times 10^{-5}$and target HQ of 1. This provides a risk estimate that will meet both the EPA target risk range and ADEM criteria. For any soil vapor sample with at least one chemical exceeding its VISL, the EPA VISL calculator will be used to calculate indoor air risk estimates for a hypothetical resident living in a building constructed above the sampling location. This is expected to provide a conservative evaluation of potential current and future exposure scenarios at the soil vapor sampling location.

Data from soil vapor samples collected adjacent to the County Annex III Building and the north wing of the Alabama AG's Building will also be compared to the most recent version of EPA's commercial VISLs based on a target ELCR of 1×10^{-5} and target HQ of 1. For any soil vapor sample with at least one chemical exceeding its VISL, the EPA VISL calculator will be used to calculate indoor air risk estimates for workers in the building adjacent to the sample with the exceedance.

6.1.3 Hydraulic Study Evaluation

The results of the hydraulic study at Cypress Creek will be used to assess whether the identified reach of the creek is either a losing or gaining reach. Surface water elevation recorded over the length of each study period (estimated to be conducted over 4 weeks) will be compared to groundwater elevation data collected at the piezometer (TMPZ-1; Figure 5-1). If the data indicate that the reach of Cypress Creek is losing over both study periods, then it will be concluded that the Creek acts as a hydraulic barrier to groundwater flow. No additional investigation will be conducted within the Creek.

If, during any phase of the study, the data indicate that this reach of Cypress Creek is a gaining reach, further evaluation will be proposed.

6.2 Environmental Investigation Report

Once all three components of the investigation are concluded and the data have been evaluated as described in Section 6.1, the results of the investigations within the DEAP will be compiled in an EI Report. The EI Report will include historical groundwater sampling results, available well construction details in tabular form, and maps depicting historical one-time grab sample results. The EI Report is scheduled to be completed 9 months after ADEM approval of this Work Plan.

SECTION 7

References

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Tables

TABLE 2-1

Historical Data Related to Downtown Environmental Assessment Project

Technical Work Plan--DEAP, Montgomery, Alabama

Investigations of the Downtown Environmental Assessment Project

Year	Title	Author
1991	The Montgomery Water Works and Sanitary Sewer Board Notifies ADEM of Contamination in PW-9W	MWWSB
1993	Special Projects Phase I Report	ADEM
1993	Special Projects Phase II Report	ADEM
1995	Preliminary Assessment - Capitol City Plume	ADEM
1996	Site Inspection - Capitol City Plume	ADEM
1999	CH2M HILL Sewer Data Collection	CH2M HILL
2000	Data Evaluation Report, Capitol City Plume Site Remedial Investigation	Black & Veatch Special Projects Corp.
2002	Remedial Investigation Report, Capitol City Plume	Black & Veatch Special Projects Corp.
2004	Capitol City Plume, Montgomery, Montgomery County, Alabama	U.S. Department of Health and Human Services
2005	CERCLA: Brownfield Site Inspection	ADEM
2007	Ground Water Monitoring Report, Capitol City Plume Site	JM Hall Strategic Environmental Analysis
2010	Request for Information Pursuant to Section 104 of CERCLA and Section 3007 of RCRA for the Capitol City Plume Superfund Site in Montgomery, Alabama	Krevolin and Horst, LLC.
2010	TO-15 Analytical Data and Summary Tables, Montgomery County Annex III	Environmental-Materials Consultants, Inc.
2010	Report of the Continued Monitoring of Contamination in the Shallow Ground Water within the Capitol City Plume Site	EPA
2011	"Sewer Gas" Testing, Montgomery County Annex III	Environmental-Materials Consultants, Inc.
2011	GORE Surveys Final Report, CCP - Baseball Field Parking	W.L. Gore and Associates, Inc.
2011	GORE Surveys Final Report, Alabama Site Phase II	W.L. Gore and Associates, Inc.
2012	Sampling Investigation Report, Capitol City Plume	EPA
2012	Investigation of the Potential Source Area, Contamination Pathway, and Probable Release History of Chlorinated-Solvent-Contaminated Groundwater at the Capitol City Plume Site, Montgomery, Alabama, 2008-2010	USGS
2012	USEPA TO-15 Data Report, Capitol City Plume	USGS
2012	GORE Surveys Analytical Results, Alabama Site, Montgomery, AL	USGS
2012	GORE Surveys Laboratory Report, Alabama Site - Air Sampling, Montgomery, AL	W.L. Gore and Associates, Inc.
2012	GORE Surveys Laboratory Report, Alabama Site - Soil Gas, Montgomery, AL	W.L. Gore and Associates, Inc.

Additional Investigations Used to Support Conceptual Site Model Development

Year	Title	Author
1998	Phase II Environmental Site Assessment, Statehouse Inn	The CWA Group, Inc.
1999	Phase II Environmental Site Assessment, Old Red Taxi Site	The CWA Group, Inc.
2007	Geotechnical Report, Proposed Coosa Street Parking Deck, Montgomery, Alabama	TTL, Inc.
2003	Environmental Site Assessment, Montgomery Advertiser Properties	Environmental-Materials Consultants, Inc.
2004	Voluntary Cleanup Program Assessment Report, Proposed Montgomery County Jail Site	Goodwyn, Mills, & Cawood Incorporated
2004	Phase II Environmental Site Assessment, Riverfront Inn Property--Tract No. 2	Christian Testing Laboratories, Inc.

TABLE 2-1

Historical Data Related to Downtown Environmental Assessment Project

Technical Work Plan--DEAP, Montgomery, Alabama

Additional Investigations Used to Support Conceptual Site Model Development		
Year	**Title**	**Author**
2005	Phase II Soil and Groundwater Testing, Montgomery Civic Center Site	Environmental-Materials Consultants, Inc.
2010	Proposed Signal Foundations, Madison Avenue Resignalization at North Decatur Street and North Union Street, Montgomery County	AECOM Technical Services, Inc.
2010	Brownfields Phase 2 Assessment: Montgomery Urban Garden	ADEM
2010	Report of Geotechnical Exploration, Proposed Multi-Purpose Facility and Improvements to Cramton Bowl	Christian Testing Laboratories, Inc.
2011	Supplemental Geotechnical Testing, Multi Purpose Building, Cramton Bowl, Montgomery, Alabama	Christian Testing Laboratories, Inc.
2012	Report of Geotechnical Subsurface Investigation, Alabama Capitol Complex Parking Deck	Carmichael Engineering, Inc.
2012	Report of Geotechnical Subsurface Investigation, Five Story Building	Carmichael Engineering, Inc.
2012	Phase I Environmental Site Assessment, State House Inn Plaza, Montgomery, Alabama	Goodwyn, Mills, & Cawood Incorporated
2013	Report of Geotechnical Exploration, Proposed Justice Center, Madison Avenue, Montgomery, Alabama	CTL Geotechnical Services, Inc.

Notes:

ADEM - Alabama Department of Environmental Management
EPA - U.S. Environmental Protection Agency
USGS - U.S. Geological Survey
DEAP - Downtown Environmental Assessment Project
MWWSB - Montgomery Water Works and Sanitary Sewer Board

TABLE 3-1

Screening Levels for Groundwater, Surface Water, Soil, Soil Vapor, and Indoor Air

Technical Work Plan--DEAP, Montgomery, Alabama

	Groundwater (µg/L)			Surface Water (µg/L)	Soil (mg/kg)	Soil Vapor (µg/m^3)	Indoor Air (µg/m^3)
Analyte	**VISL**	**MCL**	**RSL**	**TPC**	**RSL**	**VISL**	**RSL**
PCE	15	5	11	1.9	24	360	11
TCE	1.2	5	0.49	17.5	0.94	16	0.48
cis-1,2-DCE	NA	70	36	5,907*	160	NA	NA
trans-1,2-DCE	NA	100	360	5,907	1,600	NA	NA
Vinyl chloride	0.15	2	0.019	1.4	0.059	5.6	0.17
Benzene	1.6	5	0.46	15.5	1.2	12	0.36
Toluene	3.5	1,000	1,100	8,723	4,900	37	5,200
Ethylbenzene	19,000	700	1.5	1,244	5.8	170,000	1.1
m,p-Xylene**	360	10,000	190	NA	580	3,500	100
o-Xylene**	370	10,000	190	NA	580	3,500	100

Notes:

Groundwater and surface water screening levels are in micrograms per liter (µg/L).

Soil screening levels are in milligrams per kilogram (mg/kg).

Soil vapor and indoor air screening levels are in micrograms per cubic meter (µg/m^3).

* the TPC for trans-1,2-DCE was used

** the RSL for total Xylenes was used

PCE - tetrachloroethene

TCE - trichloroethene

DCE - dichloroethene

VISL - EPA Residential Vapor Intrusion Screening Level (based on target risk of 1x10^{-6} and target hazard quotient of 1)

MCL - U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level

RSL - EPA Regional Screening Level (based on target risk of 1x10^{-6} and target hazard quotient of 1), November 2015

TPC - toxic pollutant criteria per ADEM Admin. Code R. 335-6-10.07

ADEM - Alabama Department of Environmental Quality

RSL - Regional Screening Level

NA - no screening level available

EPA - U.S. Environmental Protection Agency

DEAP - Downtown Environmental Assessment Project

TABLE 3-2

Comparison of Most Recent Groundwater Data to Screening Levels

Technical Work Plan--DEAP, Montgomery, Alabama

Well ID	2010			2011		
	PCE VISL: 15 MCL: 5 RSL: 11	**TCE** VISL: 1.2 MCL: 5 RSL: 0.49	**cis-1,2-DCE** VISL: NA MCL: 70 RSL: 36	**PCE** VISL: 15 MCL: 5 RSL: 11	**TCE** VISL: 1.2 MCL: 5 RSL: 0.49	**cis-1,2-DCE** VISL: NA MCL: 70 RSL: 36
Shallow Interval Wells						
MW-01S	0.26 J	< 0.5	< 0.5	1.5	< 0.5	< 0.5
MW-02S	**45**	0.17 J	< 0.5	**44**	0.18 J	< 0.5
MW-04S	**62**	**4.8**	6.7	**38**	**2.8**	2.2
MW-07S	0.57	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
MW-08S	**22**	**0.54**	< 0.5	**55**	**0.72**	< 0.5
MW-09S	< 0.5	**3.5**	< 0.5	< 0.5	**2.1**	< 0.5
MW-10S	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
MW-12S	**270**	**1.2**	1.2	**120**	**0.64**	0.48 J
Intermediate Interval Wells						
MW-01I	0.13 J	< 0.5	< 0.5	0.28 J	< 0.5	< 0.5
MW-05I	**14**	**1.4**	< 0.5	**20**	**0.57**	< 0.5
MW-07I	0.19 J	< 0.5	< 0.5	2.1	< 0.5	< 0.5
MW-08I	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
MW-12I	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

Former Public Supply Well PW-09W			
Date	**PCE** VISL: 15 MCL: 5 RSL: 11	**TCE** VISL: 1.2 MCL: 5 RSL: 0.49	**cis-1,2-DCE** VISL: NA MCL: 70 RSL: 36
12/17/2013	0.76	< 0.5	< 0.5
1/23/2014	0.84	< 0.5	< 0.5

Notes:

Values are in micrograms per liter (µg/L).

Shaded cells are shallow interval well concentrations exceeding EPA residential VISLs.

Exceedances of the lower of the MCL/RSL are **bold**.

trans-1,2-DCE, vinyl chloride and BTEX constituents were not detected in any sample.

The detection limit for trans-1,2-DCE, VC, benzene, toluene, ethylbenzene and o-xylene is 0.5 µg/L.

The detection limit for m,p-xylene is 1 µg/L.

BTEX - benzene, toluene, ethylbenzene, and xylenes

PCE - tetrachloroethene

TCE - trichloroethene

DCE - dichloroethene

MCL - U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level

RSL - EPA Regional Screening Level (based on target risk of 1x10^{-6} and target hazard quotient of 1), November 2015

VISL - vapor intrusion screening level (EPA, 2015)

NA - no VISL available

DEAP - Downtown Environmental Assessment Project

TABLE 3-3

Groundwater Elevations - August 2011

Technical Work Plan--DEAP, Montgomery, Alabama

Well	TOC Elevations	DTW	Groundwater Elevation
MW-01S	189.37	39.24	150.13
MW-02S	188.59	41.31	147.28
MW-04S	178.72	32.24	146.48
MW-07S	179.65	35.66	143.99
MW-08S	173.46	37.11	136.35
MW-09S	213.41	55.15	158.26
MW-10S	212.67	56.94	155.73
MW-12S	157.58	26.20	131.38
MW-05I	210.98	58.31	152.67
MW-01I	190.00	40.21	149.79
MW-07I	179.76	35.70	144.06
MW-08I	173.42	37.01	136.41
MW-12I	157.82	26.24	131.58

Notes:

TOC - top of casing in feet above mean sea level

DTW - depth to water in feet below TOC

Elevation in feet above mean sea level

TABLE 3-4

Surface Water Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

	2006								
Station ID	**PCE** TPC: 1.9	**TCE** TPC: 17.5	**cis-1,2-DCE** TPC: 5,907	**trans-1,2-DCE** TPC: 5,907	**Vinyl chloride** TPC: 1.4	**Benzene** TPC: 15.5	**Toluene** TPC: 8,723	**Ethyl-benzene** TPC: 1.244	**total Xylenes** TPC: NA
0241998804	0.23	0.04 J	< 0.02	< 0.032	< 0.08	< 0.021	0.05 J	< 0.03	< 0.038
0241998805	0.22	0.04 J	< 0.02	< 0.032	< 0.08	< 0.021	0.02 J	< 0.03	< 0.038
0241998807	0.03 J	< 0.04	< 0.02	< 0.032	< 0.08	< 0.021	< 0.02	< 0.03	< 0.038
0241998808	< 0.03	< 0.04	< 0.02	< 0.032	< 0.08	< 0.021	0.03 J	< 0.03	< 0.038

	2008								
Station ID	**PCE**	**TCE**	**cis-1,2-DCE**	**trans-1,2-DCE**	**Vinyl chloride**	**Benzene**	**Toluene**	**Ethyl-benzene**	**total Xylenes**
0241998802	< 0.04	< 0.02	< 0.02	< 0.02	< 0.08	< 0.02	0.07 J	< 0.04	< 0.04
0241998804	0.11	0.03 J	< 0.02	< 0.02	< 0.08	< 0.02	0.06 J	< 0.04	< 0.04
0241998805	0.09 J	0.03 J	< 0.02	< 0.02	< 0.08	< 0.02	0.04 J	< 0.04	< 0.04
0241998806	0.09 J	0.03 J	< 0.02	< 0.02	< 0.08	< 0.02	0.04 J	< 0.04	< 0.04
0241998807	0.03 J	< 0.02	< 0.02	< 0.02	< 0.08	< 0.02	< 0.02	< 0.04	< 0.04
0241998808	0.03 J	< 0.02	< 0.02	< 0.02	< 0.08	< 0.02	0.06 J	< 0.04	< 0.04
0241998809	0.52	< 0.02	< 0.02	< 0.02	< 0.08	< 0.02	0.03 J	< 0.04	< 0.04

Notes:

Concentrations are in micrograms per liter.

J - the value is estimated

PCE - tetrachloroethene

TCE - trichloroethene

DCE - dichloroethene

TPC - toxic pollutant criteria per ADEM Admin. Code R. 335-6-10.07

ADEM - Alabama Department of Environmental Management

NA - no screening level available

DEAP - Downtown Environmental Assessment Project

TABLE 3-5

Soil Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

Station ID	Sample Depth Interval (ft bgs)	PCE RSL: 24	TCE RSL: 0.94	cis-1,2-DCE RSL: 160	trans-1,2-DCE RSL: 1,600	Vinyl chloride RSL: 0.059	Benzene RSL: 1.2	Toluene RSL: 4,900	Ethyl-benzene RSL: 5.8	total Xylenes RSL: 580
1993										
RSA-1	1.5 - 4	< 0.050	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
RSA-1	25 - 25	**3989**	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
RSA-2	4 - 6.5	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
RSA-2	21.5 - 21.5	**7066**	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
RSA-2	25 - 25	**7268**	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
RSA-3	25 - 25	**7843**	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
ADEM-T4	0 - 4	0.06	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
H-1	1.5 - 4	ND[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
H-1	4 - 6	ND[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
H-4	1.5 - 4	ND[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
TR-5	0 - 4	0.06	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
TR-6	0 - 4	0.13	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
HSA-1	1.5 - 4	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
HSA-1	4 - 6.5	0.09	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
HSA-2	1.5 - 4	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
HSA-2	4 - 6.5	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
HSA-3	1.5 - 4	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
HSA-3	4 - 6.5	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
HSA-3	6.5 - 8	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
SP-2C	4 - 6.5	ND[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
BH-1	1.5 - 4	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
BH-1	4 - 6.5	< 0.025	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
BH-5	6.5 - 8	0.02	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]	NR[1]
MW-02S	11 - 13	< 0.050	< 0.050	< 0.050	ND[1]	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
MW-02S	18 - 20	< 0.050	< 0.050	< 0.050	ND[1]	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
MW-02S	25 - 27	< 0.050	< 0.050	< 0.050	ND[1]	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
MW-02S	32 - 34	< 0.050	< 0.050	< 0.050	ND[1]	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
MW-02S	4 - 6	< 0.050	< 0.050	< 0.050	ND[1]	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
MW-03S	4 - 6	< 0.050	< 0.05	< 0.050	ND[1]	< 0.05	< 0.050	< 0.050	< 0.050	< 0.05
MW-03S	11 - 13	< 0.050	< 0.05	< 0.050	ND[1]	< 0.05	< 0.050	< 0.050	< 0.050	< 0.05
MW-03S	18 - 20	< 0.050	< 0.05	< 0.050	ND[1]	< 0.05	< 0.050	< 0.050	< 0.050	< 0.05
MW-03S	25 - 27	< 0.050	< 0.05	< 0.050	ND[1]	< 0.05	< 0.050	< 0.050	< 0.050	< 0.05
MW-03S	32 - 34	< 0.050	< 0.05	< 0.050	ND[1]	< 0.05	< 0.050	< 0.050	< 0.050	< 0.05
B1	4 - 6	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
B1	11 - 13	< 0.025	ND[1]	ND[1]	ND[1]	ND[1]	ND[1]	ND[1]	ND[1]	ND[1]
B1	18 - 20	< 0.025	ND[1]	ND[1]	ND[1]	ND[1]	< 0.025	ND[1]	ND[1]	ND[1]
B1	25 - 27	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
B1	32 - 34	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
B2	4 - 6	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
B2	11 - 13	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
B2	18 - 20	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
B2	25 - 27	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
B2	32 - 34	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
B4	4 - 6	< 0.050	< 0.05	< 0.050	ND[1]	< 0.05	< 0.050	< 0.050	< 0.050	< 0.05
B4	11 - 13	< 0.018	< 0.018	< 0.018	ND[1]	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018
B4	18 - 20	< 0.050	< 0.05	< 0.050	ND[1]	< 0.05	< 0.050	< 0.050	< 0.050	< 0.05
B4	25 - 27	< 0.050	< 0.05	< 0.050	ND[1]	< 0.05	< 0.050	< 0.050	< 0.050	< 0.05
B4	32 - 34	< 0.025	< 0.025	< 0.025	ND[1]	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025
1998										
RI_B-1	20 - 21.5	ND[2]	ND[2]	ND[2]	ND[2]	N/A	ND[2]	ND[2]	ND[2]	ND[2]
RI_B-1	30 - 31.5	ND[2]	ND[2]	ND[2]	ND[2]	N/A	ND[2]	ND[2]	ND[2]	ND[2]
RI_B-2	10 - 11.5	ND[2]	ND[2]	ND[2]	ND[2]	N/A	ND[2]	ND[2]	ND[2]	ND[2]
RI_B-2	30 - 31.5	ND[2]	ND[2]	ND[2]	ND[2]	N/A	ND[2]	ND[2]	ND[2]	ND[2]
RI_B-3	5 - 6.5	**27**	**22**	ND[2]	ND[2]	N/A	ND[2]	ND[2]	ND[2]	ND[2]
RI_B-3	30 - 31.5	ND[2]	ND[2]	ND[2]	ND[2]	N/A	ND[2]	ND[2]	ND[2]	ND[2]

TABLE 3-5

Soil Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

Station ID	**Sample Depth Interval (ft bgs)**	**PCE** RSL: 24	**TCE** RSL: 0.94	**cis-1,2-DCE** RSL: 160	**trans-1,2-DCE** RSL: 1,600	**Vinyl chloride** RSL: 0.059	**Benzene** RSL: 1.2	**Toluene** RSL: 4,900	**Ethyl-benzene** RSL: 5.8	**total Xylenes** RSL: 580
					1999					
CH2-SB01	5 - 7	0.00071	0.00012	< 0.002	< 0.002	< 0.002	0.00097	0.00071	0.00042	*0.00038*
CH2-SB01	10 - 12	0.00041	0.00015	< 0.002	0.0001	< 0.002	0.00016	0.00043	0.00052	*0.00036*
CH2-SB01	15 - 17	0.00047	< 0.002	< 0.002	< 0.002	< 0.002	0.00055	0.00079	0.00052	*0.00032*
CH2-SB01	20 - 22	0.0002	0.00005	< 0.002	< 0.002	< 0.002	0.00018	0.00051	0.0003	*0.00019*
CH2-SB01	25 - 27	0.00013	0.00006	< 0.002	< 0.002	< 0.002	0.00011	0.00056	0.00037	*0.0002*
CH2-SB01	30 - 32	0.00002	< 0.002	< 0.002	< 0.002	< 0.002	0.00007	0.0002	0.00025	*0.00011*
CH2-SB02	5 - 7	0.00025	< 0.002	< 0.002	< 0.002	< 0.002	0.00013	0.00066	0.00027	*0.00017*
CH2-SB02	10 - 12	0.00006	< 0.002	< 0.002	< 0.002	< 0.002	0.00009	0.00026	0.00026	*0.00014*
CH2-SB02	15 - 17	0.00008	0.00002	< 0.002	< 0.002	< 0.002	0.00008	0.00027	0.00026	*0.00013*
CH2-SB02	20 - 22	0.00005	< 0.002	< 0.002	< 0.002	< 0.002	0.00015	0.00051	0.0002	*0.0001*
CH2-SB02	25 - 27	0.00001	< 0.002	< 0.002	< 0.002	< 0.002	0.00008	0.00045	0.00026	*0.00012*
CH2-SB02	30 - 32	0.00009	0.00001	< 0.002	< 0.002	< 0.002	0.00012	0.00039	0.0001	*0.00009*
CH2-SB03	5 - 7	0.00023	0.00015	< 0.002	< 0.002	< 0.002	0.00013	0.00074	0.00021	*0.00016*
CH2-SB03	10 - 12	0.00105	0.00065	< 0.002	0.00024	< 0.002	0.00041	0.00154	0.00074	*0.00063*
CH2-SB03	15 - 17	0.00088	0.00067	0.00034	0.00057	0.00006	0.0004	0.00135	0.00087	*0.00087*
CH2-SB03	20 - 22	0.00024	0.00003	< 0.002	< 0.002	< 0.002	0.00012	0.00035	0.00037	*0.00022*
CH2-SB03	25 - 27	0.00008	0.00003	< 0.002	< 0.002	< 0.002	0.0001	0.00011	0.00031	*0.00014*
CH2-SB03	30 - 32	0.00019	0.00008	< 0.002	0.00008	< 0.002	0.00014	0.00038	0.00027	*0.00018*
CH2-SB04	5 - 7	0.00007	< 0.002	< 0.002	< 0.002	< 0.002	0.00013	0.00041	0.00031	*0.00012*
CH2-SB04	10 - 12	0.00021	0.00001	< 0.002	< 0.002	< 0.002	0.01028	0.00362	0.00073	*0.00047*
CH2-SB04	15 - 17	0.00007	< 0.002	< 0.002	< 0.002	< 0.002	0.00011	0.00036	0.00019	*0.00012*
CH2-SB04	20 - 22	0.00007	< 0.002	< 0.002	< 0.002	< 0.002	0.00033	0.00048	0.00018	*0.00011*
CH2-SB04	25 - 27	0.00005	< 0.002	< 0.002	< 0.002	< 0.002	0.00027	0.0004	0.00017	*0.00011*
CH2-SB04	30 - 32	0.00003	0.00004	< 0.002	< 0.002	< 0.002	0.00007	0.00018	0.00015	*0.00008*
CH2-SB05	5 - 7	< 0.002	0.0015	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.01277	*0.00685*
CH2-SB05	10 - 12	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.00092	0.00085	0.00124	*0.00044*
CH2-SB05	15 - 17	0.00022	0.00012	< 0.002	0.00007	< 0.002	0.00285	0.00064	0.00248	*0.00053*
CH2-SB05	20 - 22	0.00244	0.00045	< 0.002	< 0.002	< 0.002	0.00086	0.00201	0.00249	*0.00281*
CH2-SB05	25 - 27	0.00005	0.00005	< 0.002	< 0.002	< 0.002	0.00015	0.00017	0.00038	*0.00017*
CH2-SB05	30 - 32	0.00017	0.00013	< 0.002	< 0.002	< 0.002	0.00022	0.00098	0.00031	*0.00022*
CH2-SB06	5 - 7	0.00132	0.00017	< 0.002	< 0.002	< 0.002	0.00019	0.00113	0.00022	*0.00025*
CH2-SB06	10 - 12	0.00184	0.00059	0.00016	0.00037	0.00003	0.00029	0.00146	0.00044	*0.00045*
CH2-SB06	15 - 17	0.0006	0.00008	< 0.002	0.00037	< 0.002	0.00014	0.00127	0.0002	*0.00015*
CH2-SB06	20 - 22	0.00154	0.00036	0.00014	0.00031	< 0.002	0.00027	0.00124	0.00034	*0.00027*
CH2-SB06	25 - 27	0.00176	0.00023	0.0001	0.00017	< 0.002	0.00021	0.00119	0.00043	*0.00031*
CH2-SB06	30 - 32	0.00086	0.0007	0.0001	0.00036	< 0.002	0.00041	0.00112	0.00063	*0.00047*
CH2-SB07	5 - 7	0.00004	0.00001	< 0.002	< 0.002	< 0.002	0.00006	0.00007	0.00009	*0.00012*
CH2-SB07	10 - 12	0.00004	0.00001	< 0.002	< 0.002	0.00001	0.00007	0.00008	0.00033	*0.00025*
CH2-SB07	15 - 17	0.00003	0.00001	< 0.002	< 0.002	< 0.002	0.00005	0.00007	0.00029	*0.00022*
CH2-SB07	20 - 22	0.00004	0.00002	< 0.002	< 0.002	< 0.002	0.00007	0.00008	0.00026	*0.00021*
CH2-SB07	25 - 27	0.00017	0.00002	< 0.002	< 0.002	< 0.002	0.0001	0.0001	0.00032	*0.00021*
CH2-SB07	30 - 32	0.00005	0.00001	< 0.002	< 0.002	< 0.002	0.00006	0.00008	0.00021	*0.00018*
CH2-SB07	35 - 37	0.00003	0.00001	< 0.002	< 0.002	< 0.002	0.00006	0.00011	0.00015	*0.00019*
CH2-SB08	5 - 7	0.00016	0.00002	< 0.002	< 0.002	< 0.002	0.00021	0.00054	0.00075	*0.00098*
CH2-SB08	10 - 12	0.00006	< 0.002	< 0.002	< 0.002	< 0.002	0.00007	0.00008	0.00031	*0.00024*
CH2-SB08	15 - 17	0.00005	0.00001	< 0.002	< 0.002	< 0.002	0.00007	0.00007	0.00012	*0.00019*
CH2-SB08	20 - 22	0.00004	< 0.002	< 0.002	< 0.002	< 0.002	0.00005	0.00006	0.0002	*0.00016*
CH2-SB08	25 - 27	0.0001	0.00004	< 0.002	< 0.002	< 0.002	0.0001	0.00043	0.00016	*0.00015*
CH2-SB08	30 - 32	0.00009	0.00001	< 0.002	< 0.002	< 0.002	0.00007	0.00041	< 0.002	*0.00026*
CH2-SB09	5 - 7	< 0.002	< 0.002	< 0.002	0.00222	< 0.002	0.00181	0.0139	0.16148	*0.19918*
CH2-SB09	10 - 12	0.00006	< 0.002	< 0.002	< 0.002	< 0.002	0.00007	0.00025	0.00031	*0.00018*
CH2-SB09	15 - 17	0.00007	< 0.002	< 0.002	< 0.002	< 0.002	0.00007	0.00016	0.00018	*0.00019*
CH2-SB09	20 - 22	0.00005	< 0.002	< 0.002	< 0.002	< 0.002	0.00005	0.00025	0.00021	*0.00023*
CH2-SB09	25 - 27	0.00006	< 0.002	< 0.002	< 0.002	< 0.002	0.00006	0.00019	0.00019	*0.00011*
CH2-SB09	30 - 32	0.00011	0.00003	< 0.002	< 0.002	< 0.002	0.00008	0.00023	0.00032	*0.00025*
CH2-SB10	5 - 7	0.00027	0.00015	0.00006	0.0001	0.00006	0.00011	0.00018	0.00038	*0.00036*

TABLE 3-5

Soil Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

Station ID	**Sample Depth Interval (ft bgs)**	**PCE** RSL: 24	**TCE** RSL: 0.94	**cis-1,2-DCE** RSL: 160	**trans-1,2-DCE** RSL: 1,600	**Vinyl chloride** RSL: 0.059	**Benzene** RSL: 1.2	**Toluene** RSL: 4,900	**Ethyl-benzene** RSL: 5.8	**total Xylenes** RSL: 580
1999 (cont'd)										
CH2-SB10	10 - 12	0.00007	0.00001	< 0.002	< 0.002	< 0.002	0.00011	0.00012	0.00019	*0.00021*
CH2-SB10	15 - 17	0.00007	0.00002	0.00002	< 0.002	0.00002	0.00011	0.00014	0.00022	*0.00021*
CH2-SB10	20 - 22	0.00003	< 0.002	< 0.002	< 0.002	< 0.002	0.00006	0.00008	0.00012	*0.00018*
CH2-SB10	25 - 27	0.00008	0.00003	0.00002	0.00003	< 0.002	0.00006	0.00008	0.00024	*0.00016*
CH2-SB10	30 - 32	0.00005	0.00001	< 0.002	< 0.002	< 0.002	0.00007	0.00012	0.00018	*0.00022*
CH2-SB10	35 - 37	0.00005	< 0.002	< 0.002	< 0.002	< 0.002	0.00007	0.00008	0.00022	*0.00015*
CH2-SB10	40 - 42	0.00009	0.00003	< 0.002	< 0.002	< 0.002	0.00006	0.00031	0.00035	*0.00027*
CH2-SB11	5 - 7	0.00005	< 0.002	< 0.002	< 0.002	< 0.002	0.00009	0.0001	0.00011	*0.00013*
CH2-SB11	10 - 12	0.00013	< 0.002	< 0.002	< 0.002	< 0.002	0.00008	0.00033	0.0007	*0.0004*
CH2-SB11	15 - 17	0.00009	0.00002	< 0.002	< 0.002	< 0.002	0.00007	0.00032	0.0002	*0.00034*
CH2-SB11	20 - 22	0.0001	0.00003	< 0.002	< 0.002	< 0.002	0.00006	0.00032	0.0001	*0.00019*
CH2-SB11	25 - 27	0.00019	0.00003	< 0.002	< 0.002	< 0.002	0.00007	0.00027	< 0.002	*0.0003*
CH2-SB11	30 - 32	0.00008	0.00002	< 0.002	< 0.002	< 0.002	0.00009	0.00031	0.00033	*0.00024*
CH2-SB11	35 - 37	0.00012	0.00002	< 0.002	< 0.002	< 0.002	0.00018	0.00031	0.0005	*0.00031*
CH2-SB11	40 - 42	0.00011	0.00002	< 0.002	< 0.002	< 0.002	0.00007	0.00032	0.0005	*0.00024*
CH2-SB12	5 - 7	0.00008	0.00001	< 0.002	< 0.002	< 0.002	0.00005	0.00017	0.00023	*0.00015*
CH2-SB12	10 - 12	0.00005	< 0.002	< 0.002	< 0.002	< 0.002	0.00007	0.00016	0.00015	*0.00016*
CH2-SB12	15 - 17	0.00005	< 0.002	< 0.002	< 0.002	< 0.002	0.00006	0.00017	0.00032	*0.00018*
CH2-SB12	20 - 22	0.00005	0.00001	< 0.002	< 0.002	< 0.002	0.00005	0.00016	0.00016	*0.00013*
CH2-SB12	25 - 27	0.00008	0.00002	< 0.002	< 0.002	< 0.002	0.00009	0.00019	0.00044	*0.00026*
CH2-SB12	30 - 32	0.00018	0.00017	0.00003	0.00011	0.00013	0.00011	0.0002	0.00043	*0.00039*
CH2-SB12	35 - 37	0.00022	0.00007	0.00002	0.00006	< 0.002	0.00007	0.0002	0.00037	*0.00028*
CH2-SB12	40 - 42	0.00046	0.0002	0.00007	0.00016	< 0.002	0.00015	0.00042	0.00047	*0.00052*
CH2-SB13	5 - 7	< 0.002	0.00002	< 0.002	< 0.002	< 0.002	0.00013	0.00018	0.00089	*0.00033*
CH2-SB13	10 - 12	0.00018	0.00007	0.00003	< 0.002	< 0.002	0.00009	0.00033	0.00066	*0.0005*
CH2-SB13	15 - 17	0.00017	0.00005	< 0.002	< 0.002	< 0.002	0.0001	0.00027	0.00051	*0.00028*
CH2-SB13	20 - 22	0.00015	0.00001	< 0.002	< 0.002	< 0.002	0.00009	0.00023	< 0.002	*0.00039*
CH2-SB13	25 - 27	0.00013	0.00001	< 0.002	< 0.002	< 0.002	0.00007	0.0002	0.00047	*0.00024*
CH2-SB13	30 - 32	0.00007	0.00002	< 0.002	< 0.002	< 0.002	0.00006	0.00019	0.00049	*0.00017*
CH2-SB13	35 - 37	0.00006	0.00002	< 0.002	< 0.002	< 0.002	0.00006	0.00017	0.0004	*0.00024*
CH2-SB13	40 - 42	0.00011	0.00001	< 0.002	< 0.002	< 0.002	0.00007	0.00007	0.00026	*0.00011*
CH2-SB14	5 - 7	< 0.002	0.00001	< 0.002	< 0.002	< 0.002	0.00007	0.00007	0.00007	*0.0001*
CH2-SB14	10 - 12	0.00069	0.0002	0.0001	0.00013	0.0001	0.0003	0.00033	0.00066	*0.00062*
CH2-SB14	15 - 17	0.00004	0.00001	< 0.002	< 0.002	< 0.002	0.00004	0.00015	0.00005	*0.00016*
CH2-SB14	20 - 22	0.00278	0.00005	0.00002	0.00004	< 0.002	0.00006	0.00012	0.00087	*0.00096*
CH2-SB14	25 - 27	0.00009	0.00003	< 0.002	< 0.002	< 0.002	0.00006	0.00014	0.00042	*0.00024*
CH2-SB14	30 - 32	< 0.002	0.00002	< 0.002	< 0.002	< 0.002	0.00004	0.0002	0.00029	*0.0002*
CH2-SB14	35 - 37	0.00046	0.00022	0.00008	0.00015	0.00006	0.00014	0.00028	0.00057	*0.00053*
CH2-SB14	40 - 42	0.00013	0.00004	0.00001	0.00003	0.00002	0.00005	0.00017	0.0003	*0.00023*
CH2-SB14	45 - 47	0.00022	0.00007	0.00002	0.00005	< 0.002	0.00007	0.00014	0.00043	*0.00025*
CH2-SB14	50 - 52	0.00004	0.00001	< 0.002	< 0.002	< 0.002	0.00005	0.0001	0.00021	*0.00013*
CH2-SB15	5 - 7	0.00018	0.00001	< 0.002	< 0.002	< 0.002	0.00006	0.0001	0.00017	*0.00014*
CH2-SB15	10 - 12	0.21027	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.12467	*0.12869*
CH2-SB15	15 - 17	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	4.176	5.575	*11*
CH2-SB15	20 - 22	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.04739	11.8	< 0.002	*20.9*
CH2-SB15	25 - 27	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.02239	4.075	**6.11**	*10.8*
CH2-SB15	30 - 32	0.0032	0.00122	0.00035	0.0007	0.00029	0.00058	0.00168	0.0025	*0.00372*
CH2-SB15	35 - 37	0.00025	0.00001	< 0.002	< 0.002	< 0.002	0.00007	0.00014	0.00021	*0.00021*
CH2-SB15	40 - 42	0.00068	0.00018	0.00007	0.00014	0.00007	0.00016	0.00034	0.0005	*0.00066*
CH2-SB15	45 - 47	0.00016	< 0.002	< 0.002	< 0.002	< 0.002	0.00016	0.00027	0.00035	*0.00035*
CH2-SB15	50 - 52	0.00006	< 0.002	< 0.002	< 0.002	< 0.002	0.00005	0.00012	0.00015	*0.00014*
CH2-SB15	55 - 57	0.0013	0.00019	< 0.002	0.00002	< 0.002	0.00008	0.00006	0.00014	*0.00009*
CH2-SB15	60 - 62	0.00012	0.00003	< 0.002	0.00003	< 0.002	0.00008	0.00032	0.00026	*0.00035*
CH2-SB16	5 - 7	0.00035	0.00015	0.00004	0.00008	< 0.002	0.00011	0.00027	0.00049	*0.00044*
CH2-SB16	10 - 12	0.00003	0.00003	< 0.002	< 0.002	< 0.002	0.00013	0.00039	0.00062	*0.00055*

TABLE 3-5

Soil Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

Station ID	**Sample Depth Interval (ft bgs)**	**PCE** RSL: 24	**TCE** RSL: 0.94	**cis-1,2-DCE** RSL: 160	**trans-1,2-DCE** RSL: 1,600	**Vinyl chloride** RSL: 0.059	**Benzene** RSL: 1.2	**Toluene** RSL: 4,900	**Ethyl-benzene** RSL: 5.8	**total Xylenes** RSL: 580
1999 (cont'd)										
CH2-SB16	15 - 17	0.00012	< 0.002	< 0.002	< 0.002	< 0.002	0.0001	0.00017	0.00028	*0.0002*
CH2-SB16	20 - 22	0.00009	0.00002	< 0.002	< 0.002	< 0.002	0.00006	0.00007	0.00024	*0.00021*
CH2-SB16	25 - 27	0.00084	0.00039	0.00012	0.00023	0.00032	0.00023	0.00047	0.00101	*0.00076*
CH2-SB16	30 - 32	0.00009	0.00001	< 0.002	< 0.002	< 0.002	0.00009	0.00024	0.00044	*0.00035*
CH2-SB16	35 - 37	0.00007	0.00003	< 0.002	< 0.002	< 0.002	0.00011	0.00026	0.00041	*0.00033*
CH2-SB16	40 - 42	0.00045	0.00028	0.00009	0.0002	0.00017	0.00016	0.00031	0.00056	*0.00043*
CH2-SB16	45 - 47	0.0013	0.00059	0.00018	0.00043	0.0002	0.00029	0.00066	0.00085	*0.00097*
CH2-SB16	50 - 52	0.00049	0.00026	0.0001	0.00019	0.00004	0.00019	0.00036	0.00051	*0.00061*
CH2-SB16	55 - 57	0.00007	< 0.002	< 0.002	< 0.002	< 0.002	0.00009	0.00021	0.00034	*0.0005*
CH2-SB16	60 - 62	0.00008	0.00004	< 0.002	< 0.002	< 0.002	0.00006	0.00019	0.00017	*0.00012*
CH2-SB16	65 - 67	0.00004	0.00001	< 0.002	< 0.002	< 0.002	0.00007	0.0002	0.00018	*0.00021*
CH2-SB17	5 - 7	0.00001	0.00003	< 0.002	< 0.002	< 0.002	0.00001	0.00015	0.00002	*0.00034*
CH2-SB17	10 - 12	< 0.002	0.00044	< 0.002	< 0.002	< 0.002	0.00053	0.00044	0.00092	*0.00018*
CH2-SB17	15 - 17	< 0.002	0.00044	< 0.002	< 0.002	< 0.002	0.00053	0.00042	0.00077	*0.00003*
CH2-SB17	20 - 22	< 0.002	0.00045	< 0.002	< 0.002	< 0.002	0.00051	0.00048	0.00069	*0.00022*
CH2-SB17	25 - 27	0.0001	0.00002	< 0.002	0.00001	< 0.002	0.00006	0.00008	0.00022	*0.00019*
CH2-SB17	30 - 32	0.00006	< 0.002	< 0.002	< 0.002	< 0.002	0.00006	0.00006	0.00015	*0.00014*
CH2-SB17	35 - 37	< 0.002	0.00059	< 0.002	< 0.002	< 0.002	0.0006	0.00082	0.00184	*0.00117*
CH2-SB17	40 - 42	0.0002	0.00006	< 0.002	< 0.002	< 0.002	0.00012	0.00036	0.00016	*0.00026*
CH2-SB17	45 - 47	0.00003	0.00003	< 0.002	< 0.002	< 0.002	0.00007	0.00021	< 0.002	*0.00009*
CH2-SB18	5 - 7	0.00012	0.00001	< 0.002	< 0.002	< 0.002	0.00021	0.00034	0.00044	*0.00039*
CH2-SB18	10 - 12	0.00008	< 0.002	< 0.002	< 0.002	< 0.002	0.0001	0.00016	0.00035	*0.00019*
CH2-SB18	15 - 17	< 0.002	0.00001	< 0.002	< 0.002	< 0.002	0.00008	0.00015	0.00011	*0.00016*
CH2-SB18	20 - 22	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.00042	0.01661	0.00824	*0.01941*
CH2-SB18	25 - 27	0.00003	0.00002	< 0.002	< 0.002	< 0.002	0.00007	0.00012	0.00023	*0.00026*
CH2-SB18	30 - 32	0.00007	0.00001	< 0.002	< 0.002	< 0.002	0.00009	0.00022	0.00019	*0.00019*
CH2-SB18	35 - 37	0.00022	0.0001	0.00004	0.00007	< 0.002	0.00012	0.00032	0.00029	*0.00032*
CH2-SB18	40 - 42	< 0.002	0.00027	< 0.002	< 0.002	< 0.002	0.00035	0.00022	0.00011	*0.00011*
2000										
SB-01I	8 - 9	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-01I	25 - 26	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-01I	31 - 32	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-01I	41 - 42	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-01I	55 - 56	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013
SB-01I	61 - 62	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013
SB-01I	71 - 72	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-01I	83 - 84	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-01I	91 - 92	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-01I	101 - 102	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-01I	112 - 113	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-01I	122 - 123	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-01I	131 - 132	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-01I	140 - 141	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-04I	25 - 26	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
SB-04I	137 - 139	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014	< 0.014
SB-05I	8 - 10	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-05I	24 - 26	0.002 J	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	28 - 30	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	45 - 47	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	55 - 57	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-05I	59 - 61	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	74 - 76	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	78 - 80	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	95 - 97	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	105 - 107	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	109 - 111	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012

TABLE 3-5

Soil Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

Station ID	**Sample Depth Interval (ft bgs)**	**PCE** RSL: 24	**TCE** RSL: 0.94	**cis-1,2-DCE** RSL: 160	**trans-1,2-DCE** RSL: 1,600	**Vinyl chloride** RSL: 0.059	**Benzene** RSL: 1.2	**Toluene** RSL: 4,900	**Ethyl-benzene** RSL: 5.8	**total Xylenes** RSL: 580
2000 (cont'd)										
SB-05I	125 - 127	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	129 - 131	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	142 - 144	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-05I	155 - 157	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-05I	160 - 162	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	0.002 J	< 0.013	< 0.013
SB-06S	25 - 27	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-06S	65 - 67	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-07I	53 - 55	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013
SB-07I	127 - 129	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013
SB-08S	30 - 31	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-08S	39 - 40	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-08I	118 - 119	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013
SB-09S	58 - 59	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-10S	58 - 59	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-11S	15 - 16	< 0.012	0.002 J	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-11S	33 - 35	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
SB-11I	74 - 75	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-11I	99 - 100	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-11I	139 - 140	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-11I	180 - 181	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-11I	237 - 238	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
2001										
SB-06	34 - 36	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-07	28 - 30	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-08	35 - 36	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
SB-09	34 - 39	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	0.003 J	0.002 J	< 0.013	< 0.013
SB-10	48 - 49	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
SB-11	37 - 38	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013
SB-12	33 - 34	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	< 0.015	0.002 J	< 0.015	< 0.015
SB-13	33 - 36	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
TW-01	45 - 50	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
TW-02	50 - 52	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013
TW-03	50 - 52	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013	< 0.013
TW-04	36 - 38	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
TW-05	28 - 30	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011	< 0.011
2002										
MW-12S	131 - 131	< 0.0017	< 0.0017	< 0.0017	< 0.0017	< 0.0084	< 0.0017	< 0.0017	< 0.0017	*< 0.0033*
TW-14	0 - 1	< 0.0013	< 0.0013	< 0.0013	< 0.0013	< 0.0063	< 0.0013	< 0.0013	< 0.0013	*< 0.0025*
TW-15	32 - 33.6	< 0.001	< 0.001	< 0.001	< 0.001	< 0.0052	< 0.001	< 0.001	< 0.001	*< 0.001*
TW-16	0 - 1	< 0.0013	< 0.0013	< 0.0013	< 0.0013	< 0.0066	0.0028 J	0.0016 J	< 0.0013	*< 0.0026*
2003										
ESA-MW1	30 - 35	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-MW1	60 - 65	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-MW2	0 - 5	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-MW2	25 - 30	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-MW3	35 - 40	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-MW3	55 - 60	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-SB1	10 - 10	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-SB4	10 - 10	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-SB5	10 - 10	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-SB6	10 - 10	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-SB7	10 - 10	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-SB8	10 - 10	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005
ESA-SB9	10 - 10	< 0.005	N/A	N/A	N/A	N/A	< 0.005	< 0.005	< 0.005	< 0.005

TABLE 3-5

Soil Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

Station ID	**Sample Depth Interval (ft bgs)**	**PCE** RSL: 24	**TCE** RSL: 0.94	**cis-1,2-DCE** RSL: 160	**trans-1,2-DCE** RSL: 1,600	**Vinyl chloride** RSL: 0.059	**Benzene** RSL: 1.2	**Toluene** RSL: 4,900	**Ethyl-benzene** RSL: 5.8	**total Xylenes** RSL: 580
2005										
SB1	9 - 11	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	*< 0.005*
SB1	14 - 16	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	*< 0.005*
SB2	9 - 11	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	*< 0.005*
SB2	14 - 16	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	*< 0.005*
SB3	9 - 11	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	*< 0.005*
SB3	14 - 16	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	*< 0.005*

Notes:

Concentrations are in milligrams per kilogram (mg/kg).

Concentrations in **bold** exceed respective RSL.

PCE - tetrachloroethene

TCE - trichloroethene

DCE - dichloroethene

RSL - EPA Regional Screening Leve l (based on target risk of 1 x 10^{6} and target hazard quotient of 1), November 2015

J - the concentration is estimated

< not detected above the laboratory detection limit

[1] - not detected (ND) or not reported (NR), analyte may or may not have been analyzed, (Phase I Site Assessment [ADEM, 1996], laboratory reports not provided)

[2] - River Front Phase II ESA (CWA Group, 1998), laboratory report did not provide the detection limit

[3] - Phase 2: Montgomery Urban Garden (ADEM, 2010), only detected values presented in report

N/A - not analyzed

Total xylene results are italicized when results are based on individual isomer concentrations.

ADEM - Alabama Department of Environmental Quality

EPA - U.S. Environmental Protection Agency

TABLE 3-6

Soil Vapor Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

	PCE VISL: 360	**TCE** VISL: 16	**cis-1,2-DCE** VISL: NA	**trans-1,2-DCE** VISL: NA	**Benzene** VISL: 12	**Toluene** VISL: 37	**Ethylbenzene** VISL: 170,000	**m,p-Xylenes** VISL: 3,500	**o-Xylenes** VISL: 3,500
Annex Building, November 2010 (Summa Canisters), units in ppbv									
3082-01	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	**3.5**	< 0.5	< 0.5	< 0.5
3082-12	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	**2**	< 0.5	< 0.5	< 0.5
Phytoremediation Site, April 2011 (Gore Modules), units in ug									
660513	0.16	< 0.02	< 0.02	< 0.5	< 0.01	0.27	< 0.02	< 0.02	< 0.01
660514	0.43	< 0.02	< 0.02	< 0.5	< 0.01	0.05	< 0.02	< 0.02	< 0.01
660515	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	< 0.01	< 0.02	< 0.02	< 0.01
660516	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	0.04	< 0.02	< 0.02	< 0.01
660517	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	< 0.01	< 0.02	< 0.02	< 0.01
660518	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	0.05	< 0.02	< 0.02	< 0.01
660519	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	< 0.01	< 0.02	0.02	< 0.01
660520	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	< 0.01	< 0.02	< 0.02	< 0.01
660521	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	< 0.01	< 0.02	< 0.02	< 0.01
660522	0.08	< 0.02	< 0.02	< 0.5	< 0.01	< 0.01	< 0.02	< 0.02	< 0.01
660523	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	< 0.01	< 0.02	< 0.02	< 0.01
660524	< 0.02	< 0.02	< 0.02	< 0.5	< 0.01	< 0.01	< 0.02	< 0.02	< 0.01
Annex Building, August 2011 (Gore Modules), units in μg/m^{3*}									
670798	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	< 0.09	< 0.15	0.15	< 0.08
670799	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.11	< 0.15	0.16	0.09
670800	2.92	< 1.41	< 3.06	< 16.01	1.04	< 0.47	< 0.82	< 0.82	< 0.43
670801	2.3	< 1.41	< 3.06	< 16.01	< 0.76	1.02	< 0.82	< 0.82	< 0.43
670803	4.6	< 1.41	< 3.06	< 16.01	< 0.76	< 0.47	< 0.82	< 0.82	< 0.43
670804	6.78	< 1.41	< 3.06	< 16.01	< 0.76	2.58	< 0.82	< 0.82	< 0.43
Alabama Attorney General's Building, August 2011 (Gore Modules), units in μg/m^{3*}									
670807	2.11	< 1.41	< 3.06	< 16.01	< 0.76	14.45	< 0.82	< 0.82	< 0.43
670808	< 0.97	< 1.41	< 3.06	< 16.01	< 0.76	0.63	< 0.82	< 0.82	< 0.43
670809	1.84	< 1.41	< 3.06	< 16.01	3.1	17.68	< 0.82	< 0.82	0.44
670810	20.3	< 1.41	< 3.06	< 16.01	< 0.76	3.22	< 0.82	< 0.82	< 0.43
670811	57.78	< 1.41	< 3.06	< 16.01	< 0.76	< 0.47	< 0.82	< 0.82	< 0.43
670813	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.11	< 0.15	0.16	< 0.08
670814	< 0.97	1.53	< 3.06	< 16.01	< 0.76	2.92	< 0.82	< 0.82	< 0.43
670815	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	< 0.09	< 0.15	0.31	0.17
670816	1.51	< 1.41	< 3.06	< 16.01	< 0.76	< 0.47	< 0.82	< 0.82	< 0.43
VIMS, 24 hour sample collection, February 2012 (Gore Modules), units in μg/m^{3*}									
684996	0.64	**290.85**	2.45	< 1.94	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
684997	5.83	**> 3697.09**	203.4	2.34	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
684998	4.18	**> 3124.05**	192.02	2.57	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
684999	20.55	**> 4521.86**	87.53	< 1.94	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
685000	30.03	**> 4596.01**	39.41	< 1.94	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
VIMS, 72 hour sample collection, February 2012 (Gore Modules), units in μg/m^{3*}									
685009	0.33	**143.98**	1.06	< 1.94	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
685010	2.75	**> 1168.74**	45.15	< 1.94	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
685011	2.79	**> 1777.25**	83.71	< 1.94	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
685012	21.41	**> 2307.67**	37.28	< 1.94	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26
685013	27.58	**> 2198.33**	16.93	< 1.94	< 0.46	< 0.28	< 0.25	< 0.25	< 0.26

TABLE 3-6

Soil Vapor Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

	PCE VISL: 360	**TCE** VISL: 16	**cis-1,2-DCE** VISL: NA	**trans-1,2-DCE** VISL: NA	**Benzene** VISL: 12	**Toluene** VISL: 37	**Ethylbenzene** VISL: 170,000	**m,p-Xylenes** VISL: 3,500	**o-Xylenes** VISL: 3,500
Right-of-Way for Attorney General's, Wallace, and Folsom Buildings, February 2012 (Gore Modules), units in µg/m ^{3*}									
685001	< 0.86	< 1.25	< 2.71	< 5.68	< 1.34	< 0.83	< 0.73	< 0.72	< 0.77
685002	< 0.86	< 1.25	< 2.71	< 5.68	< 1.34	< 0.83	< 0.73	< 0.72	< 0.77
685003	< 0.86	< 1.25	< 2.71	< 5.68	< 1.34	< 0.83	< 0.73	< 0.72	< 0.77
685004	< 0.86	< 1.25	< 2.71	< 5.68	< 1.34	< 0.83	< 0.73	< 0.72	< 0.77
685005	< 0.86	< 1.25	< 2.71	< 5.68	< 1.34	< 0.83	< 0.73	< 0.72	< 0.77
685006	< 0.86	< 1.25	< 2.71	< 5.68	2.8	1.87	< 0.73	< 0.72	< 0.77
685007	< 0.86	< 1.25	< 2.71	< 5.68	< 1.34	< 0.83	< 0.73	< 0.72	< 0.77
685008	< 0.86	< 1.25	< 2.71	< 5.68	< 1.34	< 0.83	< 0.73	< 0.72	< 0.77

Notes:

*At locations where concentrations are provided in both micrograms and micrograms per cubic meter (µg/m^3), results are presented in µg/m^3

ppbv - parts per billion vapor

< not detected above the laboratory detection limit

> Concentrations estimated; concentrations are likely higher than presented

Bold values exceed EPA 2015 residential Vapor Intrusion Screening Level (VISL); NA - no VISL available

EPA - U.S. Environmental Protection Agency

PCE - tetrachloroethene

TCE - trichloroethene

DCE - dichloroethene

VIMS - vapor intrusion monitoring system

DEAP - Downtown Environmental Assessment Project

TABLE 3-7

Indoor Air Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

	PCE RSL: 11	**TCE** RSL: 0.48	**cis-1,2-DCE** RSL: NA	**trans-1,2-DCE** RSL: NA	**Benzene** RSL: 0.36	**Toluene** RSL: 5,200	**Ethylbenzene** RSL: 1.1	**m,p-Xylenes** RSL: 100	**o-Xylenes** RSL: 100
Annex Building, November 2010 (Summa Canisters), units in μg/m ^{3}									
3082-02	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	4	< 0.5	< 1.0	< 0.5
3082-03	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	2.3	< 0.5	< 1.0	< 0.5
3082-04	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	4.1	< 0.5	< 1.0	< 0.5
3082-05	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	3.3	< 0.5	< 1.0	< 0.5
3082-06	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	3.4	< 0.5	< 1.0	< 0.5
3082-07	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	4.6	< 0.5	< 1.0	< 0.5
3082-08	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	2.7	< 0.5	< 1.0	< 0.5
3082-09	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	2.2	< 0.5	< 1.0	< 0.5
3082-10	**13**	< 0.5	< 0.5	< 0.5	< 0.5	4.4	**6.3**	16	3.4
3082-11	4.8	< 0.5	< 0.5	< 0.5	< 0.5	4.5	< 0.5	5.5	< 0.5
Annex Building, August 2011 (Gore Modules), units in μg/m ^{3} *****									
667984	0.41	< 0.26	< 0.56	< 2.92	< 0.14	0.29	0.81	2.31	0.66
667985	0.4	< 0.26	< 0.56	< 2.92	< 0.14	0.28	0.76	2.25	0.68
667986	0.4	< 0.26	< 0.56	< 2.92	< 0.14	0.28	0.78	2.3	0.68
667987	0.37	< 0.26	< 0.56	< 2.92	< 0.14	0.26	0.71	2.07	0.61
667988	0.36	< 0.26	< 0.56	< 2.92	< 0.14	0.25	0.64	1.89	0.56
667989	1.74	< 0.26	< 0.56	< 2.92	< 0.14	0.22	**1.24**	3.29	0.86
667990	0.37	< 0.26	< 0.56	< 2.92	< 0.14	0.17	0.5	1.46	0.48
667991	0.7	**0.99**	< 0.56	< 2.92	< 0.14	0.32	**1.16**	3.42	1.03
667992	0.52	< 0.26	< 0.56	< 2.92	< 0.14	0.38	0.99	3.01	1.04
667993	1.6	< 0.26	< 0.56	< 2.92	< 0.14	0.32	**1.64**	4.56	1.16
667994	1.42	< 0.26	< 0.56	< 2.92	< 0.14	0.29	**1.34**	3.68	1.03
667995	1.23	< 0.26	< 0.56	< 2.92	< 0.14	0.27	**1.72**	5.02	1.37
670802	1.91	< 0.26	< 0.56	< 2.92	< 0.14	1.04	0.91	2.58	1.18
Alabama Attorney General's Building, August 2011 (Gore Modules), units in μg/m ^{3} *****									
667998	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.2	0.29	0.68	0.27
667999	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.39	0.82	2.86	0.73
668000	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.4	0.81	2.84	0.73
668001	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.43	0.82	2.86	0.72
668002	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.4	0.85	3.03	0.78
668003	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.93	0.36	1.18	0.41
668004	< 0.18	< 0.26	< 0.56	< 2.92	< 0.14	0.55	0.65	2.15	0.61
Annex Building, February 2012 (Gore Modules), units in μg/m ^{3} *****									
684975	< 0.29	< 0.43	< 0.92	< 1.94	< 0.46	6.91	**1.35**	5.12	2.71
684976	< 0.29	< 0.43	< 0.92	< 1.94	< 0.46	10.31	**1.33**	5.86	3.54
684977	5.15	< 0.43	< 0.92	< 1.94	< 0.46	2.86	**2.13**	9.78	3.94
684978	4.65	< 0.43	< 0.92	< 1.94	< 0.46	2.66	**2.34**	11	4.51
684979	4.95	< 0.43	< 0.92	< 1.94	< 0.46	2.74	**2.28**	10.55	4.28
684980	4.18	< 0.43	< 0.92	< 1.94	< 0.46	2.43	**1.98**	9.14	3.71
684981	4.08	< 0.43	< 0.92	< 1.94	< 0.46	2.49	**2.04**	9.48	3.85
684982	9.96	< 0.43	< 0.92	< 1.94	< 0.46	2.37	**3.57**	17.08	7.02
684983	6.83	< 0.43	< 0.92	< 1.94	< 0.46	4.54	**2.83**	12.57	5.15
684984	7.3	< 0.43	< 0.92	< 1.94	< 0.46	4.7	**3.29**	14.99	6.32
684991	2.41	< 0.43	< 0.92	< 1.94	< 0.46	3.17	**1.42**	6.04	2.56
684992	**13.44**	< 0.43	< 0.92	< 1.94	< 0.46	3.46	**4.59**	21.03	8.44
684993	4.82	< 0.43	< 0.92	< 1.94	**0.86**	5.97	**2.26**	9.63	3.82
684994	< 0.29	< 0.43	< 0.92	< 1.94	< 0.46	1.66	0.6	2.29	0.99
684995	< 0.29	< 0.43	< 0.92	< 1.94	< 0.46	0.77	0.3	0.97	0.39

TABLE 3-7

Indoor Air Sample Results

Technical Work Plan--DEAP, Montgomery, Alabama

	PCE RSL: 11	**TCE** RSL: 0.48	**cis-1,2-DCE** RSL: NA	**trans-1,2-DCE** RSL: NA	**Benzene** RSL: 0.36	**Toluene** RSL: 5,200	**Ethylbenzene** RSL: 1.1	**m,p-Xylenes** RSL: 100	**o-Xylenes** RSL: 100
Annex Building, February 2012 (Summa Canisters), units in µg/m^3									
491200221-1	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	16	< 0.50	4.8	2.4
491200221-2	8.8	< 0.50	< 0.50	< 0.50	< 0.50	4.8	< 0.50	8.2	3
491200221-3	**14**	< 0.50	< 0.50	< 0.50	< 0.50	8.5	**2.8**	14	5.3
491200221-4	**17**	< 0.50	< 0.50	< 0.50	< 0.50	5.1	**3.2**	14	5.1
491200221-5	8.0	< 0.50	< 0.50	< 0.50	< 0.50	8.7	< 0.50	6.4	2.5
Annex Building, May 2012 (Gore Modules), units in µg/m^3 *									
685014	2.04	< 2.07	< 11.60	< 29.67	< 3.99	4.52	1.05	3.68	2.01
685015	1.77	< 2.07	< 11.60	< 29.67	< 3.99	3.88	0.86	2.87	1.58
685016	2.19	< 2.07	< 11.60	< 29.67	< 3.99	4.56	1.05	3.83	2.14
685017	1.72	< 2.07	< 11.60	< 29.67	< 3.99	4.11	0.80	3.00	1.54
685018	1.95	< 2.07	< 11.60	< 29.67	< 3.99	4.02	0.96	3.31	1.76
685019	2.88	< 2.07	< 11.60	< 29.67	< 3.99	4.28	**1.36**	4.92	2.61
685020	1.81	< 2.07	< 11.60	< 29.67	< 3.99	15.41	**1.42**	5.86	4.18
685021	1.18	< 2.07	< 11.60	< 29.67	< 3.99	67.93	**5.34**	26.10	18.10
685022	1.89	< 2.07	< 11.60	< 29.67	< 3.99	5.78	**2.44**	10.24	4.82
685025	3.76	< 2.07	< 11.60	< 29.67	< 3.99	5.85	**1.82**	7.26	3.97
685026	5.77	< 2.07	< 11.60	< 29.67	< 3.99	6.26	**2.69**	11.01	5.90
685029	5.87	< 2.07	< 11.60	< 29.67	< 3.99	7.68	**2.73**	11.50	5.48
685030	3.29	< 2.07	< 11.60	< 29.67	< 3.99	3.73	**1.52**	5.74	2.85

Notes:

*At locations where concentrations are provided in both micrograms and micrograms per cubic meter (µg/m^3), results are presented in µg/m^3

< not detected above the laboratory detection limit

Bold values exceed EPA regional screening level (RSL)

PCE - tetrachloroethene

TCE - trichloroethene

DCE - dichloroethene

EPA - U.S. Environmental Protection Agency

NA - no screening level available

DEAP - Downtown Environmental Assessment Project

TABLE 5-1

Proposed Sampling by Media

Technical Work Plan--DEAP, Montgomery, Alabama

Location ID	Number of Samples	Analyses	Method
Shallow Groundwater			
MW-01S	1	tetrachloroethene trichloroethene cis-1,2-dichloroethene trans-1,2-dichloroethene vinyl chloride (COCs)	SW8260B
MW-02S	1		
MW-03S	1		
MW-07S	1		
MW-08S	1		
MW-09S	1		
MW-10S	1		
MW-12S	1		
TMPZ-1	1		
Intermediate or Deep Groundwater			
MW-01I	1	COCs	SW8260B
MW-05I	1		
MW-07I	1		
MW-08I	1		
MW-12I	1		
Soil - Shelby tube			
co-located with soil vapor sample locations	To be determined	bulk density	ASTM D7263-09
		total porosity	ASTM D7263-09
		saturated porosity	ASTM D7263-09
		fraction organic carbon	Walkley Black Method
Soil Vapor Samples			
Two samples per shallow groundwater sample that exceeds one or more VISLs	To be determined (up to 18)	COCs	TO-15
VIMS-10 and VIMS-50	2 total (1 each)		
Alabama AG's Building	3 (around northern wing)		
County Annex III Building	4 (1 per side)		

Notes:

VISL - U.S. Environmental Protection Agency residential vapor intrusion screening levels

SW - SW-846 Test Methods for Evaluating Solid Waste Physical/Chemical Methods

VIMS - vapor intrusion monitoring system

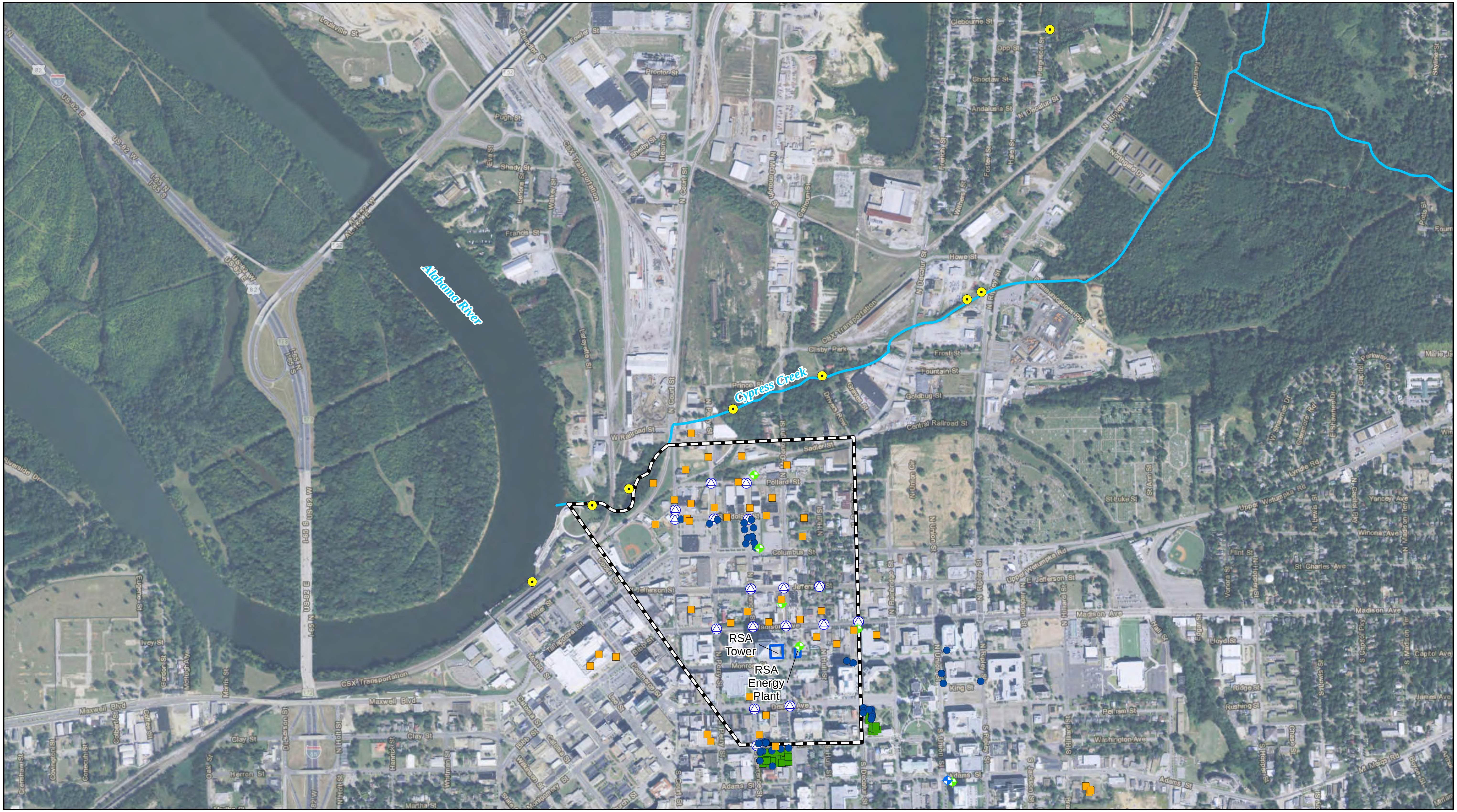
AG - Attorney General

Figures

Note:
1. RSA - Retirement Systems of Alabama
2. AG - Attorney General

FIGURE 1-1
Site Boundary
Downtown Environmental Assessment Project
Montgomery, AL

SCO \\galt\proj\CityOfMontgomery\464649\MapFiles\Fig1-1_SiteBoundary.mxd AESPEJO 12/21/2015



LEGEND

- 🔵 Shallow Monitoring Well
- 🟢 Deep Monitoring Well
- △ Sewer Manhole
- ● Soil Vapor Sample Location
- 🟩 Indoor Air Sample Location
- 🟧 One-time Groundwater Sample Location
- ⊙ Surface Water Sample
- ▭ RSA Building
- ▭ Site Boundary

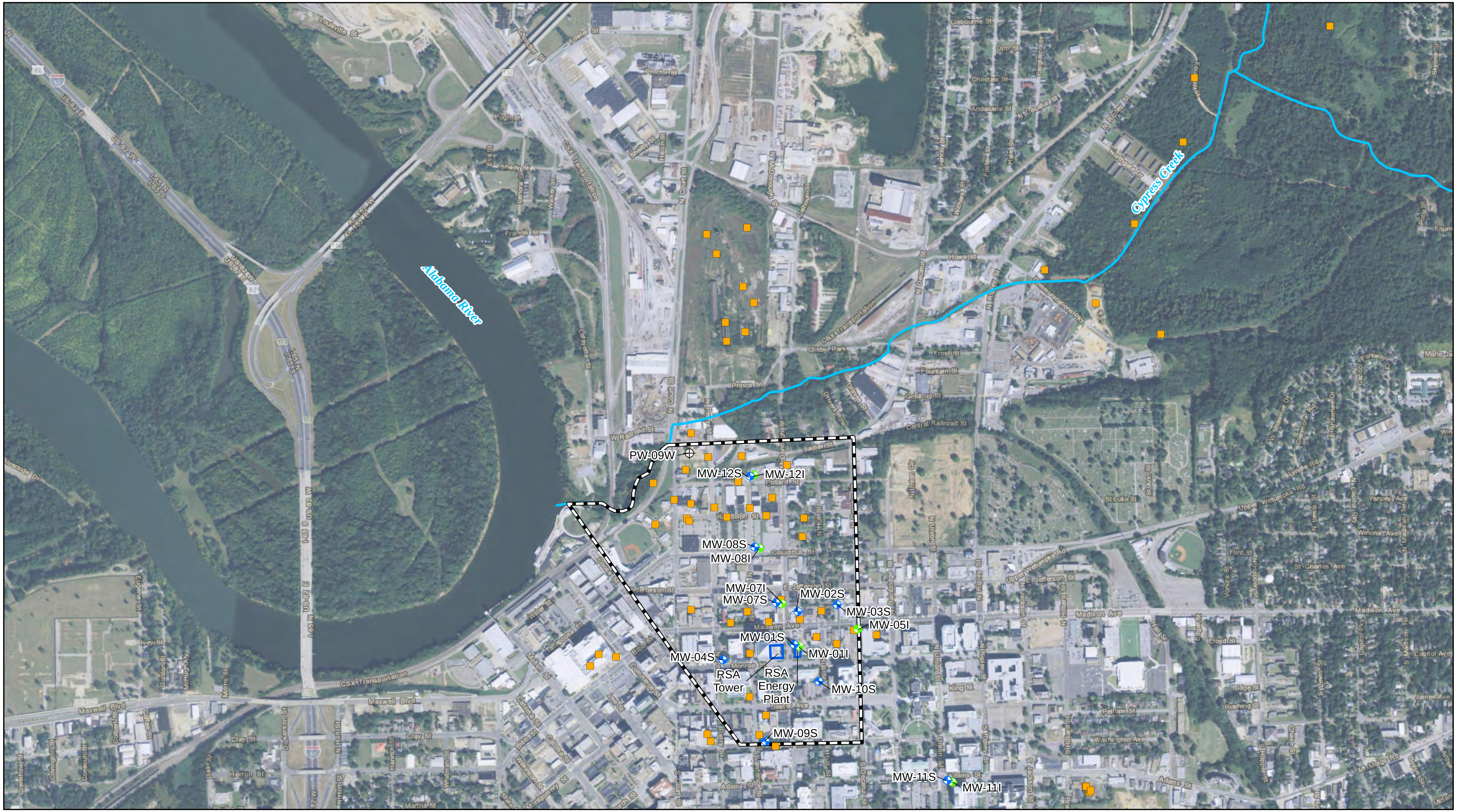
Note:
Refer to Figure 3-5 for soil sample locations.

N

0 500 1,000
Feet

FIGURE 3-1
Historical Sample Locations
Downtown Environmental Assessment Project
Montgomery, AL

ch2m:



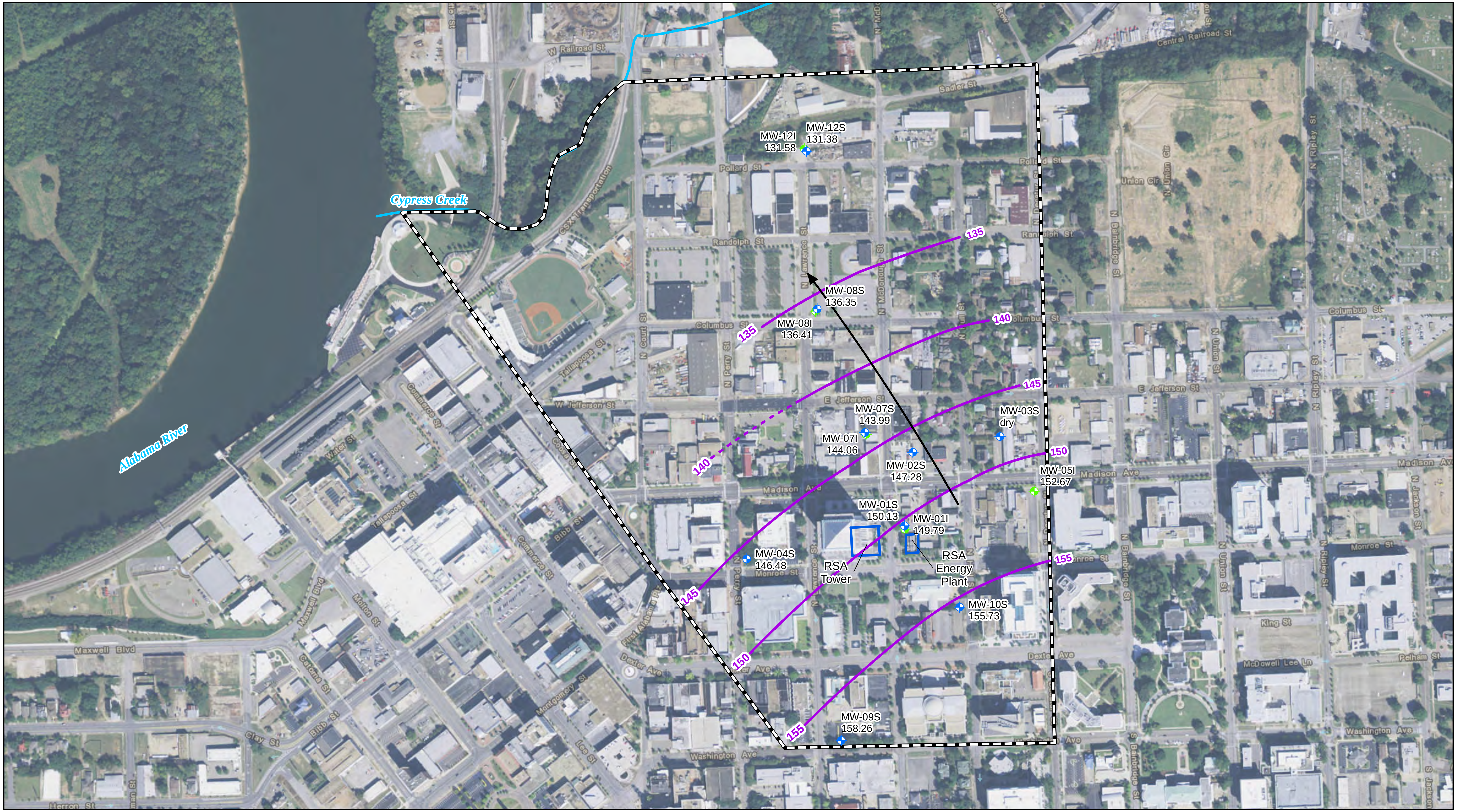
LEGEND

- Shallow Monitoring Well
- Deep Monitoring Well
- ⊕ Former City Water Supply Well
- 🟧 One-time Sample Location
- RSA Building
- Site Boundary

Note:
RSA - Retirement Systems of Alabama

FIGURE 3-2
Groundwater Sample Locations
Downtown Environmental Assessment Project
Montgomery, AL

SCO \\galt\proj\CityOfMontgomery\464649\MapFiles\Fig3-2_Groundwater.mxd AESPEJO 11/30/2015



LEGEND

- Shallow Monitoring Well
- Deep Monitoring Well
- Groundwater Elevation Contour (Dashed Where Inferred)
- Generalized Groundwater Flow Direction
- RSA Building
- Site Boundary

Notes:
1. RSA - Retirement Systems of Alabama
2. Groundwater elevations presented in feet above mean sea level.
3. Only shallow interval wells used in contouring.

N
0 225 450
Feet

FIGURE 3-3
Potentiometric Surface - Shallow Interval
Downtown Environmental Assessment Project
Montgomery, AL

ch2m:

SCO \\galt\proj\CityOfMontgomery\464649\MapFiles\Fig3-3_Potentiometric_Surface_Shallow.mxd AESPEJO 12/7/2015

LEGEND

● Surface Water Sample

▭ RSA Building

▭ Site Boundary

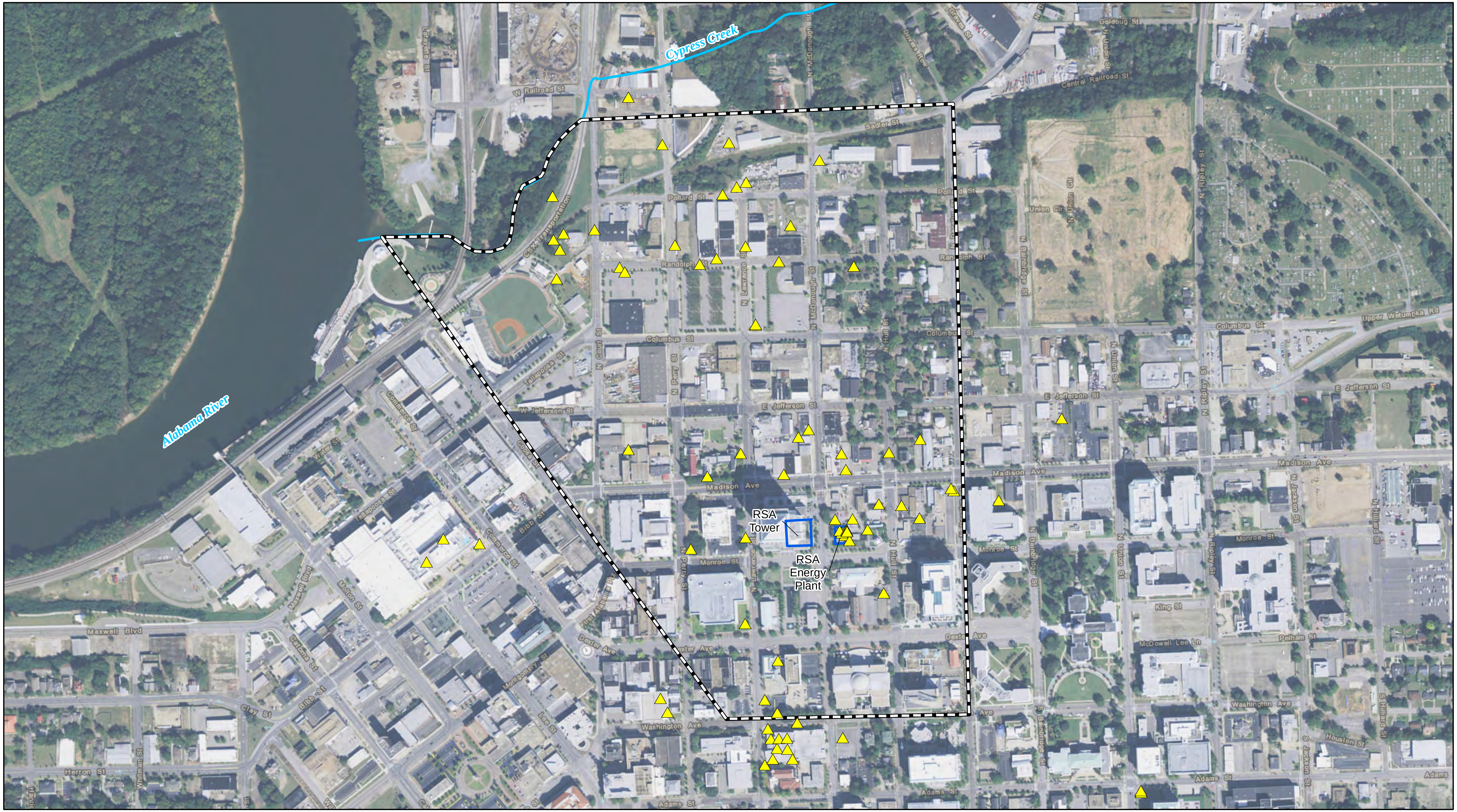
Note:
RSA - Retirement Systems of Alabama

N

0 500 1,000
Feet

FIGURE 3-4
Historical Surface Water Sample Locations
Downtown Environmental Assessment Project
Montgomery, AL

SCO \\galt\proj\CityOfMontgomery\464649\MapFiles\Fig3-4_SurfaceWater.mxd AESPEJO 12/11/2015



LEGEND

▲ Soil Sample Location

RSA Building

Site Boundary

N

0 250 500

Feet

FIGURE 3-5
Historical Soil Sample Locations
Downtown Environmental Assessment Project
Montgomery, AL

LEGEND

● Soil Vapor Sample Location

🟦 RSA Building

🟧 Inset Area Sample Locations Shown in Figure 3-7

▨ Site Boundary

Note:
1. RSA - Retirement Systems of Alabama
2. AG - Attorney General
3. Locations are approximate where text description were provided in lieu of coordinates.

N

0 250 500
Feet

FIGURE 3-6
Historical Soil Vapor Sample Locations
Downtown Environmental Assessment Project
Montgomery, AL

ch2m:

SCO \\galt\proj\CityOfMontgomery\464649\MapFiles\Fig3-6_SoilVapor.mxd AESPEJO 12/21/2015

LEGEND

● Soil Vapor Sample Location

🟨 Vapor Intrusion Monitoring System

Notes:
1. AG - Attorney General
2. Soil vapor locations are approximate where text description were provided in lieu of coordinates.
3. All indoor air samples were collected within the building under the areas shaded in green.

FIGURE 3-7
Annex and Alabama Attorney General's Buildings
Historical Indoor Air and Soil Vapor Sample Locations
Downtown Environmental Assessment Project
Montgomery, AL

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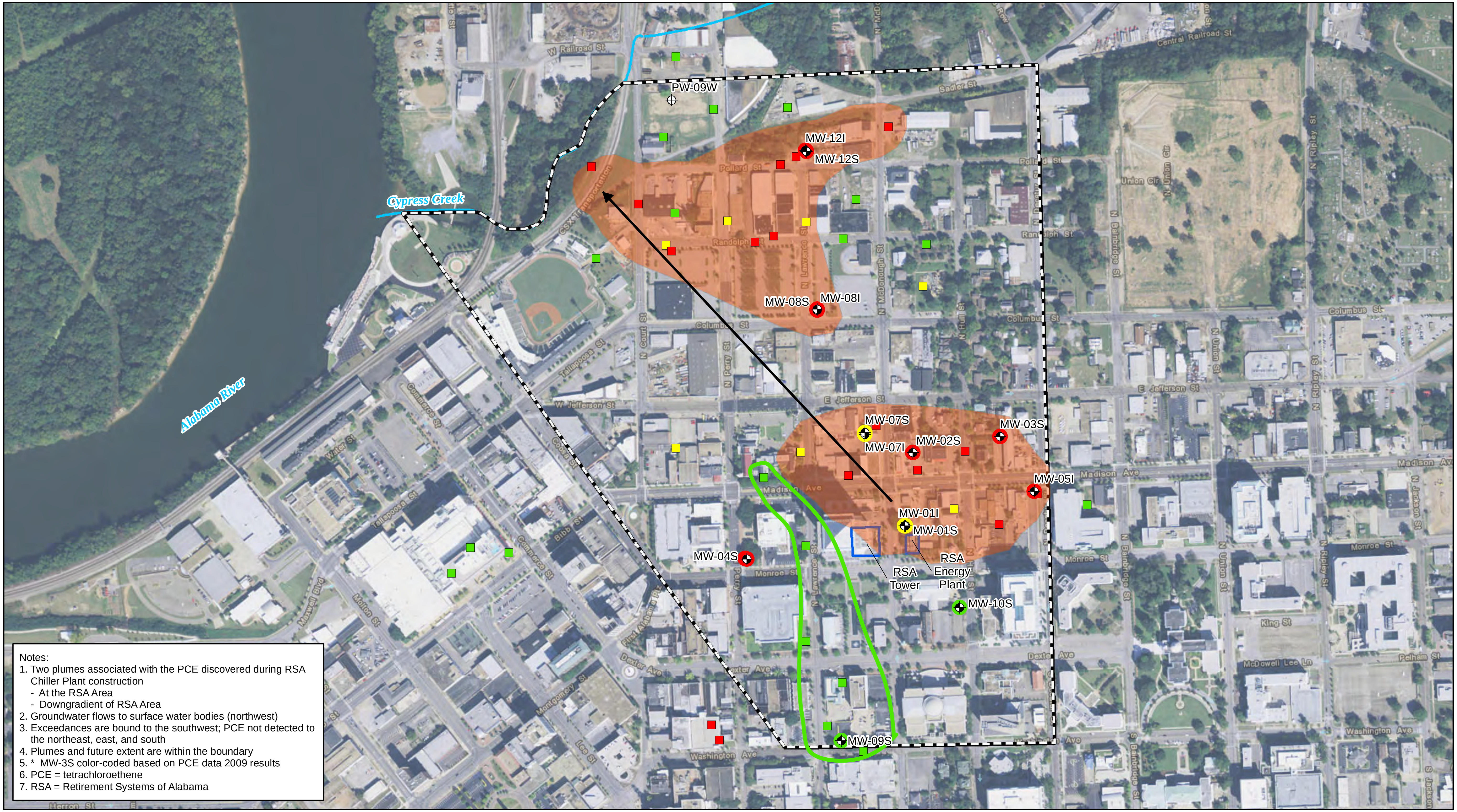


Notes:
1. Two plumes associated with the PCE discovered during RSA Chiller Plant construction
   - At the RSA Area
   - Downgradient of RSA Area
2. Groundwater flows to surface water bodies (northwest)
3. Exceedances are bound to the southwest; PCE not detected to the northeast, east, and south
4. Plumes and future extent are within the boundary
5. * MW-3S color-coded based on PCE data 2009 results
6. PCE = tetrachloroethene
7. RSA = Retirement Systems of Alabama

LEGEND

⊕ Monitoring Well
⌖ Former City Water Supply Well
→ Generalized Flow Direction
▨ PCE Plume
☐ RSA Building
⬚ Site Boundary

Wells Color-coded Based on PCE data 2011 Results*

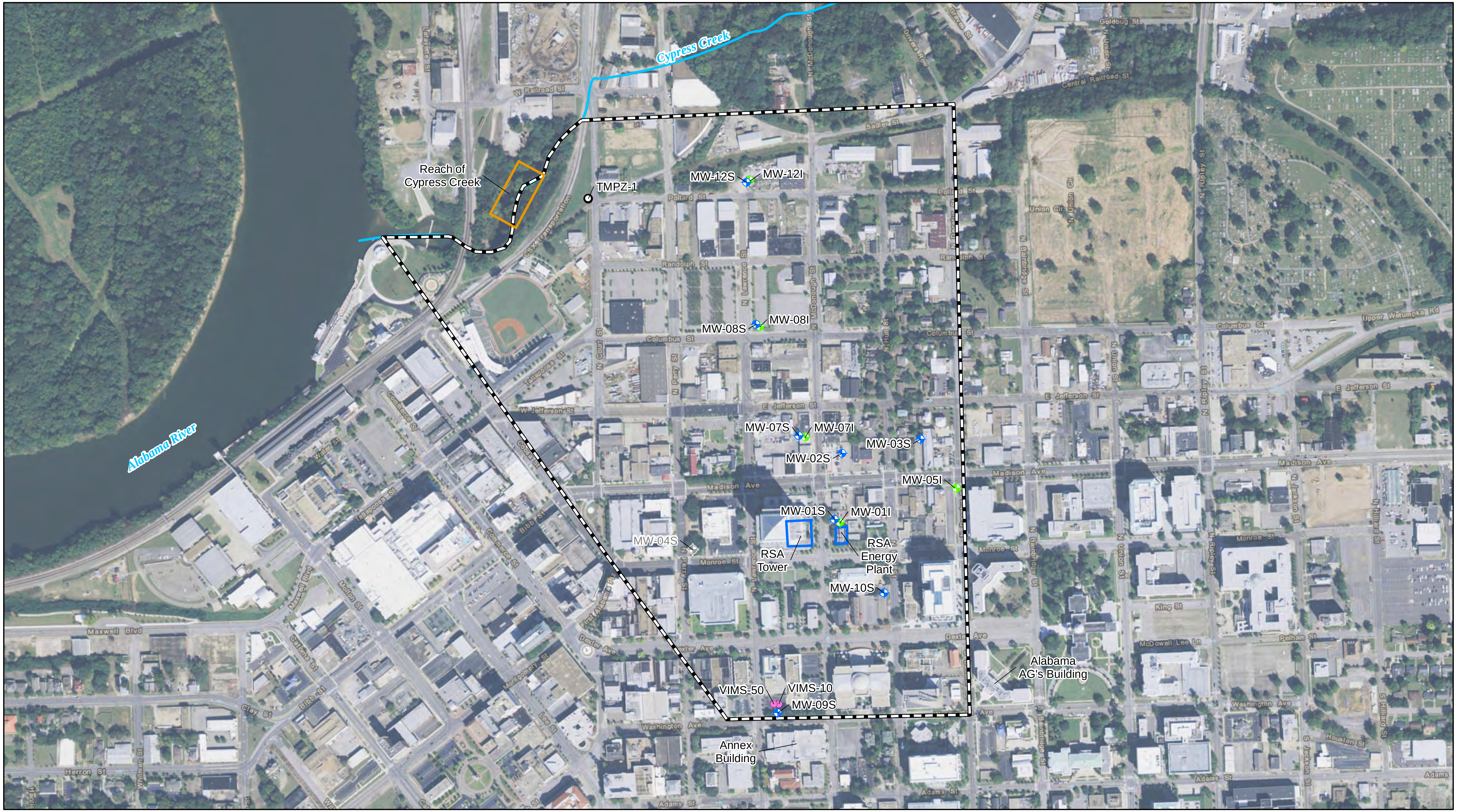
🟩 Not Detected
🟨 Detected, Not Exceeded
🟥 Exceeded

N

0 225 450
Feet

FIGURE 4-1
Conceptual Site Model
Downtown Environmental Assessment Project
Montgomery, AL

ch2m



LEGEND

⊕ Shallow Monitoring Well
⊕ Non-monitored Well
⊕ Deep Monitoring Well
○ Temporary Piezometer
● Vapor-Intrusion Monitoring System
▭ RSA Building
▭ Reach of Cypress Creek
▭ Site Boundary

Note:
1. RSA - Retirement Systems of Alabama
2. AG - Attorney General
3. MW-04S not proposed to be sampled, as contamination in the well is not related to the PCE discovered at the RSA Building (see Figure 4-1).
4. Proposed location of TMPZ-1 is approximate. Final location will be selected based on accessibility.

N

0 250 500
Feet

FIGURE 5-1
Proposed Sample Locations
Downtown Environmental Assessment Project
Montgomery, AL

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ch2m

Appendix A
Sampling and Analysis Plan

APPENDIX A

Sampling and Analysis Plan – Downtown Environmental Assessment Project, Montgomery, Alabama

Prepared for

Alabama Department of Environmental Management by the Downtown Environmental Alliance

May 2016

CH2M HILL, Inc.
4121 Carmichael Rd.
Suite 400
Montgomery, Alabama 36106

Contents

Attachments

Figure

Acronyms and Abbreviations

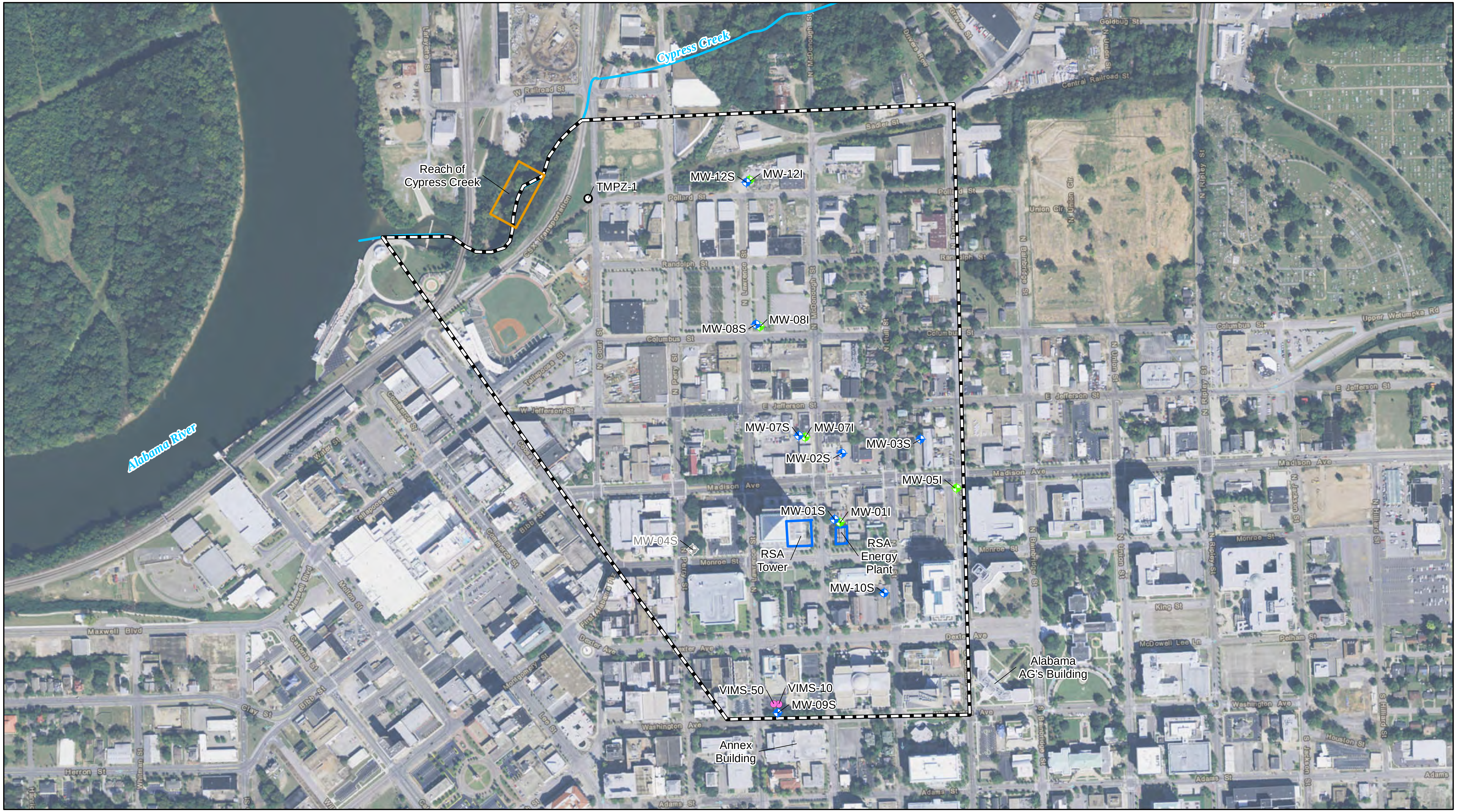
ADEM	Alabama Department of environmental Management
AEIRG	Alabama Environmental Investigation and Remediation Guidance
bgs	below ground surface
COC	chemical of concern
DEA	Downtown Environmental Alliance
DPT	direct-push technology
EPA	U.S. Environmental Protection Agency
HSA	hollow-stem auger
IDW	investigation-derived waste
MS	matrix spike
MSD	matrix spike duplicate
PCE	tetrachloroethene
PID	photoionization detector
PRT	post-run tubing
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
SAP	Sampling and Analysis Plan
SOP	standard operating procedure
SSC	site safety coordinator
RSA	Retirement Systems of Alabama
TCLP	toxicity characteristic leaching procedure
VIMS	vapor intrusion monitoring system
VISL	vapor intrusion screening level
VOC	volatile organic compound

SECTION 1

Introduction

The Downtown Environmental Alliance (DEA) retained CH2M HILL, Inc. (CH2M) to provide assistance to further evaluate tetrachloroethene (PCE) identified historically in public water supply well PW-9W and during the construction of the Retirement Systems of Alabama (RSA) energy plant located in downtown Montgomery, Alabama. Additional sampling needed to conduct the evaluation includes groundwater sampling for analyses of chemicals of concern (COCs), soil sampling for geotechnical evaluation, soil vapor sampling for analyses of COCs, and a hydraulic study to assess the interaction between groundwater and Cypress Creek (Figure 1-1). The purpose of this sampling and analysis plan (SAP) is to describe the recommended procedures and methods proposed for data collection. All work will be performed in accordance with the Alabama Environmental Investigation and Remediation Guidance (AEIRG; Alabama Department of Environmental Management [ADEM], 2008). The following CH2M Standard Operating Procedures (SOPs) are attached as part of this SAP:

1. Final Standard Procedures for Logging of Soil Borings and Monitoring Wells
2. Low Flow Groundwater Sampling from Monitoring Wells (SOP No. 7)
3. Undisturbed Soil Sampling (SOP FWSL-08)
4. Installation of Temporary Soil Vapor Probes (Rev 12/21/15)
5. Subslab Soil Vapor Sampling from Cox-Colvin Vapor Pins (Rev 12/21/15)
6. Collection of Soil Vapor Samples from Temporary and Permanent Probes using Canisters (Rev 12/21/15)



LEGEND

- ⊕ Shallow Monitoring Well
- ⊕ Non-monitored Well
- ⊕ Deep Monitoring Well
- ○ Temporary Piezometer
- ● Vapor-Intrusion Monitoring System
- ▭ RSA Building
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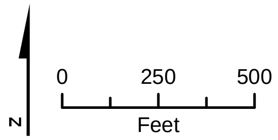


FIGURE 1-1
Proposed Sample Locations
Sampling and Analysis Plan - DEAP
Montgomery, AL

ch2m

SECTION 2

Hydraulic Study Field Activities

2.1 Temporary Creek Gauge

A temporary creek gauge will be installed within Cypress Creek to continuously monitor the Creek stage in the reach where the DEAP groundwater may be interacting with the Creek based on the conceptual site model. The Creek gauge will consist of a Level Troll transducer housed in a 2-inch inner-diameter Schedule 40 polyvinyl chloride (PVC) casing. The PVC casing serves to dampen the effects of short-term water level changes (i.e., waves), protect the transducer from damage, and fix the position of the transducer within the Creek.

Prior to installation of the temporary Creek gauge, the proposed location will be cleared of underground utilities. The Alabama One Call service will be notified to have the public utilities located and marked. Utility locations will be marked and recorded on a site map. To install the Creek gauge, the casing will be manually submerged several feet into the bed of Cypress Creek, with pre-drilled holes in the PVC to allow for water within the casing to reach equilibrium with the Creek stage. Care will be taken to install the temporary gauge in an area of the Creek where erosion is limited and where the transducer is guaranteed to remain submerged when the Creek is at its lowest stage (baseflow). If Creek dynamics require more stability than is provided by the PVC casing alone, a segment of rebar (or similar) may be driven into the Creek bed immediately adjacent to the PVC casing to be used as a brace.

Once installed, the casing will be surveyed to allow for calculation of Creek elevation. The transducer readings will be collected hourly and downloaded weekly. A separate transducer will be deployed in the vicinity of the temporary creek gauge and downloaded weekly; this second transducer will be exposed to the atmosphere and will be used to correct for barometric pressure.

2.2 Piezometer Installation

A temporary piezometer (TMPZ-1) is proposed to be installed to monitor the water table elevation immediately adjacent to Cypress Creek (Figure 1-1). Prior to installation of the piezometer, the proposed location will be cleared of underground utilities at the same time as the temporary Creek gauge.

To ensure the groundwater elevation observed within the temporary piezometer accurately reflects the water table elevation, the temporary piezometer will be installed at a depth so that the water table intersects the screened interval. During drilling, soil will be logged continuously by the onsite geologist to ensure proper vertical placement of the well screen. Cores will be logged according to the *Final Standard Procedures for Logging of Soil Borings and Monitoring Wells* (Attachment 1). Once the appropriate depth has been reached, the piezometer will be installed as a standard ADEM Class II well.

A vertical well borehole will be drilled using the hollow-stem auger (HSA) method (or similar) to a depth sufficient to observe seasonal fluctuations of the water table. Once the final depth of the boring is reached, a minimum of 6 inches of filter sand material will be placed at the bottom of the borehole to serve as footing for the well screen. The piezometer will consist of 10-foot lengths of 2-inch inner diameter PVC. The screened segment will consist of a 10-foot long, 0.01-inch machine-slotted PVC screen. Above the screen, unslotted segments of PVC will be extended to the ground surface. A filter pack consisting of 10/20 mesh quartz sand will be placed in the annular space around the well screen to a minimum height of 2 feet above the top of the screen. A minimum 2-foot-thick bentonite seal will then be placed directly on top of the filter pack and allowed to hydrate for a minimum of 8 hours. After hydration of the bentonite seal is completed, Portland Type II cement grout will be pumped via tremie method into the annular space around the casing from the top of the bentonite seal to within 2 feet of the ground surface.

After the grout is allowed to set a minimum of 24 hours, a protective casing with a locking cap will be installed around the piezometer. The piezometer will also be protected by a 2-foot by 2-foot square concrete surface pad. Following construction of the well completion, the piezometer will be developed using the surge block method until water is sufficiently clear and free of sediment. The piezometer will not be sampled for a minimum of 24 hours after development to allow the formation to stabilize to pre-well construction conditions.

Once installed, the temporary piezometer will be surveyed by a licensed Alabama surveyor. A transducer will be deployed, and readings will be collected and downloaded on the same schedule as the temporary Cypress Creek gauge data.

SECTION 3

Sampling, and Analytical Requirements

This section outlines the procedures for collecting groundwater, soil, and soil vapor samples. In addition, it lists the parameters and analytical methods required for each sample matrix.

3.1 Groundwater Sampling

Groundwater samples will be collected from 14 existing wells and proposed temporary piezometer (TMPZ-1; Figure 1-1) for the analysis of COCs listed in Table 3-1.

Groundwater sampling will be conducted in accordance with the CH2M standard operating procedure (SOP) for Low-Flow Groundwater Sampling from Monitoring Wells (Attachment 2).

Sample labels will include, at a minimum: the well identification number, sample identification, time, date, the sampler's initials, container preservative, and the analytical method to be performed. Sample identification will include the well identification and sample month and year as follows – MW01S-MMYY where the well is MW-01S and MM represents the two-digit month and YY represents the two-digit year. For quality assurance (QA)/quality control (QC) samples, in lieu of the well identification, FD-01 will be substituted for the field duplicate sample, EB-0X will be substituted for the equipment blanks (where X will be numbered sequentially and the type of equipment will be documented in the field logbook), and TB-0X will be substituted for the trip blanks (where X will be sequentially numbered for each day that samples are shipped). The following field QA/QC samples will be collected during the groundwater sampling event:

- One field duplicate
- One matrix spike/matrix spike duplicate (MS/MSD)
- Equipment blanks (per sampling equipment)
- Trip blanks (per shipping event)

The MS/MSD sample will be named the same as the native sample with MS or MSD appended to the sample identification.

3.2 Geotechnical Soil Sampling

Undisturbed soil samples will be collected from up to 3 borings (co-located with soil vapor sampling) and submitted for geotechnical parameters listed in Table 3-1. One Shelby tube will be collected for each lithologic change identified in the available boring log (to be selected by the field geologist). For estimating purposes, one sample is assumed every 10 feet in the vadose zone to an estimated 70 feet at each boring.

Soil sampling will be conducted in accordance with the CH2M SOP for Undisturbed Soil Sampling (Attachment 3). Sample labels will include, at a minimum:

- Sample identification
- Date and time
- Sampler's initials
- Geotechnical test to be performed

Sample identification will include sample location (GT-X, where X is numbered sequentially and the location identified in the field logbook) and sample month and year as MMYY where the MM represents the two-digit month and YY represents the two-digit year.

3.3 Soil Vapor Sampling

Temporary dual-depth soil vapor probes will be installed, sampled, and subsequently abandoned near each shallow groundwater monitoring well where COC concentrations exceed one or more vapor intrusion screening levels (VISLs) (up to 9 locations for a total of up to 18 soil vapor samples). Temporary exterior subslab soil vapor probes will be installed, sampled, and subsequently abandoned adjacent to the County Annex III (four) and Alabama AG's buildings (three adjacent to the northern wing). Additionally, soil vapor samples will be collected from two of the existing vapor intrusion monitoring systems (VIMS) (10- and 50-foot depths) located across Washington Avenue from the County Annex III Building.

The proposed temporary soil vapor sampling locations will be cleared of underground utilities prior to installing soil vapor probes. The Alabama One Call service will be notified to have the public utilities located and marked. A third-party utility locate subcontractor will locate private utilities near the proposed soil vapor probe locations, if needed. Utility locations will be marked and recorded on a site map.

No soil vapor sampling will take place within 48 hours after a rainfall event of 1 inch or greater or in standing or ponded water areas.

3.3.1 Dual-Depth Soil Vapor Probe Installation and Abandonment Methodology

Temporary soil vapor probes will be installed in accordance with the CH2M SOP for Standard Operating Procedure for the Installation of Temporary Soil Vapor Probes (Attachment 4).

A soil core will be collected from each proposed soil vapor sampling location prior to soil vapor probe installation to determine lithology and the depth to groundwater. The soil core will be collected using a direct-push technology (DPT) drill rig in an acetate sleeve. General descriptions of the soil type, and the depth at which soils become saturated will be recorded in the field book. Geotechnical sampling will be performed at three of soil core locations, as discussed in Section 3.2. The soil and acetate sleeves will be disposed of as solid investigation-derived waste (IDW), as discussed in Section 3.5.

The shallower depth probe, 6 to 8 feet below ground surface (bgs), will be installed and sampled first. The deeper depth probe will then be installed in a separate hole. Each of the borings will be located at least 5 feet away from the monitoring well and each other. The deeper depth probe will be within several feet of the groundwater table as determined from the soil core, which ranges from approximately 25 to 60 feet bgs throughout the site.

Temporary soil vapor probes will be installed by a DPT drill rig utilizing the post-run tubing (PRT) method. Each temporary soil vapor probe will be constructed with an expendable drive point, PRT point holder and adapter, and 1.25-inch outer diameter drive rods. Quarter-inch outer diameter Teflon tubing will be connected to the PRT system. The PRT system will be pushed by the DPT drilling rig to the target depth and the probe will be retracted approximately 6 to 12 inches to create an annular space.

The DPT drive rods and PRT equipment will be decontaminated between each soil vapor probe by either steam cleaning or washing with a phosphate-free, non-ionic detergent and rinsing twice with distilled water. The decontamination water will be disposed of as liquid IDW, as discussed in Section 3.5. Dedicated tubing will be used for sampling each probe.

The temporary probes, and soil core boreholes will be abandoned by removing the DPT rods and filling the holes with bentonite chips while hydrating in lifts. The ground cover will be restored to its original condition.

3.3.2 Temporary Exterior Subslab Soil Vapor Probe Installation and Abandonment Methodology

Temporary exterior subslab soil vapor probes will be installed and abandoned in accordance with the CH2M SOP for Subslab Soil Vapor Sampling from Cox-Colvin Vapor Pins (Attachment 5).

The temporary subslab soil vapor probes will be installed in large intact concrete pads located near each building. The probes will be installed by drilling through the concrete and securing a Cox Colvin brand Vapor Pin into the hole with a silicon sleeve.

Once sampling is completed, the probes will be abandoned by removing the Vapor Pin and patching the hole with concrete.

3.3.3 Soil Vapor Sampling Methodology

Soil vapor sampling from the temporary dual-depth soil vapor probes and the VIMS will be performed in accordance with the CH2M SOP for Collection of Soil Vapor Samples from Temporary and Permanent Probes Using Canisters (Attachment 6). Soil vapor sampling from the temporary exterior subslab soil vapor probes will be performed in accordance with the CH2M SOP for Subslab Soil Vapor Sampling from Cox-Colvin Vapor Pins (Attachment 5).

Following installation of the temporary soil vapor probes, each probe will be allowed to equilibrate for 30 minutes. The soil vapor probes will be helium-leak checked and purged prior to sample collection. Three dead volumes of soil vapor will be purged with a vacuum pump at 200 milliliters per minute. The dead volume of the dual-depth exterior soil vapor probes will include the annular space created by retracting the rod, and the probe tubing. The dead volume of the temporary exterior subslab soil vapor probes will include the hole in the concrete beneath the installed probe. Prior to sampling, the dead volume of the VIMS will be determined upon further evaluation of the VIMS construction.

A helium enclosure surrounding the probe at the ground surface will be flooded with at least 10 percent ultra-high purity helium during purging. The purged soil vapor will be screened in the field with a photoionization detector (PID) for total volatile organic compounds (VOCs) and a helium detector. The probe will pass the leak test if less than 1 percent of the helium concentration measured in the enclosure is detected in the purged soil vapor. Once the probe passes the leak test, and purging is completed, a soil vapor sample will be collected into a 1-liter evacuated stainless steel canister (such as a SUMMA canister) equipped with a flow controller set to regulate the sampling flow rate to 180 milliliters per minute (for an approximate 5-minute sample collection time). One duplicate sample will be collected per 10 soil vapor samples; a T-connector will be used to collect both samples using one flow controller at the same time.

The PID and helium detector will be operated, calibrated, and maintained according to the manufacturers' guidelines. The PID will be calibrated before beginning work each day, and the calibration data will be recorded in the field logbook along with the equipment serial number.

Canisters for soil vapor sampling will be supplied by the contracted laboratory. Each individual canister must be certified clean by the contract laboratory and the certification analysis provided for the project record. Canisters must be used within 15 days from the date they were shipped from the laboratory. Sample labels will include, at a minimum: sample identification, time, date, the sampler's initials, and the analytical method to be performed. Sample identification will include sample location and sample month and year as MMYY where the MM represents the two-digit month and YY represents the two-digit year. Sample location for dual-depth samples collected adjacent to monitoring wells will be identified as SV-XXS-SD-DD where XXS is the corresponding well number and SD-DD is the sample interval in feet bgs (SD is the shallow depth and DD is the deep depth). Samples location for the VIMS will be identified as VIMS10 and VIMS50 for the 10- and 50-foot sample depths, respectively. Sample locations adjacent to each building with be identified as SV-BB0# where BB represent the associated building as:

- AG – Alabama AG's Building, and
- CA – County Annex III Building.

The remainder, 0#, will be numbered sequentially and the location identified in the field logbook.

The canisters will be shipped under standard chain-of-custody procedures to the contracted laboratory for analysis by U.S. Environmental Protection Agency (EPA) Method TO-15; COCs will be analyzed as detailed in Table 3-1.

3.4 Analytical Requirements

The parameters requiring analysis for the DEAP investigation are presented in Table 3-1. The laboratory should provide all sample containers as described in Table 1 of Appendix G of the AEIRG (ADEM, 2005), preservatives, chain-of-custody forms, shipping coolers, packing material, and absorbent necessary to properly collect and ship the samples to the laboratory. Arrangements should be made with the laboratory so that sample kits are received at the site before sampling.

Samples should be shipped to the laboratory on the day of collection for overnight delivery. Advance notification should be provided to the laboratory by the field team in the event that samples are shipped on a Friday for receipt by the laboratory on a Saturday.

3.5 Management of Investigation Derived Waste

IDW generated during investigation of the DEAP will include both solid and liquid waste. Solid IDW will include both soils and acetate liners. Liquid IDW will include both decontamination fluids and purged groundwater. IDW will be contained in 55-gallon U.S. Department of Transportation-approved drums upon generation, rated for liquids (such as, water and wet soils) or solids (such as, soils with minimal liquid). Each drum will bear a label that identifies the contents as solid or liquid IDW from the DEAP project, including the start date (when material is first placed in the drum), and will identify the contents as "pending analysis." The drums will be stored in a secure area within the DEAP boundary and managed as non-hazardous waste. Based on historical knowledge and sampling data, the IDW is not a listed hazardous waste and is expected to be a non-hazardous waste. To confirm that the IDW is non-hazardous, CH2M will collect one representative sample of the solid waste and one representative sample of the liquid waste, and analyze each sample for the VOCs and SVOCs (total analysis only) included in Table 1 of ADEM Admin. Code R. 335-14-2-.05. For profiling purposes, the pH will also be analyzed for both samples, and the percent liquids will be analyzed for the solid sample. Once the IDW is characterized, it will be appropriately labeled, managed, manifested, and disposed per the ADEM Administrative code.

TABLE 3-1
Groundwater, Soil, and Soil Vapor Sample Numbers, Methods, and Collection Requirements
Sampling and Analysis Plan—DEAP, Montgomery, Alabama

Parameter	Number of Native Samples	Sample Location	Method	Container	Preservative	Holding Time
Groundwater Samples						
VOC: PCE, TCE, DCE, vinyl chloride	14[a]	MWs-01S, -01I, -02S, -03S, -05I, -07S, -07I, -08S, -08I, 09S, -10S, -12S, -12I, and TMPZ-1	SW8260B	3x40-mL vials with Teflon lined caps	Hydrochloric Acid to pH<2, ≤6 °C	14 Days
Soil Samples						
Bulk Density, Total Porosity, Saturated Porosity	21[b]	Co-located with soil vapor sample locations	ASTM D7263-09	Shelby Tube	None	NA
FOC			Walkley-Black			

TABLE 3-1

Groundwater, Soil, and Soil Vapor Sample Numbers, Methods, and Collection Requirements

Sampling and Analysis Plan—DEAP, Montgomery, Alabama

Parameter	Number of Native Samples	Sample Location	Method	Container	Preservative	Holding Time
Soil Vapor Samples						
VOC: PCE, TCE, DCE, vinyl chloride	27[c]	Site wide and adjacent to the County Annex III and Alabama AG buildings[c]	TO-15	1-liter SUMMA Canister	None	30 days[d]

Notes:
VOC = volatile organic compounds
PCE = tetrachloroethene
TCE = trichloroethene
DCE = dichloroethene (cis and trans isomers)
FOC = fraction organic carbon
EPA = U.S. Environmental Protection Agency
SW = SW-846 Test Methods for Evaluating Solid Waste Physical/Chemical Methods
°C = degrees Celsius

[a] Groundwater sample count will included 15 native samples plus 1 field duplicate sample, 1 matrix spike/matrix spike duplicate sample set, 1 equipment blank sample, and 1 trip blank sample.

[b] Number of samples estimated based on samples every 10 feet at three borings to 70 feet total depth.

[c] Two soil vapor samples will be collected adjacent to each shallow well where COC concentrations exceed one or more VISLs (up to nine locations). Soil vapor samples will also be collected adjacent to the County Annex III (6 samples including 2 from the VIMS) and Alabama AG's buildings (3 samples). Estimated number assumes each shallow well will report 1 or more exceedance. One duplicate sample will be collected per 10 soil vapor samples for a total of up to 3 duplicate samples.

[d] There is a 15-day holding time from the date the canisters leave the laboratory to the date of sample collection. The holding time from the date of sample collection to analysis is 30 days.

SECTION 4

Sample Implementation

This section outlines the basic guidelines for sampling implementation by discussing personnel and training requirements, safety precautions, and laboratory coordination for those who are responsible for the sampling.

4.1 Sampling Personnel and Training

Samples for the DEAP investigation will be collected under the oversight of CH2M. Samples should be collected by a person experienced in collecting groundwater, Shelby tube, and soil vapor samples. The sampling team should be familiar with the following:

- Identification of sampling locations
- Equipment needed and proper use
- Sampling parameters, associated container types, and volume requirements
- Method for delivering analytical samples to the laboratory
- Forms to be completed during the sampling event

All sample containers must be marked before each sample is collected. The date, time, sample identification, and preservative (if required) must be marked on each sample bottle.

4.2 Health and Safety

Precautions should be taken to ensure the safety of the sampling team members. A site safety coordinator (SSC) will be designated prior to the sampling event. Tailgate health and safety meetings will be held daily and documented in the logbooks. Any health and/or safety related issues that arise in the field should be directed to the SSC; the SSC will be responsible for contacting additional personnel (i.e., project manager or Health and Safety Manager) as required.

4.3 Laboratory Coordination

Sampling kits will be pre-assembled at the contracted laboratory before the actual sampling event. These kits should contain the necessary number and type of containers to analyze samples for the parameters listed in Table 3-1. Any changes to the analytical methods, sample containers, or preservation must be approved by the project chemist prior to sample collection. The volume, preservative requirements, and types of containers to be used in transporting the samples should be provided by the contract laboratory.

Attachment 1

Final Standard Procedures for Logging of Soil Borings and Monitoring Wells

Policies, Procedures, and Guidelines

Standard Procedures for Logging of Soil Borings and Monitoring Wells

January 2016

Contents

Tables

Figures

Standard Procedures for Logging of Soil Borings

Introduction

The purpose of this document is to establish soil classification and logging procedures for CH2M HILL. The document will guide CH2M HILL staff in recording and presenting the field data that are necessary to adequately describe, label, and package soil samples recovered from borings. Adherence to a standard format for recording data will help streamline project efforts and allow a consistent presentation of subsurface data.

Policy

These soil boring procedures should be followed for CH2M HILL projects in which soil boring techniques are used during field exploration. These procedures establish the *minimum* standards for information that should be recorded in the field to adequately characterize recovered soil samples. In environmental work, there can be instances in which soil borings are advanced solely to collect soil or water samples for analytical results. The project manager and senior technical consultant should determine the level of soil logging required for a project. Geotechnical engineers should refer to this link:

http://wwwtest.int.ch2m.com/intrnl/voffice/dc/WebManuals/GeotechDesign/GeoTechDesign.htm

for CH2M HILL's policy on soil logging for geotechnical exploration. Because job requirements can vary widely, the minimum standards presented might need to be supplemented with additional technical descriptions or field test results.

The boring log should be completed in the field according to the instructions that follow. Forms should be filled out neatly and completely. Forms may also be filled out electronically in the field. Laboratory testing, if required, should be initiated immediately after completion of the field work. For geotechnical projects, it is important to check field classifications against laboratory test results. Corrections should be noted in red, initialed, and dated on the field boring log. For environmental projects, the decision to check against laboratory results will be determined on a case-by-case basis. However, if laboratory tests are run, boring log descriptions should be double checked against the lab classifications.

Instructions for Completing Soil Boring Logs

CH2M HILL currently uses several forms on which to record soil logging information. Two forms often used are (1) the WinLog form formatted specifically for CH2M HILL, which is similar to the previous CH2M HILL Standard Form D1586 (Soil Boring Log Form), and (2) the GINT form, which is used on many federal projects. Whichever form is selected for a project, the form should, at a minimum, contain space for the information specified in this document. Instructions follow for completing the log forms in the field. See Figures 1 and 2 for examples of blank and completed field logs (the WinLog form).

The heading information should be completely filled out on each log sheet, and the technical items in each column must be addressed in the field. Field personnel should review completed logs for accuracy, clarity, and thoroughness. It is important that information be correctly recorded on both the sample container and the log sheets.

Heading Information

Project Number. Use the standard six-digit project number and appropriate point numbers.

Boring Number. Enter the boring number. A numbering system should be chosen that does not conflict with information recorded for previous exploratory work done at the site. Number the sheets consecutively for each boring. If rock core log sheets are also used, continue the consecutive numbering.

Project. Fill in the name of the project or client.

Location. If stationing, coordinates, mileposts, or similar project layout information is available, indicate the position of the boring to that system by means of modifiers, such as *approximate* or *estimated*, as appropriate. If this information is not available, identify the client facility (e.g., Richland STP, center of Clarifier No. 2 site), or the town and state.

Elevation. Enter the elevation. If it was estimated from a topographic map, or roughly determined using a hand level, use the modifier *approximate*. It is important to tie the boring elevation to a recoverable reference point (e.g., fire hydrant, floor slab), if no other elevation data are available. Such points can be picked up later in a site survey, and boring elevations can be determined. Or, if no survey is done, at least the relative boring elevation with respect to pertinent project facilities will be known.

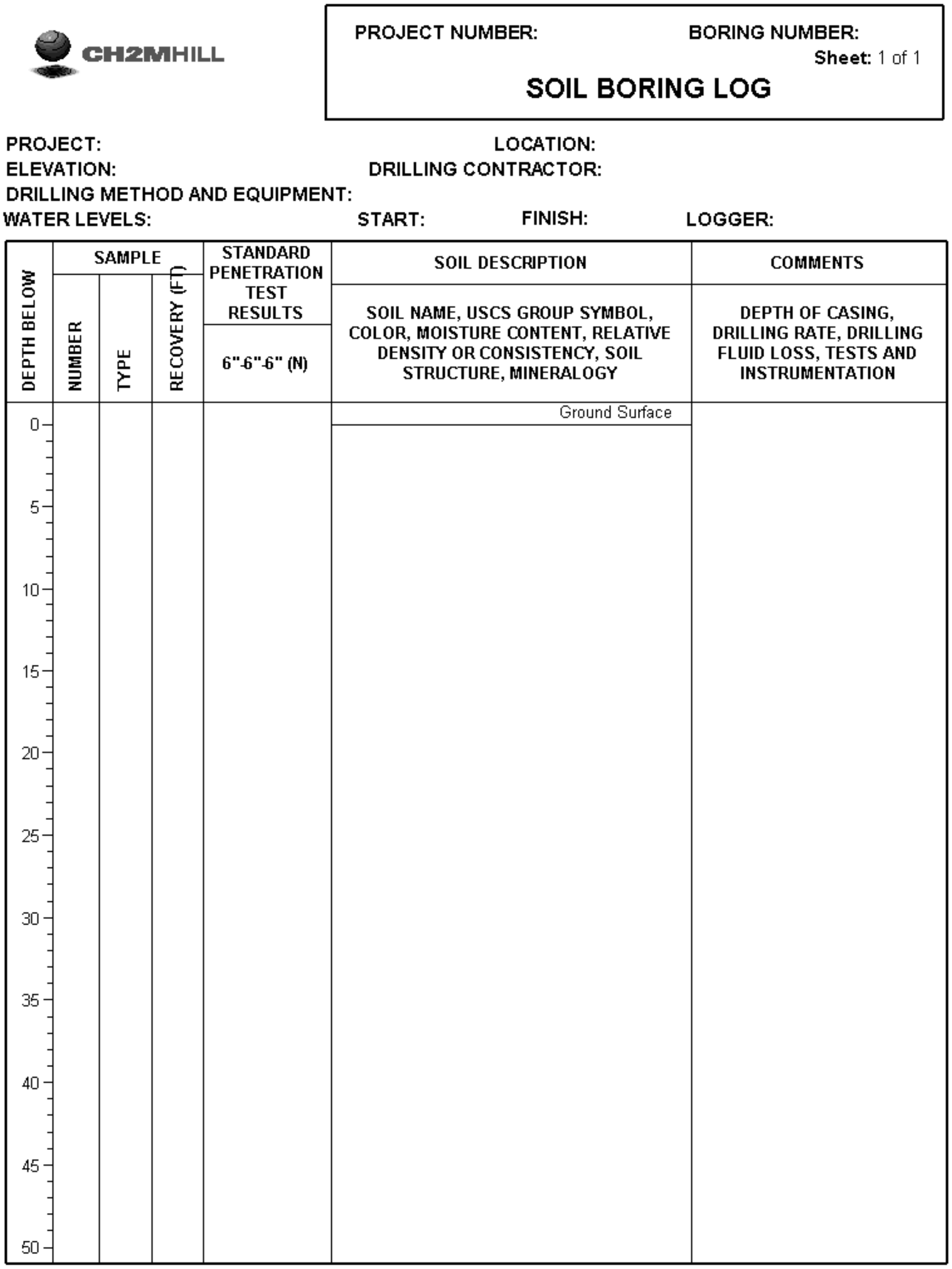
Drilling Contractor. Enter the name of the drilling company and the city and state where the company is based.

Drilling Method and Equipment. Identify the bit size and type, drilling fluid (if used), and method of drilling (e.g., rotary, hollow-stem auger, sonic, direct push). In addition, enter information on the drilling equipment (e.g., CME 55, Mobile B61, GeoProbe).

Water Level and Date. Enter the depth below ground surface (bgs) to the static water level in the borehole, if encountered. If multiple water level measurements are taken for the boring, this field should list the last or most representative measurement. Frequent water measurements are recommended to capture differences between water-bearing zones, and to capture the stable water level. Record the information in the Comments column. If free water is not encountered during drilling, or cannot be detected because of the drilling method, make a note of this information. Generally, water levels should be measured each morning before resuming drilling and at the completion of each boring. Record the date and time of day (for tides, river stage) of each water level measurement.

Date of Start and Finish. Enter the dates the boring was begun and completed. Add the time of day, if several borings are performed on the same day.

Logger. Enter the full name.



CH2MHILL

PROJECT NUMBER: **BORING NUMBER:**
Sheet: 1 of 1

SOIL BORING LOG

PROJECT: **LOCATION:**
ELEVATION: **DRILLING CONTRACTOR:**
DRILLING METHOD AND EQUIPMENT:
WATER LEVELS: **START:** **FINISH:** **LOGGER:**

DEPTH BELOW	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	NUMBER	TYPE	RECOVERY (FT)	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
					Ground Surface	
0						
5						
10						
15						
20						
25						
30						
35						
40						
45						
50						

FIGURE 1
Example of the WinLog CH2M HILL Soil Boring Log Template

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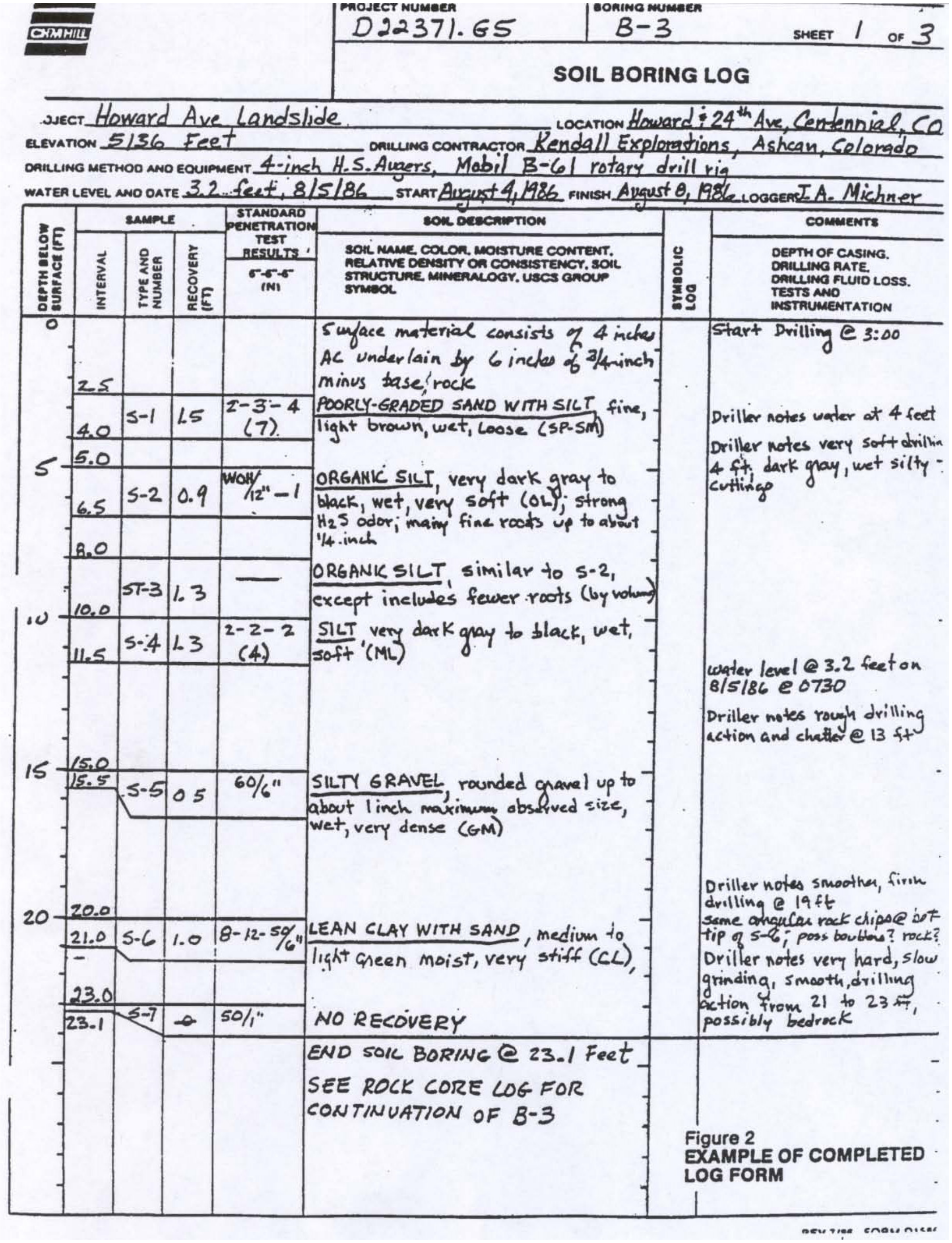


CH2M HILL

PROJECT NUMBER D22371.65

BORING NUMBER B-3

SHEET 1 OF 3

SOIL BORING LOG

PROJECT Howard Ave Landslide

LOCATION Howard & 24th Ave, Centennial, CO

ELEVATION 5136 Feet

DRILLING CONTRACTOR Kendall Explorations, Ashcan, Colorado

DRILLING METHOD AND EQUIPMENT 4-inch H.S. Augers, Mobil B-61 rotary drill rig

WATER LEVEL AND DATE 3.2 feet, 8/5/86

START August 4, 1986

FINISH August 8, 1986

LOGGER I.A. Michner

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY (FT)	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0	2.5				Surface material consists of 4 inches AC underlain by 6 inches of 3/4-inch minus base rock		Start Drilling @ 3:00
	4.0	S-1	1.5	2-3-4 (7)	POORLY-GRADED SAND WITH SILT, fine, light brown, wet, Loose (SP-SM)		Driller notes water at 4 feet
5	5.0						Driller notes very soft drillin 4 ft. dark gray, wet silty cuttings
	6.5	S-2	0.9	WOH/12"—1	ORGANIC SILT, very dark gray to black, wet, very soft (OL); strong H_2S odor; many fine roots up to about 1/4 inch		
	8.0						
10	10.0	ST-3	1.3	—	ORGANIC SILT, similar to S-2, except includes fewer roots (by volume)		
	11.5	S-4	1.3	2-2-2 (4)	SILT, very dark gray to black, wet, soft (ML)		water level @ 3.2 feet on 8/5/86 @ 0730 Driller notes rough drilling action and chatter @ 13 ft
15	15.0 15.5	S-5	0.5	60/6"	SILTY GRAVEL, rounded gravel up to about 1 inch maximum observed size, wet, very dense (GM)		
20	20.0 21.0	S-6	1.0	8-12-50/6"	LEAN CLAY WITH SAND, medium to light green, moist, very stiff (CL),		Driller notes smoother, firm drilling @ 19 ft Some angular rock chips @ bot tip of S-6; poss boulders? rock? Driller notes very hard, slow grinding, smooth, drilling action from 21 to 23 ft, possibly bedrock
	23.0 23.1	S-7	-0-	50/1"	NO RECOVERY		
					END SOIL BORING @ 23.1 Feet SEE ROCK CORE LOG FOR CONTINUATION OF B-3		

Figure 2
EXAMPLE OF COMPLETED LOG FORM

FIGEURE 2
Example of a Completed CH2M HILL Soil Boring Log Form

Technical Data

Depth Below Surface. Use a depth scale that is appropriate for the sample spacing and for the complexity of subsurface conditions.

Sample Interval. Draw horizontal lines at the top and bottom depth of each sample interval. These lines should extend to the soil description column. For a very short sample interval, the bottom line can be lowered after the interval column to provide room for writing the information (see Figure 2). Enter the depth at the top and bottom of the sample interval.

Sample Type and Number. Enter the sample type and number. For instance, 1-S or SS 1 equals first sample, split spoon. Number samples consecutively, regardless of type. Enter a sample number, even if no material was recovered in the sampler.

Sample Recovery. Enter the length to the nearest 0.1 foot of soil sample recovered from the sampler. Often, there will be some wash or caved material above the sample; do not include the wash material in the measurement.

Standard Penetration Test Results. In this column, enter the number of blows required for each 6 inches of sampler penetration and the “N” value, which is the sum of the blows in the last two 6-inch penetration intervals, if the standard penetration test is being used. A typical standard penetration test involving successive blow counts of 2, 3, and 4 is recorded as 2-3-4 and (7). The standard penetration test is terminated if the sampler encounters refusal. Refusal is a penetration of more than 6 inches, but less than 12 inches, with a blow count of 100, or a penetration of less than 6 inches with a blow count of 50. A partial penetration of 50 blows for 4 inches is recorded as 50′4″. See the subsection, “Standard Penetration Test Procedures,” for additional discussion. In order for the standard penetration test to be useful, the hammer weight and split spoon size must be recorded.

Soil Description. The soil classification should follow the format described in the subsection, “Field Classification of Soil.”

Comments. Include all pertinent observations (changes in drilling fluid color, rod drops, drilling chatter, rod bounce, as in driving on a cobble, damaged Shelby tubes, and equipment malfunctions). If casing was used, record the sizes and depths installed, and make a note if drilling fluid was added or changed. You should instruct the driller to alert you to any significant changes in drilling (changes in material, occurrence of boulders, and loss of drilling fluid). Attribute such information to the driller and record it in this column.

Specific information might include the following:

- Date and the time drilling began and ended each day
- Depth and size of casing and the method of installation
- Date, time, and depth of water level measurements
- Depth of rod chatter
- Depth and percentage of drilling fluid loss
- Depth of hole caving or heaving
- Depth of change in material
- Drilling interval through a boulder

- The results of pocket penetrometer or torvane test reported as: “PP = _____ TSF” or “TV = _____ TSF,” respectively

Record the depth of piezometers and the results of in situ tests in the Comments column.

Field Classification of Soil

This section describes the format for the field classification of soil. In general, the approach and format for classifying soils should conform to ASTM International (ASTM) D 2488-year (use the most current version of the ASTM standard), *Visual-Manual Procedure for Description and Identification of Soils*, which is available through ASTM.

The Unified Soil Classification System is based on numerical values of certain soil properties measured by laboratory tests (ASTM D 2487). It is possible, however, to estimate these values in the field reasonably accurately with visual-manual procedures (ASTM D 2488). Also, some elements of a complete soil description, such as the presence of cobbles or boulders, changes in strata, and the relative proportions of soil types in a bedded deposit, can be obtained only in the field. Corrections and additions to the field classification can be provided, when necessary, through laboratory testing of the soil samples.

Soil descriptions should be precise and comprehensive without being verbose. The correct overall impression of the soil should not be distorted by excessive emphasis on insignificant details. In general, similarities between consecutive samples, rather than differences, should be stressed.

Soil descriptions must be recorded in the Soil Description column for every soil sample collected. The format and order for soil descriptions should be as follows:

1. Soil name (synonymous with ASTM D 2488 Group Name) with appropriate modifiers
2. Group symbol
3. Color
4. Moisture content
5. Relative density or consistency
6. Soil structure, mineralogy, or other descriptors

This order follows, in general, the format described in ASTM D 2488. Examples of soil descriptions are provided in Table 1.

Soil Name

The basic name of a soil should be identical to the ASTM D 2488-84 Group Name, based on visual estimates of gradation and plasticity. The soil name should be capitalized. The only acceptable soil names are those listed in Figures 3 and 4, from ASTM D 2488-84.

Examples of acceptable soil names are illustrated by the following descriptions:

- A soil sample is visually estimated to contain 15 percent gravel, 55 percent sand, and 30 percent fines (passing No. 200 sieve). The fines are estimated as either low or highly plastic silt. This visual classification is SILTY SAND WITH GRAVEL, with a Group Symbol of (SM).

- Another soil sample has the following visual estimate: 10 percent gravel, 30 percent sand, and 60 percent fines (passing the No. 200 sieve). The fines are estimated as low plastic silt. This visual classification is SANDY SILT. The gravel portion is not included in the soil name because the gravel portion was estimated as less than 15 percent. The Group Symbol is (ML).

TABLE 1
Example Soil Descriptions

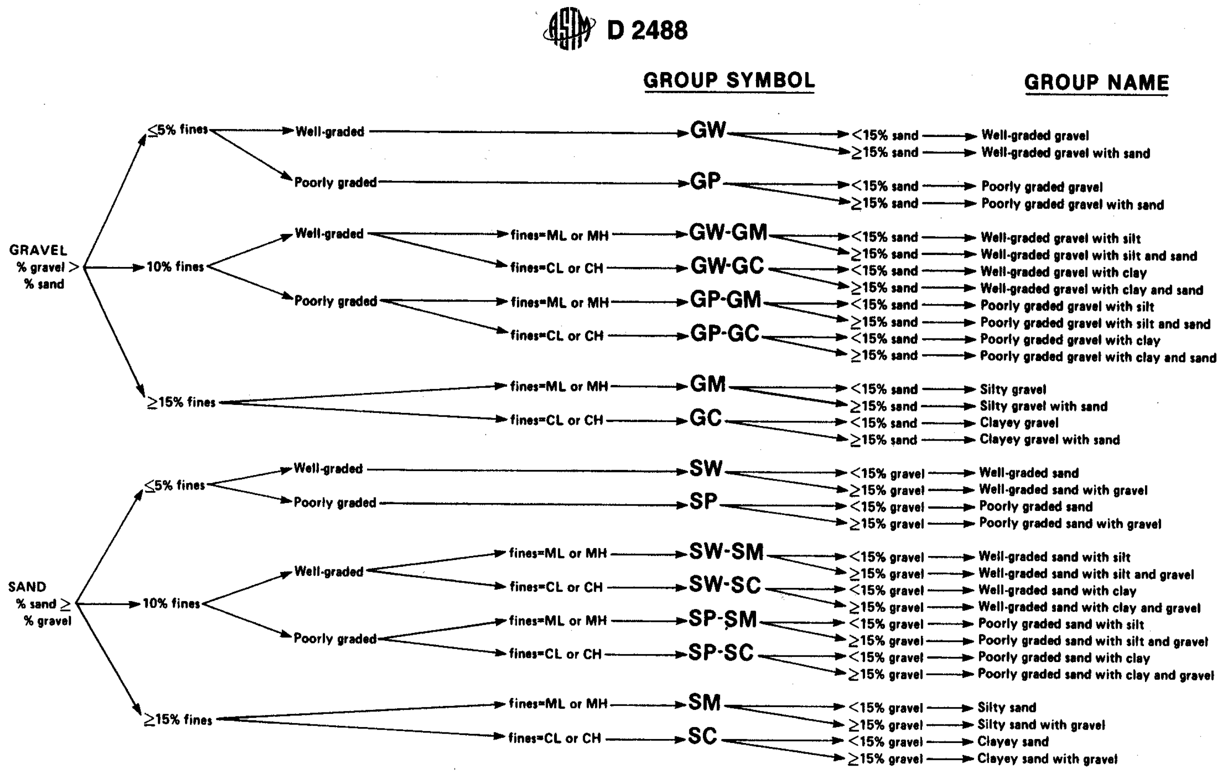
POORLY GRADED SAND (SP), light brown, moist, loose, fine sand size
FAT CLAY (CH), dark gray, moist, stiff
SILT (ML), light greenish gray, wet, very loose, some mica
WELL-GRADED SAND WITH GRAVEL (SM), reddish brown, moist, dense, sub-angular gravel to 0.6 inches max
POORLY GRADED SAND WITH SILT (SP-SM), white, wet, medium dense
ORGANIC SOIL WITH SAND (OH), dark brown to black, wet, firm to stiff but spongy undisturbed, becomes soft and sticky when remolded, many fine roots, trace of mica
SILTY GRAVEL WITH SAND (GM), brownish red, moist, very dense, sub-rounded gravel to 1.2 inches maximum
INTERLAYERED SILT (60 percent) AND CLAY (40 percent): SILT WITH SAND (ML), medium greenish gray, non-plastic, sudden reaction to shaking, layers mostly 1.5 to 8.3 inches thick; LEAN CLAY (CL), dark gray, firm and brittle undisturbed, becomes very soft and sticky when remolded, layers 0.2 to 1.2 inches thick
SILTY SAND WITH GRAVEL FILL(SM), light yellowish brown, moist, medium dense, weak gravel to 1.0 inches max, very few small particles of coal
SANDY ELASTIC SILT (MH), very light gray to white, wet, stiff, weak calcareous cementation
LEAN CLAY WITH SAND (CL/MH), dark brownish gray, moist, stiff
WELL-GRADED GRAVEL WITH SILT (GW-GM), brown, moist, very dense, rounded gravel to 1.0 inches max

The gradation of coarse-grained soil (more than 50 percent retained on No. 200 sieve) is included in the specific soil name in accordance with ASTM D 2488-84. For a coarse-grained soil, note whether the soil is well-graded or poorly graded. If poorly graded, note whether it is fine-, medium-, or coarse-graded. Also record the maximum size and angularity or roundedness of gravel and sand-sized particles. For fine-grained soil (50 percent or more passing the No. 200 sieve), modify the name by the appropriate plasticity/elasticity term, in accordance with ASTM D 2488-84.

For interlayered soils, describe each, starting with the predominant type. Use an introductory name, such as *Interlayered Sand and Silt*. Also indicate the relative proportion of each soil type and layer thickness (see Table 1 for example).

Where helpful, the evaluation of plasticity/elasticity can be justified (in the Comments section of the log) by describing results from any of the visual-manual procedures for

identifying fine-grained soils, such as reaction to shaking, toughness of a soil thread, or dry strength, as described in ASTM D2488-84



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

FIGURE 3
Flow Chart for Identifying Coarse-Grained Soils (less than 50% fines); Unified Soil Classification System (American Society for Testing and Materials, 1985)

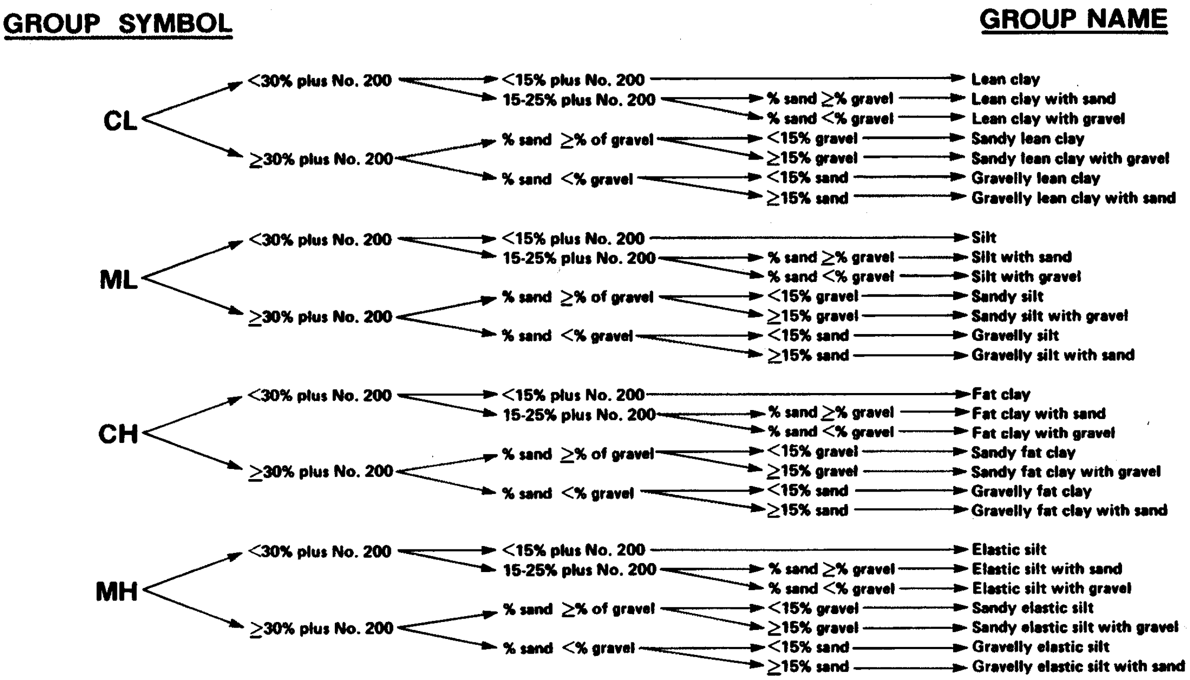
Group Symbol

The appropriate group symbol from ASTM D 2488-84 (see Figure 3) must be given after each soil name. Place the group symbol in parentheses to indicate that the classification has been estimated.

In accordance with ASTM D 2488-84, dual symbols (e.g., GP-GM or SW-SC) can be used to indicate that a soil is estimated to have about 10 percent fines. Borderline symbols (e.g., GM/SM or SW/SP) can be used to indicate that a soil sample has been identified as having properties that do not distinctly place the soil into a specific group. Generally, the group name assigned to a soil with a borderline symbol should be the group name for the first symbol. Borderline symbols should not be used indiscriminately. Every effort should be made to first place the soil into a single group.

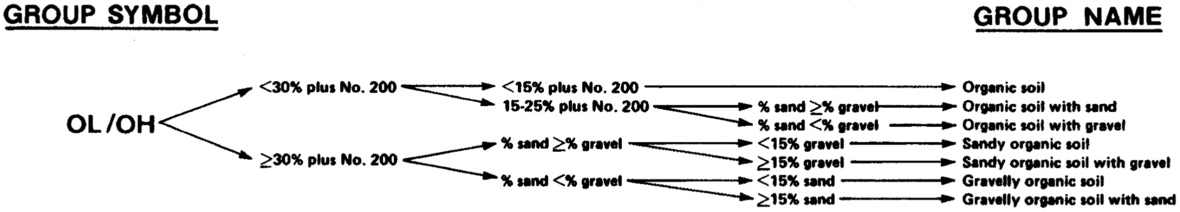
Fill is often encountered when drilling. Fill comprises any materials that people have placed on the naturally occurring ground surface. Fill material can be determined from historical information or from the discovery of human-made materials, such as concrete, brick, glass, plastic, and wood. If the soil being described is determined to be fill material, "fill" should be included in the soil description. If appropriate, provide additional details in the comment column.

D 2488



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1 b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)

FIGURE 4
Flow Chart for Identifying Inorganic Fine-Grained Soils (50% or more fines); Unified Soil Classification System (American Society for Testing and Materials, 1985)

Color

The basic color of a soil, such as brown, gray, or red, must be given. The color term can be modified, if necessary, by adjectives such as light, dark, or mottled. Especially note staining, iron staining, or mottling. This information might be useful for establishing water table fluctuations or contamination. As an alternative, consider using the Munsell soil color chart designation in addition to the color designation.

Moisture Content

The degree of moisture present in a soil sample should be defined as dry, moist, or wet. Moisture content can be estimated from the criteria listed in Table 2.

TABLE 2
Criteria For Describing Moisture Conditions

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below water table

Relative Density or Consistency

Relative density of a coarse-grained (cohesionless) soil is based on N-values (ASTM D 1586; use the most current ASTM 1586 standard). If the presence of large gravel or disturbance of the sample makes determining the in situ relative density or consistency difficult, then omit this item from the description and explain it in the Comments column of the soil boring log.

Consistency of fine-grained (cohesive) soil is properly based on results of pocket penetrometer or torvane results. In the absence of this information, consistency can be estimated from N-values. Relationships for determining relative density or consistency of soil samples are given in Tables 3 and 4.

Soil Structure, Mineralogy, and Other Descriptors

Discontinuities and inclusions are important and should be described. Such features include joints or fissures, slickensides, bedding or laminations, veins, root holes, and wood debris.

Significant mineralogical information should be recorded. Describe cementation, abundant mica, or unusual mineralogy, as well as other information, such as organic debris or odor.

Other descriptors can be included if they are important for the project or for describing the sample. These descriptors include particle size range and percentages, particular angularity, particle shape, maximum particle size, hardness of large particles, plasticity of fines, dry strength, dilatancy, toughness, reaction to HCl, and cementation.

Residual soils have characteristics of both rock and soil and can be difficult to classify. Relict rock structure should be described and the parent rock identified, if possible.

Potentially Impacted Subsurface Media

Record observations of any potentially impacted subsurface media in the soil description or as comments. Make a note about odor, but do not try to guess what chemical you smell. Also describe non-aqueous phase liquids (NAPL) if they are present. Describe *how* they are present, such as sheen, staining along joints or root casts, residual, or free NAPL seeping from the sample. Do not try to guess what fluid is present. Use terms such as phase-separated hydrocarbons if you know a fluid is a fuel, but do not use terms such as diesel, unless you have tested and know that the fluid is diesel. For larger investigation projects, it is advisable to prepare guidelines for describing site contamination in the soil samples.

TABLE 3
Relative Density of Coarse-Grained Soil
(Developed from Sowers, 1979)

Blows/Ft	Relative Density	Field Test
0-4	Very loose	Easily penetrated with 12-in. steel rod pushed by hand
5-10	Loose	Easily penetrated with 1/2-in. steel rod pushed by hand
11-30	Medium	Easily penetrated with 1/2-in. steel rod driven with 5-lb. hammer
31-50	Dense	Penetrated a foot with 1/2-in. steel rod driven with 5-lb. hammer
50	Very Dense	Penetrated only a few inches with 12-in. steel rod driven with 5-lb. hammer

TABLE 4
Consistency of Fine-Grained Soil
(Developed from Sowers, 1979)

Blows/Ft	Consistency	Pocket Penetrometer (TSF)	Torvane (TSF)	Field Test
<2	Very soft	<0.25	<0.12	Easily penetrated several inches by fist
2-4	Soft	0.25-0.50	<0.12-0.25	Easily penetrated several inches by thumb
5-8	Firm	0.50-1.0	0.25-0.5	Can be penetrated several inches by thumb with moderate effort
9-15	Stiff	1.0-2.0	0.5-1.0	Readily indented by thumb, but penetrated only with great effort
16-30	Very stiff	2.0-4.0	1.0-2.0	Readily indented by thumbnail
30	Hard	>4.0	>2.0	Indented with difficulty by thumbnail

Standard Penetration Test Procedures

Standard Penetration Tests (SPT) are conducted to obtain a measure of the resistance of the soil to penetration of the sampler and to recover a disturbed soil sample. They should be conducted in accordance with ASTM D 1586, *Penetration Test and Split Barrel Sampling of Soils*. These tests are most commonly performed on geotechnical projects. On environmental projects, a larger split spoon often must be used to collect the amount of soil required for analytical sampling. Recording blow counts can be useful for understanding variations in soil density or consistency on environmental projects, but typically is not done for an SPT.

Equipment and Calibration

Before testing is started, equipment should be inspected for compliance with the requirements of ASTM D 1586-84. The split-barrel sampler outer diameter (O.D.) should measure 2 inches; the inner diameter (I.D.) should measure $1^{3}/_{8}$ inches; the split tube should be at least 18 inches long. The dimensions should conform to those shown in Figure 1 of ASTM D 1586-84. The minimum size sampler rod allowed is the “A” rod ($1^{5}/_{8}$-inch O.D.). A stiffer rod, such as the “N” rod ($2^{5}/_{8}$-inch O.D.), is required for depths greater than 50 feet. The drive weight assembly should consist of a 140-pound hammer weight, a drive head, and a hammer guide that permits a free fall of 30 inches.

Procedures

Standard Penetration Tests ideally should be conducted at every change of stratum, or within a continuous stratum, at intervals not exceeding 5 feet. Before driving the split-barrel sampler, loose and foreign material should be removed from the bottom of the borehole. It might be helpful to measure the rod stickup to ensure that the sampler is being driven from the bottom of the borehole. Perform the SPT by driving a standard split-barrel sampler 18 inches into undisturbed soil at the bottom of the borehole with a 140-pound guided hammer or ram that falls freely from a height of 30 inches.

Observe the number of blows required to drive the sampler for three 6-inch intervals, for a total of 18 inches, and record that number on the soil boring log. The sum of the number of blows required to drive the sampler for the second and third 6-inch intervals is considered the Standard Penetration Resistance (N) or the *blow count*. If the sampler is driven less than 18 inches, but more than 1 foot, the penetration resistance (N) is the blow count for the last 1 foot of penetration. If less than 1 foot is penetrated, the log must state the number of blows and the fraction of 1 foot penetrated. It is important that the field logger observe the sampler being driven and count the blows for each sample attempt.

General Considerations

Consider the following suggestions when you perform Standard Penetration Tests:

1. The borehole should be cleaned out before every sample attempt. Because a minor amount of caving can be expected, the borehole can be considered adequately clean if no more than 4 inches of loose or foreign material has collected at the bottom. If there is a greater amount of caving, clean the borehole again.

2. The ball check valve in the split-barrel sampler should be cleaned and working properly for each sample. Bent, chipped, or damaged shoes should be replaced. The split-barrel halves should not be warped. In case of zero sample recovery (i.e., if the sample is lost during the first attempt), a spring catcher should be used during subsequent attempts to facilitate recovery.

3. During SPT sampling, it is important that all rod connections be tight and that the hammer guide be connected securely to the drill rods. If the hammer guide connection becomes loose, much of the hammer energy can be lost because of deflection of the hammer coupling. The lifting rope should not rub against the mast. Each hammer fall should be 30 inches.

4. During SPT sampling, it is important that the drill rods be positioned at the center of the drill hole to preclude the development of friction between drill rods and the walls of the borehole or casing.

5. If the hammer weight is raised by means of a cathead, generally two wraps on the cathead should be used. The optimal number of wraps varies with the condition of the rope and cathead, and with the weather. Most importantly, the driller should exercise care to prevent friction of the rope on the cathead during the fall of the hammer.

6. Nonstandard procedures or equipment occasionally are used for obtaining samples (e.g., 3-inch O.D. split-barrel samplers, or 300-pound hammers). Any nonstandard practice should be described on the boring log form. Also, the blow counts should be clearly marked as not conforming to SPT values.

Sample Labeling and Packaging

This section addresses only those sample labeling and packaging requirements that apply to *physical* testing of soil samples. For guidance on requirements for samples destined for *chemical* testing, refer to the project sampling and analysis plan. If the work is being conducted at a site containing hazardous waste (not simply hazardous constituents, but either listed or characteristic hazardous waste) or toxic waste (e.g., polychlorinated biphenyls), contact the project manager regarding appropriate sample handling procedures consistent with hazardous or toxic waste management regulations.

The samples recovered from the borehole are an important part of the boring record and must be properly packaged and labeled, if further testing is required. The following description outlines the minimum requirements for packaging and labeling the samples.

1. Place disturbed samples in zip-locked bags or jars. If you use jars, mark the jar lids and affix labels to the sides of the jars. Labels are usually available from the analytical laboratory. Mark the following information clearly on the bags or jars:

   a. Job number
   b. Boring number
   c. Sample number
   d. Sample depth
   e. Date

   Use a permanent marker. If moisture content tests are anticipated, use jars, which should be tightly sealed, then sent to the laboratory. Testing should be initiated as soon as possible (within 1 week).

2. Label boxes containing the jars, on top and on one end, with the following information:

   a. Job name
   b. Job number
   c. Boring number
   d. Sample numbers
   e. Sample depths
   f. Date

   g. Name

   It is helpful to start a new box for each new boring if the boxes are at least half full.

3. Clean Shelby tubes of mud and moisture. When they are dry, use a permanent marker to label them with the following information:

   a. Arrow indicating which way is up
   b. Job number
   c. Boring number
   d. Sample number
   e. Sample depth
   f. Amount of recovery
   g. Date

   Circumscribe the top and bottom of the sample on the outside of the tube with a marker.

4. Waxing of Shelby tubes is essential if sample testing is not to occur within a few days. In all cases, place lids on the ends and tape them with airtight tape. Be sure to seal the holes in the top of the tube. Pack the open portion of the tube above the sample to prevent shifting of the soil. Dampened newspaper is generally adequate for this purpose, but it should be separated from the soil sample with a wax seal or an inverted cap.

Field Equipment Checklist

The following equipment and supplies are necessary or useful for soil boring exploration.*

Siting

____ Lath, flagging, orange spray paint, Lumber crayon

____ 100-foot tape

____ Brunton or Silva compass

Logging Equipment

____ Soil Boring Guideline - Clipboard

____ Form D1586 on all-weather paper - Pens/pencils

____ Engineer’s pocket tape measure with tape lock

____ Field notebook on all-weather paper

____ Squirt bottle with water, Spatula

____ HCl, 10 percent solution

Sampling and Packaging

____ Jars with lids and labels (Form #131)

____ Shelby tubes and plastic end caps

____ Airtight tape (e.g., electrical)

____ Newspaper

____ Wax, stove, melting pot, and matches

____ Indelible fine felt-tipped markers (e.g., Sharpie brand)

Test Equipment

____ Pocket penetrometer

____ Torvane

____ Well sounder

Other

____ Camera, film

____ Hand lens

____ Rags

____ Ear protectors

____ Screwdrivers

____ Hard hat

____ Sunscreen

____ Insect repellent

* For potentially contaminated projects, follow the site-specific sampling and analysis plan for field monitoring and personal protective equipment.

Relevant Literature

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Attachment 2

Standard Operating Procedure for Low-Flow Groundwater Sampling from Monitoring Wells

Standard Operating Procedure No. 7

Low-Flow Groundwater Sampling from Monitoring Wells

January 2016

STANDARD OPERATING PROCEDURE NO. 7

Low-Flow Groundwater Sampling from Monitoring Wells

I. Purpose and Scope

This procedure presents general guidelines for the collection of groundwater samples from monitoring wells using a low-flow purging and sampling procedure. This method will allow for the collection of representative groundwater samples from monitoring wells, while minimizing the amount of purge water generated. This procedure is applicable for monitoring wells that are 2 inches in diameter or greater, and is considered to be appropriate for collections of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and metals. This procedure is not appropriate for the collection of light or dense non-aqueous phase liquids (LNAPLs or DNAPLs). Operations manuals should be consulted for specific calibration and operating procedures.

II. Equipment and Materials

- Flow-through cell with inlet/outlet ports for purged groundwater, watertight ports for each probe, and inlet/outlet port sizes to match tubing diameter (3/8 inch and ½ inch diameter is most common)
- pH/Eh meter: Orion Model SA250 or equivalent
- Temperature/conductivity meter: YSI Model 33 or equivalent
- Dissolved oxygen meter: YSI Model 57 or equivalent
- Water-level indicator
- In-line disposable 0.45-micron (µm) filters (for collection of dissolved metal samples): QED FF8100 or equivalent
- Bailer, teflon or stainless steel
- Adjustable-rate, positive-displacement, bladder pump
- Generator
- Disposable polyethylene or Teflon tubing of a diameter to match the port on the adjustable-rate, positive-displacement pump, and the inlet/outlet ports of the flow-through cell, and, where required, in-line disposable 0.45-µm filters (3/8 inch and ½ inch diameter is most common)
- Plastic sheeting
- Well construction data

- Photoionization detector (PID)
- Field notebook, sample bottles, sample cooler with ice
- Groundwater Sampling Forms
- Sample labels and chain-of-custody form

Note that the groundwater sampling equipment and reusable materials will be decontaminated between sampling locations in accordance with the Decontamination of Personnel and Equipment SOP No. 2. If used, dedicated tubing will either remain in the wells, or it will be stored in dedicated plastic bags for future groundwater sampling events.

III. Procedures and Guidelines

A. Setup and Purging

1. Sampling should begin at the well that is least contaminated, based on previous information (if available) or well location, and proceed systematically to well that is most contaminated.
2. For the well to be sampled, information is obtained on well location, diameter(s), depth, screened interval(s), and the method for disposal of purged water.
3. Instruments are calibrated according to manufacturer's instructions. Instrument calibration will occur a minimum of one time per sampling day.
4. The well number, site, date, and condition are recorded in the field notebook.
5. Inspect the well head, lock, and locking cap for evidence of tampering or damage. Record these observations in the field notebook.
6. Unlock the well cap and open the well. Monitor the well headspace for the presence of volatile compounds using a PID and record the readings in the field notebook.
7. Using an electronic water level probe graduated to the nearest 0.01 foot, measure the depth to water from the surveyor’s mark located on the top of the well casing. If a surveyor’s mark is not indicated, measure the depth to water from the highest point on top of the well casing. Record this information on the Groundwater Sampling Form. Clean the tip of the water level probe after completing the measurements. **Do not measure the depth to the bottom of the well at this time** (to avoid disturbing accumulated sediment at the bottom of the well). Obtain well depth information from well construction log or specification table.
8. Compute the volume of water in the well and record this information on the Groundwater Sampling Form. The volume (in gallons of water) in the well casing or in sections of telescoping well casing is calculated as follows:

   Vol. of cylinder/column of water = $(\pi r^2 h)$(7.480519 gallons/cubic foot),

   where: $\pi = 3.1415927$

   r = radius of the well pipe in feet

   h = height of water in well in feet

The volume of water in typical well casings may be calculated as follows:

- 2-inch diameter well: 0.163 gal/ft × ___ (linear feet of water) = gallons
- 4-inch diameter well: 0.653 gal/ft × ___ (linear feet of water) = gallons
- 6-inch diameter well: 1.469 gal/ft × ___ (linear feet of water) = gallons

9. Install the pump in the well. Slowly lower the pump (with the attached tubing and safety line) into the well to the desired depth. The pump will be set near the middle of the well screen, if possible. At a minimum, the pump intake will not be positioned lower than 2 feet from the bottom of the well. The depth to the pump intake will be recorded on the Groundwater Sampling Form. If there is less than 3 feet of available water, the groundwater well will be purged and sampled using a bottom-loading bailer.

10. Measure the water level in the well after pump insertion. Leave the water level probe in the well to facilitate continued water level monitoring during purging activities.

11. Start purging the well at a low flow rate between 0.2 and 0.5 liters per minute. Measure the purge rate using a container of known volume, and record this information on the Groundwater Sampling Form.

12. The water level should be monitored during purging, and ideally, the purge rate should equal the well recharge rate so there is little to no drawdown in the well. (The water level should stabilize for the specific purge rate). The purge rate may be increased as long as a constant water level in the well can be maintained. There should be at least 1 foot of water over the pump intake. This assures that there is no risk of the pump suction being broken, or of entrainment of air in the sample. Record adjustments in the purge rate and changes in depth to water in the logbook. Purge rates should, if needed, be decreased to the minimum capabilities of the pump (0.1 to 0.2 liters per minute) to avoid affecting well drawdown. The well should not be purged dry. If the recharge rate of the well is so low that the well is purged dry using the lowest operational flow rate, then allow the well to recharged to a sufficient level and collect the appropriate volume of water for the sample with the pump.

13. During purging, the water quality parameters will be measured periodically (every 3 to 5 minutes) until the parameters have stabilized. These parameters will be considered stabilized when pH measurements agree within 0.1 units, temperature measurements agree within 1degree Celsius (°C), specific conductance measurements agree within 3 percent, and dissolved oxygen and turbidity measurements agree within 10 percent. If parameter stabilization has not occurred after 4 hours, purging activities will be considered complete.

B. Sample Collection

Once purging has been completed, the well is ready to be sampled. The elapsed time between the completion of purging and the collection of the groundwater sample from the well should be minimized. Typically, the sample is collected immediately after the well has been purged, but this may also be dependent on well recovery.

After disconnection from the flow-through cell, samples will be collected directly from the discharge tubing into the appropriate sample bottles. During sample collection, the pump flow rate should be reduced to minimize drawdown. Samples for VOC analysis shall be collected first, and they should be filled to the top leaving no headspace. After capping the VOC sample bottle, the bottle shall be inverted to check for visible air bubbles. If air bubbles are present, either water should be added to the sample or another sample should be collected.

If the turbidity measurements are not below 10 NTU at stabilization (or after 4 hours) a total metals sample will not be collected (if planned at that particular location). However, a dissolved metals sample will still be collected.

Samples for dissolved metals analysis may be filtered in the field during sample collection. The recommended method for field filtering is through the use of a disposable in-line filtration module (0.45-µm filter) attached to the discharge tubing. The water sample is collected as the water is pumped through the filter by the pressure provided using the pumping device. Samples for total metals analysis are not filtered during sample collection.

Immediately upon collection, the sample bottles should be labeled and placed in an ice-filled cooler for transport to the laboratory. The sample designation, preservation, sample date, and sample time will be recorded on the sample label, the Groundwater Sampling Form, and the chain-of-custody record. The sample preservation, bottle requirements, and holding times for the analytical parameters are summarized in the QAPP.

In addition, the following information, at a minimum, will be recorded in the log book:

1. Sample identification (site name, location, and project number; sample name/number and location; sample type and matrix; time and date; sampler's identity)
2. Sample source and source description
3. Field observations and measurements (appearance, volatile screening, field chemistry, sampling method), volume of water purged prior to sampling, number of well volumes purged
4. Sample disposition (preservatives added; laboratory sent to with the date and time sent; laboratory sample number, chain-of-custody number)

IV. Attachments

- Low-Flow Well Sampling Field Data Sheet

V. Key Checks and Preventative Maintenance

Maintain field equipment in accordance with the manufacturer’s recommendations. This will include, but is not limited to:

- Inspect sampling pump regularly and replace as warranted.
- Inspect air/sample line quick-connects regularly and replace as warranted.

Verify battery charge, calibration, and proper working order of field measurement equipment prior to initial mobilization and daily during field efforts. Verify that all ports and tubing sizes are of compatible diameters.

Attachment 3
Standard Operating Procedure for Undisturbed Soil Sampling

STANDARD OPERATING PROCEDURE
(FWSL-08)

Undisturbed Soil Sampling

January 2016

STANDARD OPERATING PROCEDURE (FWSL-08)

Undisturbed Soil Sampling

I. Purpose and Scope

This Standard Operating Procedure (SOP) provides guidance for the collection and handling of undisturbed soil samples using the split tube technique. The method described for undisturbed soil sampling is applicable for soil sampling below the surface and is used to collect representative samples.

II. Equipment and Materials

The following materials are required to undertake this procedure:

- Thin wall tube or Shelby Tube Sampler
- Impervious disks
- Wax plugs
- Shipping material (Styrofoam Plug) Xylene free permanent marker pen or indelible pen
- Chain-of-custody forms
- Sample Register
- Cooler/Esky
- Ice Packs/Ice
- Sample jars.
- Nitrile gloves

Reference is also made to:

- *SOP FWGN-02 Decontamination of Personnel and Non-specific Equipment*.

III. Procedures and Guidelines

Undisturbed soil samples are collected using a thin-walled tube, or split tube, sampler which is driven into the soil profile either by hand or pneumatically to recover relatively undisturbed soil samples suitable for geotechnical laboratory tests, soil logging and chemical laboratory testing. The thin-walled sampler is usually used to collect soil samples for physical soil tests such as porosity, permeability, or grain size.

A split tube is a one-piece hollow tube that is usually 5 to 15 centimeters in outside diameter and 5 to 10 times the diameter in length. The sample tube is placed in the boring on the bottom of the hole. The tube is pushed into the soil with a continuous and rapid motion without impact or twisting to a depth of 0.5 to 0.8 meters. The sampling tube is retrieved and the disturbed material is removed from the top of the tube.

For geotechnical and or physical testing a 2-3cm plug of soil is removed from the base of the tube. An impervious disk is placed at both ends of the tube and sealed with a wax plug prior to shipment to the laboratory. The tube is labeled and positioned such that it is cushioned and remains undisturbed. It is packed in Styrofoam plugs or other cushioning material and shipped to the laboratory.

For chemical analysis the tube is carefully split lengthways, a physical description of the soil appearance and sampling depth is logged in the CH2M soil boring log sheet. Using nitrile gloved hand and stainless steel spatula the undisturbed soil is transferred into appropriate laboratory prepared sampling jars.

The following information, at a minimum, will be recorded in the field sample register during sample collection:

- Sample identification (site name, location, project number; sample ID/number; depth, sample type/matrix; time/date; analyses and sampler's identity).

All reusable equipment should be cleaned and decontaminated before and between each sampling location in accordance with *SOP FWGN-02.*

IV. References

ASTM International (ASTM) D1587-94 Standard Practice for Thin-Walled Tube Geotechnical Sampling of Soils.

V. Key Checks and Preventative Maintenance

None

Attachment 4

Standard Operating Procedure for the Installation of Temporary Soil Vapor Probes

Standard Operating Procedure for the Installation of Temporary Soil Vapor Probes

January 2016

Standard Operating Procedure for the Installation of Temporary Soil Vapor Probes

1.0 Scope and Application

This standard operating procedure (SOP) is recommended as a practical approach for the installation of temporary soil vapor probes where the intent is to collect soil vapor samples only on a single occasion. A common use of this SOP is during vapor intrusion assessments associated with subsurface volatile organic compound (VOC) contamination. This SOP should be used when its application is consistent with the project's data quality objectives (DQOs) and in conjunction with the *SOP for the Collection of Soil Vapor Samples from Temporary Probes and Permanent Implants Using Canisters*. The project team is responsible for ensuring this procedure meets all applicable regulatory standards and receives approval/concurrence from the leading regulatory agency for the project. Only persons trained in the installation of soil vapor probes should attempt this procedure.

2.0 Project-Specific Considerations

2.1 As with all intrusive site work, a utility clearance should be performed prior to mobilization. It may also be necessary to acquire permits and site access.

2.2 Soil vapor sampling should not be performed until 48 hours after a significant rain event (defined as >1 inch of rainfall).

2.3 Temporary soil vapor probes are typically installed with a drive point method, where the probe is pushed into the ground without creating a hole beforehand. The probe may either be advanced with a hand tool method (e.g., the AMS Retract-A-Tip system), or a drill rig (e.g., Geoprobe® post-run tubing [PRT] method). Equipment specifically designed for temporary soil vapor sampling is available for either method. Operation of direct-push machinery shall be performed only by trained and licensed personnel. The hand tool installation method is only applicable to relatively shallow sampling (e.g., up to 10 to 15 feet below ground surface [bgs] depending on the soil type).

2.4 Prior to attempting installing soil vapor probes there should be an understanding of subsurface conditions at the site.

2.4.1 Depth to Groundwater – soil vapor samples must be collected in the vadose zone (and above the capillary fringe).

2.4.2 Soil permeability **-** It may not be feasible to collect soil vapor from finer-grained or tight soils with little pore volume, such as clays; if there are clay layers present in the subsurface, these intervals should be avoided. For sampling in these soils, using permanent soil vapor implants with a wider borehole is recommended. Care should be taken during purging and sampling so that the vacuum in the sampling system never exceeds 7 inches mercury (inches Hg) or approximately 100 inches water.

2.4.3 Gravel or dense clay layers may make hand installation methods impracticable.

2.5 Select the probe interval length – typically probe sample intervals are 2 inches to 1 foot; however, smaller or larger intervals may be selected depending on the project's DQOs.

2.6 Selecting the probe depth interval

2.6.1 The top of the soil vapor probe should be at least 5 feet bgs to avoid short circuiting with outdoor air. If there is impermeable ground cover (e.g., concrete, asphalt), shallower sampling depths may be considered.

2.6.2 The bottom of the soil vapor probe must be above the capillary fringe.

2.6.3 As the depth of the sampling interval increases, the difficulty of installing the probe also increases, with the primary challenges being pushing the rods down with a hand tool and threading the post-run tubing (PRT) adapter into the PRT point holder.

2.6.4 It is advisable to collect a soil core from the proposed sampling area prior to installing the soil vapor probe to identify the exact depth of the capillary fringe and determine where the most permeable soil layers are located.

2.6.5 Sampling at multiple depths at each sample location (or a subset of the locations) should be considered to obtain a vertical profile of soil vapor conditions if the vadose zone height is long enough; typically the bottom of a probe should be at least 5 feet from the top of the probe beneath it. Multi-depth sampling can be performed in one hole by starting with the shallowest depth first and then continuing downward.

2.7 Temporary soil vapor probes can be installed either with or without the sample tubing in place. The sample tubing is attached after the probe is pushed to depth in the PRT method. However, the probe can be pushed with the tubing attached by using a slotted drive cap and slotted pull cap. This method is better for deeper sampling intervals.

3.0 Materials

3.1 Geoprobe PRT Method (the equipment below is typically supplied by the drilling subcontractor)

- Drive rods – 1- to 1.5-inch outer diameter drive rods
- Expendable drive points – steel or aluminum expendable drive points
- PRT expendable point holder
- PRT adapters
- Post-run point popper

3.2 AMS Retract-A-Tip Method (the equipment may be rented or purchased from AMS; they offer several different "Gas Vapor Probe Kits," which may be customized with additional pieces of equipment)

- Slide hammer or hammer drill for driving the probe (will need power supply for the hammer drill)
- Drive rods – 5/8-inch outer diameter hollow drive rods
- Removal jack
- Retract-A-Tip assembly

3.3 Probe tubing - 1/4-inch outer diameter (OD) Teflon tubing (may be supplied by the drilling subcontractor)

3.4 Probe cap (to seal the tubing during equilibration) – Swagelok part number SS-400-C

3.5 Multi-gas meter for health and safety monitoring during drilling.

3.6 Electrical tape

3.7 Leather work gloves, vice grips, and a large adjustable wrench are necessary for the AMS method

4.0 Temporary Soil Vapor Probe System Set-Up

4.1 Obtain soil vapor sampling probes in sufficient quantity to carry out the assessment. These systems and their installation can be obtained from geotechnical firms that provide direct-push supplies and services or from AMS for the hand tool method. Their basic installation procedures can be followed as long as the details below are included.

4.2 Manufactured soil vapor probes (such as the Geoprobe PRT system, and AMS Retract-A-Tip) are specifically manufactured for soil vapor collection and facilitate installation, improve sampling, are easily decontaminated between each use, and offer consistency and ease of use.

4.3 It is necessary to coordinate the hardware (i.e., size of tubing, fittings, sampling interface assembly, etc.) that mates the soil vapor probe sampling line to the sampling system (e.g., Tedlar bags, SUMMA canisters). Appropriate hardware is critical to achieving a leak-free system. All connections should be inert gas-tight compression fittings (i.e., Swagelok or equivalent), and all sample transfer lines should be made of Teflon or inert nylon tubing. Typically, all tubing and fittings should be 1/4-inch OD. These fittings will match up with the sampling manifold specified in the soil vapor sampling SOP.

4.4 The soil vapor probes and equipment must be decontaminated prior to use. Steam cleaning is the preferred method of decontamination; however, a three-stage decontamination process consisting of a wash with a non-phosphate detergent, a rinse with tap water and a final rinse with distilled water may be used. The equipment should be allowed to dry before use. Once decontaminated, the probes must be shown to be free of contaminants. At a minimum, a suitably sensitive organic vapor meter should be used for this purpose. Any probe that does not pass decontamination should not be used.

4.5 New tubing must be used for each soil vapor probe; the tubing cannot be decontaminated.

4.6 Handle and store decontaminated soil vapor probes in a manner that prevents contamination.

4.7 Inspect all probe parts for wear before each use. Replace probe tips, o-rings, adapters, and probe rods as needed. New parts and parts in good working condition greatly reduce the chances of ambient air leaking into the soil vapor sample and reduce the need for re-pushing probes. Ideally, the expendable point holder will be a single piece (as opposed to two or more).

5.0 Soil Vapor Probe Installation & Removal for the Geoprobe® PRT Method

5.1 Assemble the probe as shown in Figure 1. The PRT adaptor and tubing may be attached to the PRT point holder so that the tubing is pushed down instead of post-run if a slotted drive cap is used.

5.2 Push the probe to the desired depth. Ensure that the final depth of the drive point includes extra depth to include the length of the tip and the sampling interval when retracted (e.g., for a depth of 5 feet bgs with a 6-inch screen, push the probe to 5 feet 6 inches bgs).

5.3 Retract the probe to create an annular space. The retraction length is equal to the selected sampling interval length. It is advisable to check that the tip detached during retraction. This can be done by poking a small-diameter rod down the inside of the probe. Note: Sometimes an o-ring may be used between the tip and tip holder. If so, the tip is more likely to stay attached to the holder when the probe is retracted. Since a leak-check procedure will be utilized prior to collecting soil vapor samples, it is not necessary to use an o-ring on the tip. The force of the direct push will hold the tip against the tip holder during the push. In other words, there is no need to create a leak-free seal at this connection, as the tip will be removed before sampling.

5.4 Attach the PRT adapter to the 1/4-inch OD Teflon tubing and secure in place by wrapping the connection with about 2 inches of electrical tape. This prevents the tubing from slipping on the nipple while tightening. Double check that the o-ring on the PRT adapter is new and undamaged.

5.5 Feed the PRT adapter and tubing down the probe. When it reaches the point holder, cut the tubing so that an additional 2 to 3 feet of tubing remains above ground.

5.6 While pushing down on the tubing, twist in a counter-clockwise direction until the probe adapter and tubing seat. Test the connection by lightly tugging on the tubing.

5.7 Install the probes in a manner that creates a leak-free seal between the above-ground atmosphere and the probe tip, while minimizing the impact on ground surface covers (e.g., asphalt, concrete, driveways, lawns). Achieving a leak-free seal may require placement of an inert sealing material (i.e., hydrated bentonite) at the point where the probe penetrates the ground surface. See Figure 2.

5.8 In the event the direct-push installation technique does not work, and a pre-drilled pilot hole is needed, this procedure must be coordinated with the project engineer. Use of pre-drilled holes will require careful control as to not over-drill and may also create the need for back-grouting to overcome leakage from the aboveground ambient atmosphere.

5.9 Wait 30 minutes after the probe is installed and sealed properly to begin sampling, so that the subsurface has time to equilibrate. The probe cap should be tightened on the end of the tubing during the equilibration period. Follow the proper procedures as presented in the *SOP for the Collection of Soil Vapor Samples from Temporary Probes and Permanent Implants Using Canisters*, and **be sure that leak-check procedures are employed**.

5.10 Removal of the probes is to be carried out by trained personnel using the direct-push machinery. The probe will be removed in a manner that minimizes disruption of ground surface covers (e.g., asphalt, concrete, driveways, lawns). Abandon the borehole by filling with a hydrated bentonite slurry or concrete.

5.11 Replace ground surface covers and repair to original condition.

6.0 Soil Vapor Probe Installation & Removal for the AMS Retract-A-Tip Method

6.1 Assemble the probe as shown in Figure 2 and attach the tubing. Thread the tubing through the hollow rod and attach the drive end to the top of the rod. Electrical tape may be used to secure the tubing to the tip, and protect the tubing from the drive end.

6.2 Push the probe to the desired depth with either the slide hammer or hammer drill. Attach extra rods to achieve the desired depth. Ensure that the final depth of the drive point includes extra depth to include the length of the retracted tip.

6.3 Retract the rod with the removal jack to expose the screen within the probe tip.

6.4 Install the probes in a manner that creates a leak-free seal between the above-ground atmosphere and the probe tip, while minimizing the impact on ground surface covers (e.g., asphalt, concrete, driveways, lawns). Achieving a leak-free seal may require placement of an inert sealing material (i.e., hydrated bentonite) at the point where the probe penetrates the ground surface.

6.5 In the event the installation technique does not work, and a pre-drilled pilot hole is needed, this procedure must be coordinated with the project engineer. Use of pre-drilled holes will require careful control as to not over-drill and may also create the need for back-grouting to overcome leakage from the aboveground ambient atmosphere.

6.6 Wait 30 minutes after the probe is installed and sealed properly to begin sampling, so that the subsurface has time to equilibrate. The probe cap should be tightened on the end of the tubing during the equilibration period. Follow the proper procedures as presented in the *SOP for the Collection of Soil Vapor Samples from Temporary Probes and Permanent Implants Using Canisters*, and **be sure that leak-check procedures are employed**.

6.7 Remove the probe with the removal jack. The probe will be removed in a manner that minimizes disruption of ground surface covers (e.g., asphalt, concrete, driveways, lawns). Abandon the borehole by filling with a hydrated bentonite slurry or concrete.

6.8 Replace ground surface covers and repair to original condition.

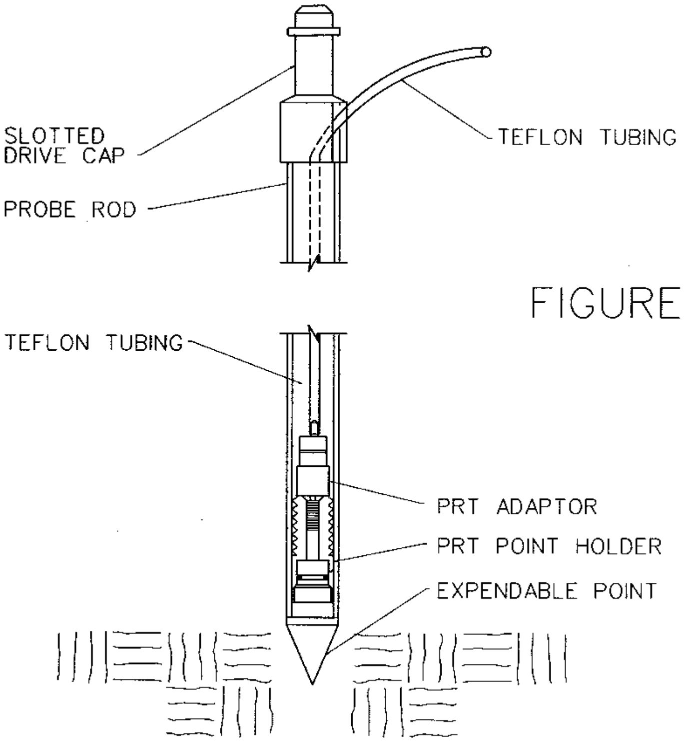

SLOTTED DRIVE CAP
TEFLON TUBING
PROBE ROD
TEFLON TUBING
PRT ADAPTOR
PRT POINT HOLDER
EXPENDABLE POINT

FIGURE 1

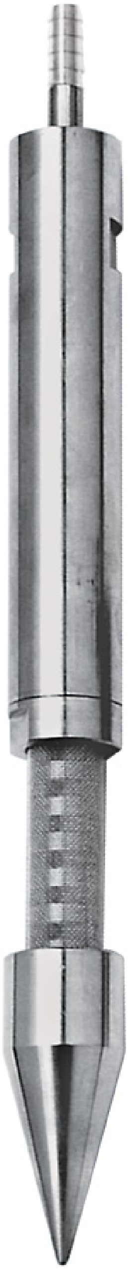


FIGURE 2

AMS Retract-A-Tip probe assembly

Attachment 5

Standard Operating Procedure for Subslab Soil Vapor Sampling from Cox-Colvin Vapor Pins

Standard Operating Procedure for Subslab Soil Vapor Sampling from Cox-Colvin Vapor Pins

January 2016

Standard Operating Procedure for Subslab Soil Vapor Sampling from Cox-Colvin Vapor Pins

1.0 Scope and Application

This standard operating procedure (SOP) describes the approach for subslab soil vapor sampling from Cox-Colvin & Associates, Inc., Vapor Pins using evacuated canisters (such as Summa canisters or equivalent); methods for purging and leak-checking the Vapor Pins are also included in this SOP. This procedure should be used in conjunction with project-specific data quality objectives. The project team is responsible for ensuring this procedure meets all applicable regulatory standards and receives approval/concurrence from the leading regulatory agency for the project. Vapor intrusion (VI) subject-matter experts should be consulted to address technical, regulatory, and/or field implementation issues associated with the use of this SOP. Only persons trained in subslab soil vapor sampling techniques should attempt this procedure.

2.0 Project-Specific Considerations

2.1 Information should be made available to building occupants prior to the sampling event that informs occupants about the sampling activities and equipment. This may be done in conjunction with a larger community outreach program associated with the site.

2.2 The Swagelok parts (quarter-turn plug valves and nuts) and Vapor Pins may be re-used if they are decontaminated. Options for decontamination include: 1) purging with air (only acceptable if there was no contact with contaminated soil or groundwater); 2) washing with Liqui-nox (**do not use Alconox**) followed by hot water rinse; or 3) rinsing with methanol followed by hot water rinse. The parts must be completely dry before reuse. It is advisable to heat the parts in an oven to a temperature of 130 degrees Celsius (266 degrees Fahrenheit) after rinsing with water. The appropriate decontamination process should be selected during the work-planning phase for each project. Typically, subslab soil vapor sampling does not generate investigation-derived waste (IDW) other than items that can be disposed of as solid waste; however, decontaminating with liquids will generate IDW. Compare the cost of buying new parts to the cost of managing and disposing of the IDW. The Teflon tubing cannot be reused or decontaminated.

3.0 Health and Safety

There are several health and safety topics to consider when sampling Vapor Pins:

3.1 Field teams should work in pairs at residential buildings or at industrial/commercial buildings where a relationship with the building occupant has not yet been established. A field team member should never enter a building alone for the first time.

3.2 Common hazards encountered during subslab soil vapor sampling include low ceilings, slip, trip, and fall hazards (from installation equipment and items stored in sampled areas), wet surfaces, biological hazards (spiders, rodents, residential pets, and so forth), sanitary hazards (animal feces), and low lighting levels.

3.3 Have a properly calibrated multi-gas meter (including lower explosive limit meter) and photoionization detector (PID) (as required by the project Health and Safety Plan) ready to screen the breathing zone during sampling. Potentially combustible atmospheres and hazardous volatile organic compound (VOC) concentrations may be present in subslab soil vapor.

3.4 Beware of pinch points and use the correct hand tools to avoid hand injuries.

4.0 Canister Security

4.1 Field teams should ensure that sampling canisters are not disturbed by building occupants. The necessary measures to accomplish this will vary by site/project.

4.2 Each sampling canister should be clearly marked with a sign that includes contact information for a point of contact.

4.3 In commercial or industrial buildings, orange cones, barricades, chairs, padlock and chain, and/or caution tape can be used to protect sampling canisters from disturbance and tampering.

5.0 Materials

5.1 Water Leak Check (standard Vapor Pin Leak Check)

- Vacuum pump with rotometer to control flow to 200 milliliter per minute (ml/min); there should also be a Swagelok filter (#SS-4-7) on the influent side of the pump to prevent concrete dust and/or dirt from getting into the pump
- Non-chlorinated (de-ionized or distilled) water
- Water dam (provided in Vapor Pin kit, or a short length of polyvinyl chloride pipe)
- VOC-free modeling clay (like Play-Doh)
- Paper towels
- Turkey baster (for removing water from the water dam)

5.2 Helium Leak Check (Some regulatory and state agencies may not accept water leak checks. MAKE SURE TO CHECK WITH AGENCY GUIDANCE BEFORE SAMPLING!)

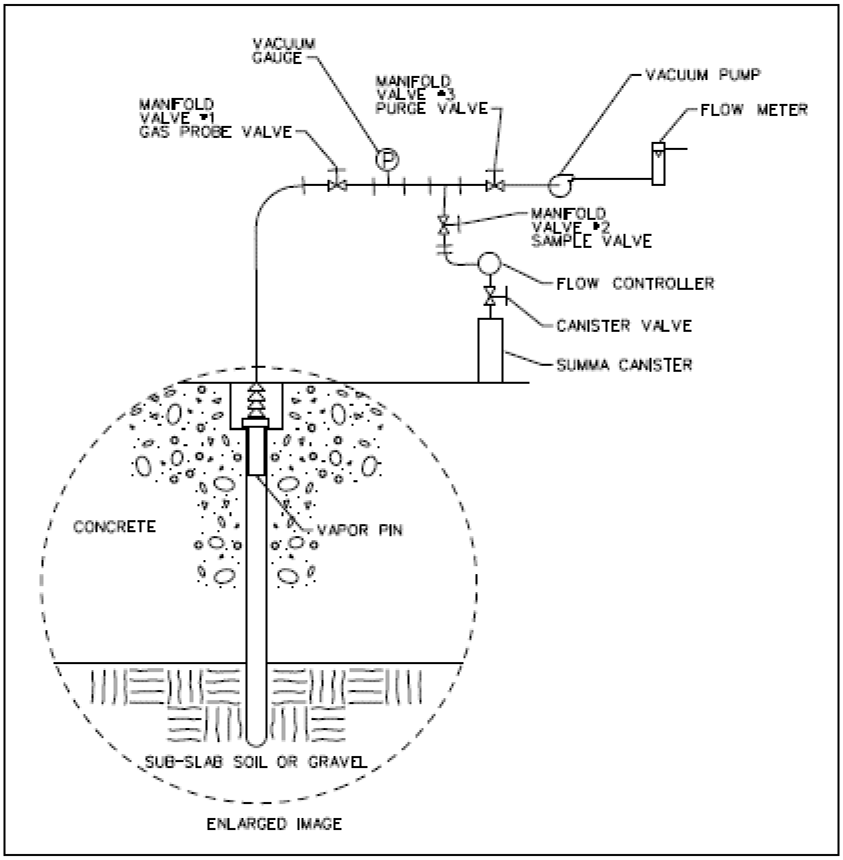
- Vacuum pump described in 5.1
- Helium canister containing high-purity 99.999 percent helium (NOT balloon grade) and regulator for the canister
- Enclosure, which may be constructed from a small bowl or container.
- Helium detector (such as a Dielectric MGD-2002), which can be rented from an equipment rental company.

5.3 Subslab Soil Vapor Purging and Sampling

The subslab soil vapor sampling set up is shown on Figure 1.

- Vacuum pump described in 5.1
- Sampling manifold consisting of Swagelok gas-tight fittings with three valves and one vacuum gauge to attach the probe to the air pump and the sample canister. See Figure 6. This manifold must be clean, free of oils, and flushed free of VOCs before use. This is accomplished by pulling three or four volumes of ambient air through the manifold and associated tubing.
- Swagelok quarter-turn plug valve (only necessary for extended sampling periods (for example, 8 or 24 hours) so that the sampling manifold can be disconnected without introducing indoor air into the probe) (part # SS-4P4T).
- Teflon tubing, 1/4-inch outer diameter (DO NOT use any other tubing material, such as nylon or polyethelyene).
- Flexible silicon tubing (3/8-inch inner diameter to connect Teflon tubing from Vapor Pin). See Figure 2.
- Tedlar bag (1-liter [L]) to collect the purged soil vapor so: (1) it is not discharged into the building; (2) the volume of purged soil vapor can be accurately measured; and (3) field screening with a PID or four-gas meter can be performed on the purged gas.
- Multi-gas meter – optional for field measurements of biodegradation parameters and health and safety monitoring.

FIGURE 1
Subslab Soil Vapor Sampling Diagram



- Photoionization Detector for health and safety to ensure breathing zone VOC concentrations and combustible atmospheres remain below levels specified by the Health and Safety Plan. It is also to collect field measurements of total VOCs from the probe or purged soil vapor; may warn the lab if high concentrations are detected so they can dilute the sample before analysis.
- Canister, stainless steel, polished, certified clean, and evacuated. These are typically cleaned, evacuated, and provided by the laboratory.
- Flow controller or critical orifice, certified clean, and set at desired sampling rate. These are typically cleaned, set, and provided by the laboratory. Common sampling rates for subslab soil vapor sampling are provided in Table 1.

TABLE 1
Common Sampling Rates for Subslab Soil Vapor Sampling

Can Size	Length of Sampling Time	Sampling Flow Rate (ml/min)
6 L	1 hour	90
6 L	8 hours	11.25
6 L	24 hours	3.75
1 L	5 minutes	180
1 L	1 hour	15

TABLE 1

Common Sampling Rates for Subslab Soil Vapor Sampling

Can Size	Length of Sampling Time	Sampling Flow Rate (ml/min)
850 ml	5 minutes	150
850 ml	1 hour	12

Note:
ml - milliliter

- Negative pressure (vacuum) gauge, oil-free and clean, to check canister vacuum. The vacuum gauges are typically provided by the laboratory. The laboratory may either provide one vacuum gauge to be used with all of the canisters, or a vacuum gauge for each canister to be left on during sample collection. If the lab only provided one external analog vacuum gauge, don't bother using it to measure the canister vacuums; only the digital vacuum readings are necessary. Sometimes the canisters are fitted with built-in vacuum gauges that are not removable. Gauges sent by the laboratory are for field use only, and are an approximate measure of the actual vacuum.
- Miscellaneous fittings (Swagelok nut and ferrule, part #SS-400-NFSET or equivalent) to connect tubing to canister, and sampling tee (Swagelok union tee, part #SS-400-3 or equivalent) for duplicate sample collection.
- Digital vacuum gauge with 0.25 percent accuracy at the -30 to 0 inches of mercury (inches Hg) range to accurately measure the initial and final Summa canister vacuum.

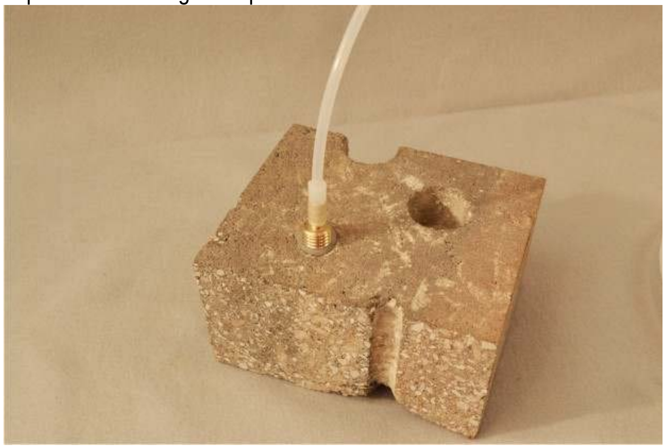
5.4 Miscellaneous

- Teflon tape for use on leaky connections. Note: Never use Teflon tape on the Swagelock fittings. They are compression fittings and the tape can actually make a leak worse.
- Wrenches and screwdrivers (clean and free of contaminants) of various sizes as needed for connecting fittings and making adjustment to the flow controller. 9/16-inch and ½-inch wrenches fit the 1/4-inch Swagelok fittings, which most canisters and flow controllers have.
- Power extension cord and ground fault current interrupter.
- Shipping container suitable for protection of canister(s) during shipping. Typically, strong cardboard boxes are used for canister shipment. The canisters should be shipped to the laboratory in the same shipping container(s) in which they were received.

6.0 Vapor Pin Sampling System Setup Procedure

6.1 For flush mount installations, first remove the secure cover or flush mount cap (whichever was installed). Remove the white cap on the Vapor Pin. Attach a new piece of flex tubing, approximately an inch long, to the barbed fitting at the top of the Vapor Pin. Then attach 1/4-inch Teflon tubing to the flex tubing. See Figure 2.

FIGURE 2
Vapor Pin™ Tubing Set-up



6.2 For flush mount installations, a water dam is not necessary because the larger 1.5-inch hole can be filled with water. For stick-up installations, place the water dam over the subslab probe by threading the Teflon tubing through the hole of the water dam. Press the water dam down so it seals on the concrete slab using VOC-free modeling clay (Figure 3). The top of the water dam should be higher than the top of the flex tubing when attached to the Vapor Pin barbed connector, so that the water level inside the dam during the leak check can be higher than the connection of the flex tubing and the ¼ -inch Teflon tubing. Fill with water. Continue with Step 6.4.

FIGURE 3
Vapor Pin Water Dam Set-up for Stick-up Installations

6.3 **OPTIONAL -** Place the helium leak-check enclosure over the subslab probe by threading the Teflon tubing through the hole of the enclosure. Slide the enclosure down so it seals on the concrete slab. Attach the other end of the sample tube to the sampling manifold with the use of a nut and ferrule set. See Figures 4 and 5.

FIGURE 4
Installing the helium leak check assembly

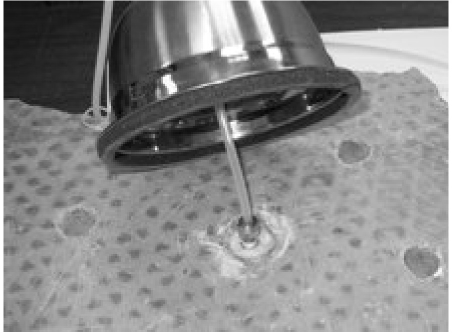
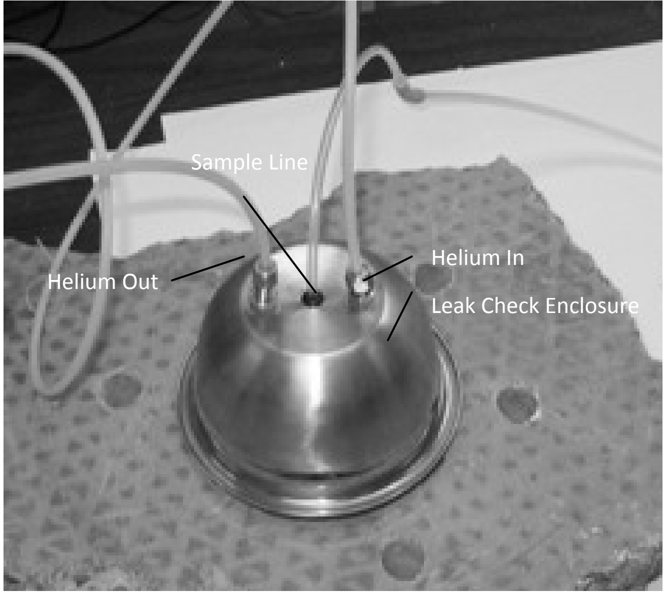


FIGURE 5
Helium leak check assembly



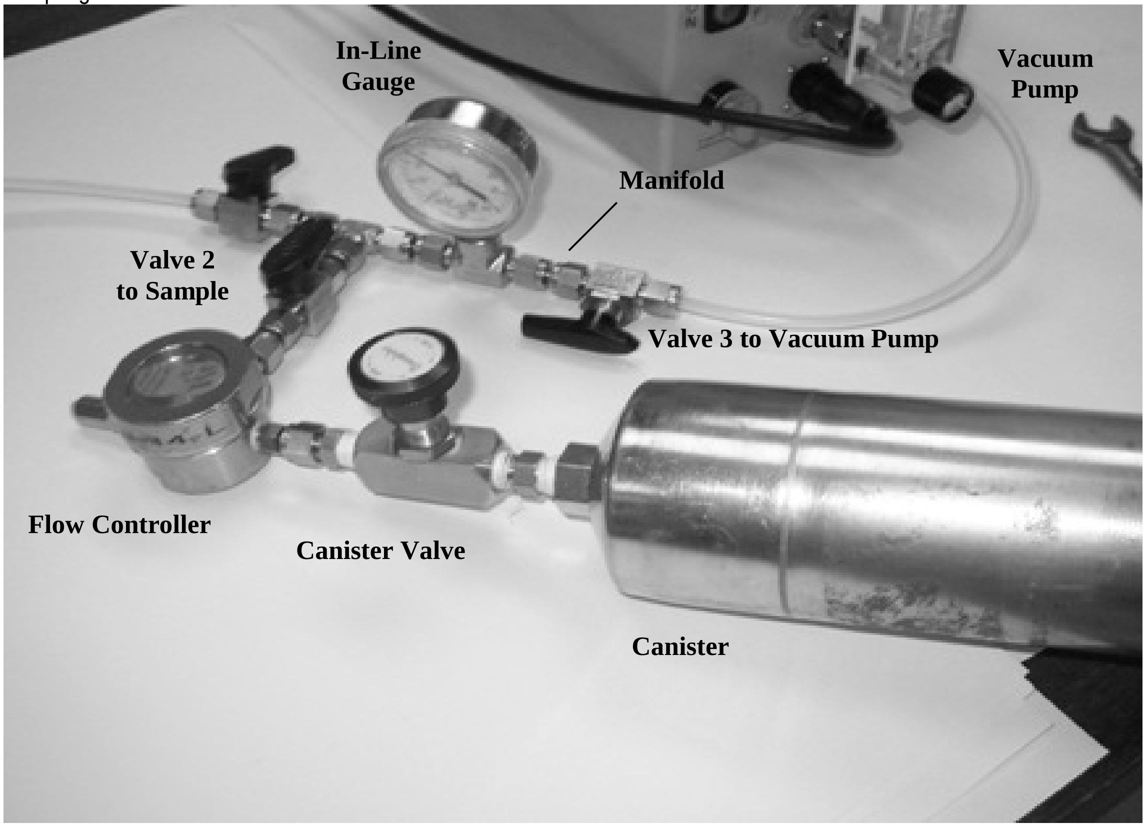
6.4 Attach the other end of the sample tube to the sampling manifold with the use of a nut and ferrule set. See Figure 6.

6.4.1 If the sample will be collected over a period of time greater than 30 minutes, a quarter-turn plug valve (Swagelok part# SS-4P4T) should be placed in-line between the Vapor Pin and the manifold above the water dam (or under the helium leak-check enclosure, if applicable). Once purging has been completed, the quarter-turn plug valve can be turned to the off position, allowing disconnection of the manifold and vacuum pump for use at another location, without the loss of purge integrity.

6.4.2 Adjust the vacuum pump to achieve the desired flow rate of 200 ml/min. This should be performed at the outlet of the vacuum pump before purging by using a suitable flow meter or calculating the amount of time required to fill a 1-L Tedlar bag.

6.5 Attach the air pump to the sampling manifold and the Tedlar bag to the air pump exhaust.

FIGURE 6
Sampling Manifold



7.0 Canister Preparation

7.1 Clean sampling protocols must be followed when handling and collecting samples. This requires care in the shipping, storage, and use of sampling equipment. The cleanliness of personnel who come in contact with the sampling equipment is also important; smoking, wearing of perfumes or deodorants, and dry-cleaned clothing should be avoided. Canisters should not be transported in vehicles with gas-powered equipment or fuel cans. Sharpie-type markers should not be used for labeling or note-taking during sampling.

7.2 When unpacking the canisters, check that the canister cap is wrench tight and knob is firmly hand tight. Newer canisters with the blue knobs are prone to opening during handling if the valve is not tightly closed. Ensure that the knob is tightened shut before removing the canister cap.

7.3 The air sampling canisters are certified clean and evacuated by the laboratory to approximately 29 to 30 inches Hg vacuum. Initial canister vacuums that are less than certified by the laboratory are a potential indication of leakage that could affect the accuracy of analytical results. Care should be used at all times to prevent inadvertent loss of canister vacuum. Always keep the canister cap on and wrench-tight when not connected to the sample train. Never open the canister knob unless the intent is to collect a sample or check the canister vacuum with an attached gauge.

7.4 Verify that the canister has sufficient initial vacuum for sampling. Measure the initial canister vacuum using an external digital vacuum gauge in the manner described as follows:

7.4.1 Remove the protective cap from the knob on the canister. **Make sure the canister knob is closed!**

7.4.2 Attach the digital vacuum gauge to the canister and tighten with a wrench. Open the canister knob and measure the initial canister pressure. After taking the reading, close the canister knob and remove the gauge.

7.4.3 Do not sample using a canister without sufficient initial vacuum. Be advised that sampling data may be flagged or rejected from canisters with low initial vacuum (less than 28 inches Hg). Low initial vacuum could create a low bias in analytical results due to air leakage. While there is also a smaller risk that air leakage could introduce contaminants into the canister, the primary concern is the low bias to analytical results; this bias is within the range of analytical variability allowed with the U.S. Environmental Protection Agency (EPA) Method TO-15 (±30 percent) for initial vacuums greater than 24 inches Hg. The table presented in Paragraph 7.4.4 identifies the field team's response based on the initial vacuum reading for a canister. In addition, this table also identifies the potential bias to results at different initial canister vacuums.

7.4.4 Use the following table to determine when to use canisters based on initial vacuum readings.

Initial Vacuum Reading	Potential Error in Analytical Results Due to Leakage	Field Team Response
Greater than 30 to 28 inches Hg	Up to -10% error	Use canister for sampling – no limitations on use.
Greater than 26 to 28 inches Hg	Up to -21% error	Use canister for sampling if necessary; replace canister with a spare if spares are available.
Greater than 24 to 26 inches Hg	Up to -30% error	Sampling with canister is not advisable. Contact Project Manager/Senior VI Technical Advisor and obtain direction before sampling with this canister. Be advised that qualifiers may be applied to analytical results sampled with canisters with vacuums less than 26 inches Hg.
Less than 24 inches Hg	Greater than -30% error	Do not use this canister for sampling. Analytical results will be rejected.

7.5 Attach the dedicated external analog vacuum gauge to the canister (if provided by the laboratory) and tighten with a wrench. (The analog pressure gauge should be installed between the canister and flow controller.) If the laboratory only provided one external analog vacuum gauge, do not bother using it to measure the canister vacuums; only the digital vacuum readings are necessary.

7.6 Attach the flow controller to the canister, via the analog vacuum gauge if one is being used. Place the canister cap on the flow controller influent point if the canister will not be attached to the sampling manifold immediately to prevent potential leakage.

8.0 Subslab Soil Vapor Sampling System Leak Checking and Purging Procedure

8.1 Physical Leak Check - Perform a leak check of the sampling manifold (Figure 6):

8.1.1 Attach the canister to the sampling manifold (Figure 6). (The connections between the sample valve [Valve #2] and the flow controller, as well as the flow controller and the canister, will be checked in the physical leak check. This step should be included to check the latter connection even if the sampling manifold will not be in-place during sample collection.) Open the sample valve (Valve #2) and make sure the valve on the canister is closed.

8.1.2 For sample trains without a quarter-turn plug valve placed in-line between the probe and the manifold, make sure the probe valve (Valve #1) is closed. For sample trains with a quarter-turn plug valve, make sure the probe valve (Valve #1) is open and the quarter-turn plug valve is closed.

8.1.3 Open the purge valve (Valve #3) and start the vacuum pump.

8.1.4 Purge until a vacuum gauge reading of 10 inches Hg is achieved, or to a vacuum that will be encountered during sampling, whichever is greater. (This should happen relatively quickly.) Then close the purge valve (Valve #3) and turn off the pump.

8.1.5 Observe the vacuum gauge for 30 seconds. A leak-free system will be evident if there is no loss of vacuum within the sampling manifold system during this time.

8.1.6 Repair any leaks prior to sample collection by tightening the fittings on the manifold, flow controller, and the quarter-turn plug valve if present. Re-test to make the sure the sampling system passes the physical leak check before proceeding.

8.1.7 Record the physical leak check date and time, and results on the Subslab Soil Vapor Sampling Log.

8.1.8 Close the sample valve (Valve #2). Detach the canister (including the flow controller) if the sampling manifold will not be in place during the sample collection period. Secure the cap onto the flow controller to prevent leakage.

8.2 Vapor Pin Purge and Leak Check - A purge of the subslab soil vapor probe and sampling manifold system and a leak test (using either water or helium) of the probe is required prior to sampling every subslab probe each time sampling is performed. This leak check will verify the integrity of the probe seal. This is accomplished by doing the following:

8.2.1 Water Leak Check

8.2.1.1 For flush mount installations, fill the entire 1 ½-inch depression containing the Vapor Pin, flex tubing, and the ¼-inch Teflon tubing with non-chlorinated (deionized or distilled) water. For stick-up installations, fill the water dam with non-chlorinated (de-ionized or distilled) water. Make sure the water level inside the dam is higher than the connection of the flex tubing and the ¼-inch Teflon tubing.

8.2.1.2 To start the Vapor Pin purge, open the probe valve (Valve #1) and start the pump. The sample valve (Valve #2) should be closed. Verify that the flow rate is still 200 ml/min.

8.2.1.3 If there is shallow groundwater in the area, carefully watch the tubing as the pump is turned on. If water is observed in the sample tubing, shut the pump off immediately. Subslab soil vapor collection will not be feasible if the probe is in contact with water.

8.2.1.4 Purge for approximately 5 minutes into a 1-L Tedlar bag. At the end of the purge time, close and remove the Tedlar bag from the pump. Proceed to Step 8.2.3.

8.2.1.5 Observe the water level in either the water dam or the flush mount depression. If there is a sudden drop in the water level, the appearance of water in the sample tubing (when groundwater is not suspected), or other indications of water entering the subslab (bubbles), then the Vapor Pin failed the leak check and corrective action is required. The leak test must be performed again after corrective actions are taken until the Vapor Pin passes the leak test. **Note: Water level might drop slightly due to absorption into the concrete.**

8.2.1.5.1 There are five corrective action options (first remove the water from the water dam or depression with a turkey baster):

8.2.1.5.1.1 Remove the Vapor Pin, clean out the drilled hole thoroughly, replace the silicone sleeve with a new one, and reinstall.

8.2.1.5.1.2 Fill in any visible concrete cracks inside the dam and drilled hole with quick-setting cement and, after allowing the cement to cure, retest.

8.2.1.5.1.3 Try fortifying the Vapor Pin seal by adding modeling clay to the base of the Vapor Pin.

8.2.1.5.1.4 Add Teflon tape to the barbed connector and the Teflon tubing, reattach the flex tubing and the Teflon tubing, make sure that all the fittings are tight and repeat the purge and leak-check procedure.

8.2.1.5.1.5 If the previous options fail, then the Vapor Pin should be abandoned.

8.2.2 <u>OPTIONAL Helium Leak Check</u>

8.2.2.1 Place the helium leak-check enclosure around the Vapor Pin to achieve a buildup of helium in the leak-check enclosure. The enclosure should not be so tightly sealed; there should be an exhaust for the helium so pressure does not build up in the enclosure.

8.2.2.2 Start the flow of helium to the leak-check enclosure at 200 ml/min. Let the helium fill the enclosure for approximately 30 seconds depending on the enclosure size.

8.2.2.3 To start the purge, open the probe valve (Valve #1) and start the pump. The sample valve (Valve #2) should be closed. Verify that the flow rate is still 200 ml/min.

8.2.2.4 If there is shallow groundwater in the area, carefully watch the tubing as the pump is turned on. If water is observed in the sample tubing, shut the pump off immediately. Subslab soil vapor collection will not be feasible if the probe is in contact with water.

8.2.2.5 Connect the helium detector to the enclosure exhaust to confirm that helium is present in the enclosure during purging. It is optional to measure the helium concentration within the enclosure (see Step 8.2.2.7). Make sure that the helium detector is exposed to ambient air and “zeros out” before measuring the purged soil vapor in Step 8.2.2.7.

8.2.2.6 Purge for approximately 5 minutes into a 1-L Tedlar bag. At the end of the purge time, close and remove the Tedlar bag from the pump.

8.2.2.7 At the end of the purge, remove the Tedlar bag from the pump and connect it to the helium detector. The helium concentration in the purged soil vapor must be less than 1 percent of what it was in the helium enclosure during purging to pass the leak test (10,000 parts per million by volume [ppmv] if the helium concentration was 100 percent) (verify that this limit is consistent with appropriate project-specific regulatory guidance). Calculate what 1 percent of the helium concentration was in the enclosure from the measured concentration in Step 8.2.2.6. If the Vapor Pin fails the leak check then corrective action is required. The leak test must be performed again after corrective actions are taken until the Vapor Pin passes the leak test.

8.2.2.7.1 There are five corrective action options:

8.2.2.7.1.1 Make sure that all the fittings are tight and/or add Teflon tape to them.

8.2.2.7.1.2 Remove the Vapor Pin, clean out the drilled hole thoroughly, replace the silicone sleeve with a new one, and reinstall.

8.2.2.7.1.3 Try fortifying the Vapor Pin seal by adding modeling clay to the base of the Vapor Pin.

8.2.2.7.1.4 Fill in any visible concrete cracks inside the dam and drilled hole with quick-setting cement and, after allowing the cement to cure, retest.

8.2.2.7.1.5 If the previous options fail, then the Vapor Pin should be abandoned.

Note: **Helium leak detectors may be sensitive to high concentrations of methane or other atmospheric gasses.** If these are expected to be present in the subslab soil vapor, then caution should be used with this technique, as false-positive readings may be encountered during leak testing. Use a multi-gas meter to determine whether methane is present in subslab soil vapor. The false-positive “helium” concentration should be measured in the soil vapor prior to applying helium in the enclosure so it can be compared with the helium concentration in the purged soil vapor during the leak test.

8.2.3 At the end of the purge and after the system is verified to be leak-free, close the purge valve (Valve #3) or the quarter-turn plug valve if it is being used. Do not open it again. Doing so will result in loss of the purge integrity and will require re-purging.

8.2.4 The purged subslab soil vapor in the Tedlar bag can be screened with the field meters described in Section 5.3. Note: Be sure to do this outdoors so that it does not introduce VOCs from beneath the slab to the indoor air that may pose as a health and safety risk and can also influence concurrent indoor air samples (if applicable).

8.2.5 Record the purge and leak check information on the Subslab Soil Vapor Sampling Log.

8.2.6 Proceed to the sampling phase. The probe may be left with the closed quarter-turn plug valve in place for several hours prior to sampling; however, purging/leak testing should occur on the same day as sampling.

9.0 Subslab Soil Vapor Sample Collection Procedure

9.1 The canister (with attached flow controller) should be attached to the probe via the sampling manifold or quarter-turn plug valve. The initial canister vacuum should have already been measured.

9.2 Slowly open (counter-clockwise) the canister’s knob approximately one full turn.

9.3 After sampling for the appropriate amount of time (determined from project instructions; see Table 1), close the sample valve (Valve #2) or the quarter-turn plug valve and the canister knob. If the canister has a built-in or assigned vacuum gauge, allow the canister to fill until the vacuum reaches 2 to 10 inches Hg. Remove the canister from the sampling manifold or the quarter-turn plug valve.

9.3.1 If sampling for extended periods of time (such as 8 or 24 hours), check the samples at some point several hours before the expected completion time (for example, at 18 to 20 hours for a 24-hour sample) to make sure the canister is collecting at the expected rate. It may also be a good idea to check the canister several hours into the sampling period (for example, 2 or 4 hours for a 24-hour sample). The flow controllers are rarely set to the exact sampling period.

9.4 Measure the final canister pressure using the same digital vacuum gauge used to measure initial canister pressure. Open the canister knob and record the reading. Close the canister knob again and remove the digital vacuum gauge. Use this reading on the chain of custody and sample labels.

9.5 Consult with the project manager before submitting the sample to the laboratory if a final vacuum greater than -10 inches Hg, or less than -2 inches Hg are encountered. Use the following table for guidance to determine how to address final vacuum measurements:

Final Vacuum Reading	Field Team Response
Less than 2 inches Hg	Contact Project Manager/Senior VI Technical Advisor before submitting sample. Notify analytical laboratory to report their laboratory-measured pressure and to get direction from the Project Manager before analyzing sample.
Greater than 2 inches Hg and less than 10 inches Hg	Submit sample for analysis - no limitations on data use.
Greater than 10 inches Hg	Contact Project Manager/Senior VI Technical Advisor before submitting sample. Verify final vacuum with the analytical laboratory before analysis.

9.6 Canisters with no vacuum left (that is, 0 inch Hg) should not be analyzed. Contact the Project Manager/Senior VI Technical Advisor before submitting a sample with a final vacuum of 0 inches Hg to determine the appropriate course of action. One option is to verify the final vacuum with the analytical laboratory. If there is vacuum remaining in the canister according to the laboratory vacuum gauge, the Project Manager may direct the analytical laboratory to analyze the sample.

9.7 The analytical laboratory should be directed to not analyze a sample showing a final vacuum of 0 inch Hg (as measured by the laboratory), and to notify the Project Manager/Senior VI Technical Advisor and obtain further guidance regarding that sample.

9.8 Record the sampling date, times, canister identification (ID), flow controller ID, vacuum gauge ID(s), and any other observations pertinent to the sampling event on the Subslab Soil Vapor Sampling Log. Also record the weather conditions (temperature, barometric pressure, precipitation, and so forth) during sampling.

9.9 Fill out all appropriate documentation (sampling forms, sample labels, chain of custody, sample tags, and so forth).

9.10 Disassemble the sampling system.

9.11 Replace the white silicone cap on the Vapor Pin.

9.12 For permanent probes, replace the flush mount cover or secure cap and make sure it is securely in place.

9.13 Evacuate the Tedlar bags outside of the building.

10.0 Altitude/Temperature Correction

10.1 Air pressure decreases with elevation. Therefore, a canister evacuated at a laboratory located at sea level will show a lower vacuum measurement at a higher altitude. Generally, a 1,000-foot rise in elevation corresponds to a 1-inch Hg drop in pressure OR a 1-inch Hg decrease in measured vacuum. For example, a canister evacuated to 30 inches at sea level and used at 3,000 feet would show an initial vacuum of 27 inches Hg.

10.2 If you plan to sample at altitude, be sure to inform the laboratory ahead of time so they adjust the flow controllers accordingly.

10.3 If sampling is being conducted at higher elevations, verify the elevation difference between the analytical laboratory and field location and determine the associated decrease in measured vacuum.

10.3.1 Calculate the pressure difference between the laboratory and field location as follows: Difference from Sea Level (field) – Difference from Sea Level (laboratory). Use the Altitude Correction Table attached to this SOP.

10.3.2 Subtract the pressure difference determined in Section 10.3.1 from allowable initial vacuum levels (Section 9.4.) and final vacuum levels (Section 9.5) to determine appropriate initial and final vacuum levels.

10.4 Observed final canister vacuum changes with significant temperature change. If canister vacuums are measured in an environment when the temperature is significantly different from 20 degrees Celsius (greater than 10 degrees different), then the vacuum may appear to change on the way to the laboratory. Be sure to communicate the temperature at which the final vacuums were measured to the project chemist so appropriate corrections can be included in the data validation. Note: Temperature difference only affects final canister vacuum measurements and only if the measurements are made in that environment (that is, a canister that is a sampled at 5 degrees Celsius, then brought into a warm 20-degree-Celsius trailer for the vacuum check won’t have an issue).

11.0 Sample Handling and Shipping Procedure

11.1 Fill out all appropriate documentation (chain of custody, sample tags) and return canisters and equipment to the laboratory

11.2 The canisters should be shipped back to the laboratory in the same shipping container in which they were received. The samples should not be cooled during shipment. DO NOT put ice in the shipping container.

11.3 When packing the canisters for shipment, verify that the valve (just past finger-tight) and valve caps are snug (1/4 turn past finger-tight), and use sufficient clean packing to prevent the valves from rubbing against any hard surfaces. Never pack the canisters with other objects or materials that could cause them to be punctured or damaged. Ensure that flow controllers and gauges are separately and adequately wrapped to prevent damage.

11.4 **Do not place sticky labels or tape on any surface of the canister.**

11.5 Place a custody seal over the openings to the shipping container.

11.6 Make sure to insure the package for the value of the sample containers and flow controllers if corporate card policy does not cover this.

11.7 Ship canisters for overnight delivery if possible. This is not critical, but does reduce the amount of time in transit and potentially reduce the chance of slight leaks becoming significant before laboratory receipt. NOTE: If sampling on a Friday, ensure the laboratory accepts samples on Saturdays (you do not want the canisters sitting on a loading dock [or worse] for 3 days).

12.0 Quality Control

12.1 Laboratories supplying canisters must follow the performance criteria and quality assurance prescribed in EPA Method TO-14/15 for canister cleaning, certification of cleanliness, and leak checking. SOPs are required.

12.2 Laboratories supplying flow controllers must follow the performance criteria and quality assurance prescribed in EPA Method TO-14/15 for flow controller cleaning and adjustment. SOPs are required.

13.0 Attachments

13.1 ***Subslab Soil Vapor Probe Installation and Sampling Log - Canister Method***

13.2 ***Altitude correction table***

Altitude Correction Table

Elevation (feet)	Pressure (inches Hg)	Difference from Sea-Level (inches Hg)	Elevation (feet)	Pressure (inches Hg)	Difference from Sea-Level (inches Hg)
0	29.92	0	1500	28.37	1.553
50	29.87	0.053	1550	28.32	1.603
100	29.81	0.106	1600	28.27	1.653
150	29.76	0.159	1650	28.22	1.703
200	29.71	0.212	1700	28.17	1.753
250	29.66	0.265	1750	28.12	1.803
300	29.60	0.317	1800	28.07	1.853
350	29.55	0.370	1850	28.02	1.903
400	29.50	0.422	1900	27.97	1.953
450	29.45	0.474	1950	27.92	2.002
500	29.39	0.527	2000	27.87	2.052
550	29.34	0.579	2050	27.82	2.101
600	29.29	0.631	2100	27.77	2.151
650	29.24	0.683	2150	27.72	2.200
700	29.19	0.735	2200	27.67	2.249
750	29.13	0.787	2250	27.62	2.298
800	29.08	0.838	2300	27.57	2.347
850	29.03	0.890	2350	27.52	2.396
900	28.98	0.941	2400	27.47	2.445
950	28.93	0.993	2450	27.43	2.494
1000	28.88	1.044	2500	27.38	2.543
1050	28.82	1.095	2550	27.33	2.591
1100	28.77	1.147	2600	27.28	2.640
1150	28.72	1.198	2650	27.23	2.688
1200	28.67	1.249	2700	27.18	2.736
1250	28.62	1.299	2750	27.14	2.785
1300	28.57	1.350	2800	27.09	2.833
1350	28.52	1.401	2850	27.04	2.881
1400	28.47	1.452	2900	26.99	2.929
1450	28.42	1.502	2950	26.94	2.977

Note: use the following equation to calculate atmospheric for altitudes not shown on this table:

$P = P_o \exp(-35.523 \times 10^{-6} y)$, where P is the pressure at the desired elevation, P_o is the atmospheric pressure at sea level, and y is the desired elevation. Source: NASA, 1996. *Elevation Correction Factor for Absolute Pressure Measurements*. NASA Technical Memorandum 107240.

ch2m:

Vapor Intrusion Best Practices
Subslab Soil Vapor Probe Installation and Sampling Log - Canister Method

Project Info

Project Name: .... **Project # :** ....

Sampler Name: .... **Date:** ....

Structure

Identification: ....

Address: ....

Slab Information:

Condition of slab ....

Describe material under the slab (gravel, sand, etc.) ....

Is water present in the soil? ....

Subslab Soil Vapor Probe Installation, Probe Purging, Leak Checking, & Sampling Log

Sample location (describe and show in diagram)		
Probe and Sample Identification (field ID)		
Probe Installation	Date and time	
	Thickness of slab (inches)	
	Depth of hole drilled (inches below slab surface)	
	Total VOCs measure in hole with PID (ppmv)	
	Depth of installed probe (inches below slab surface)	
Manifold Leak Check	Leak check (sampling manifold) - Pass/No Pass	
Probe Purge	Purge rate (mL/min)	
	Purge start time	
	Helium concentration in shroud (%)	
	Purge vacuum (" Hg)	
	Purge completion time	
Helium Leak Check*	Helium concentration in purged soil vapor (%)	
	Pass or Fail?	

Field Analysis (optional)	O_2 (%)	
	CO_2 (%)	
	CO (ppm)	
	H_2S (ppm)	
	CH_4 or LEL (%)	
	Total VOCs (ppmv)	
Canister Sampling	Canister ID	
	Flow controller ID	
	Pressure gauge ID (optional)	
	Sampling rate or period (mL/min or hours)	
	Sample start date and time	
	Initial canister pressure (" Hg)	
	Sampling vacuum (" Hg)	
	Sample completion date and time	
	Final canister pressure (" Hg)	

* The subslab soil vapor probe passes the helium leak check if the measured helium concentration in the purged soil vapor is less than 1% of the measured helium concentration in the shroud. Do NOT collect a soil vapor sample if the probe fails the helium leak test. (multiply % by 10,000 to convert to ppm)

Weather conditions during sampling: ....

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Observations and Comments: ....

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Attachment 6

Standard Operating Procedure for the Collection of Soil Vapor Samples from Temporary and Permanent Probes Using Canisters

Standard Operating Procedure for the Collection of Soil Vapor Samples from Temporary and Permanent Probes Using Canisters

January 2016

Standard Operating Procedure for the Collection of Soil Vapor Samples from Temporary and Permanent Probes Using Canisters

1.0 Scope and Application

This procedure offers a practical approach for the collection of soil vapor samples from temporary soil vapor probes [e.g., Geoprobe direct-push system with post-run tubing (PRT) adapters or the AMS Retract-A-Tip system], or from permanently installed soil vapor probes, into evacuated canisters (such as Summa canisters or equivalent). Soil vapor sample integrity is verified by using a real-time leak checking procedure before taking each sample. This must be done after probe installation and prior to sampling, as well as before each subsequent soil vapor sample from permanent probes. This standard operating procedure (SOP) should be used when its application is consistent with the project's data quality objectives (DQOs) and in conjunction with the *SOP for the Installation of Temporary Soil Vapor Sampling Probes* or the *SOP for the Installation of Permanent Soil Vapor Sampling Probes*. It is the responsibility of the project team to make sure this procedure meets all applicable regulatory standards and receives approval/concurrence from the leading regulatory agency for the project. Vapor intrusion (VI) subject-matter experts (SMEs) should be consulted as needed to address technical, regulatory or field implementation issues associated with the use of this SOP. Only persons trained in the collection of soil vapor samples should attempt this procedure.

2.0 Project-Specific Considerations

2.1 Soil vapor sampling should not be performed until 48 hours after a significant rain event (defined as >1 inch of rainfall).

2.2 It is common practice to both install and remove soil vapor probes by the direct push method using equipment specifically designed for this purpose (Geoprobe or equivalent drill rig). Operation of direct-push machinery shall be performed only by trained and licensed personnel. Soil vapor probes can also be advanced with a hand tool method (e.g., the AMS Retract-A-Tip system). The hand tool installation method is only applicable to relatively shallow sampling [e.g., up to 10 to 15 feet below ground surface depending on the soil type].

2.3 Methane and carbon dioxide (CO_2) can cause positive bias with a helium leak detector, if a helium leak-check procedure is used as detailed in this SOP. If methane or CO_2 are expected or encountered at a site, then it may be necessary to explore different strategies to determine probe integrity.

2.4 The subsurface needs time to equilibrate after probe installation; 30 minutes for temporary probes and 24 hours for permanent probes.

2.5 Prior to attempting sampling of soil vapor probes, there should be an understanding of subsurface conditions at the site.

2.5.1 Depth to Groundwater – soil vapor samples must be collected in the vadose zone (and above the capillary fringe).

2.5.2 Soil permeability **-** It may not be feasible to collect soil vapor from finer-grained or tight soils with little pore volume, such as clays; if there are clay layers present in the subsurface, these intervals should be avoided. For sampling in these soils, using permanent soil vapor probes with a wider borehole is recommended. Care should be taken during purging and sampling so that the vacuum in the sampling system never exceeds 7 inches mercury (inches Hg) or approximately 100 inches water.

3.0 Materials

3.1 Teflon tubing 1/4-inch outside diameter (OD) sample tubing. Ensure there is enough tubing to use new tubing at each sample location.

3.2 Swagelok 1/4-inch nut and ferrule sets for connecting the probe tubing to the sampling manifold (part #SS-400-NFSET).

3.3 The helium leak-check equipment (or equivalent), including the enclosure, helium cylinder (high purity helium [NO BALLOON HELIUM]), and helium detector (such as a Dielectric MGD-2002 meter). The enclosure may be provided by the driller or can be constructed from polyvinyl chloride (PVC) pipe or a plastic container. The helium detector can be rented from an equipment rental company.

3.4 Multi-gas meter. (Optional if on-site atmospheric gas analysis is required).

3.5 Vacuum pump with rotometer to control flow to 200 milliliter per minute (ml/min); there should also be a Swagelok filter (#SS-4-7) on the influent side of the pump to prevent dirt from getting into the pump

3.6 Electric supply for the pump (either battery pack, generator, or power inverter with adapter for car battery).

3.7 Sampling manifold consisting of Swagelok gas-tight fittings with three valves and one vacuum gauge to attach the probe to the air pump and the sample canister. See **Figure 1**. This manifold must be clean, free of oils, and flushed free of VOCs before use. This is accomplished by pulling three or four volumes of ambient air through the manifold and associated tubing.

3.8 Swagelok valve (only necessary for extended sampling periods [i.e., greater than 30 minutes] so that the sampling manifold can be disconnected without introducing ambient air into the probe) (part # SS-4P4T).

3.9 Wrenches (clean and free of contaminants), various sizes as needed for connecting fittings and making adjustments to the flow controller (if field-adjustable). A 9/16-inch wrench fits the ¼-inch Swagelok fittings, which most canisters and flow controllers have.

3.10 Gas sampling bag (e.g., Tedlar bag) (1-L or 3-L) to collect the purged soil vapor, so the volume of purged soil vapor can be measured and field screening with a photoionization detector (PID) or GEM2000 meter can be performed on the purged vapor.

3.11 Multi-gas meter – optional for field measurements of biodegradation parameters and health and safety monitoring.

3.12 Canister, stainless steel, polished, certified-clean, and evacuated. These are typically cleaned, evacuated, and provided by the laboratory.

3.13 Flow controller or critical orifice, certified-clean, and set at desired sampling rate. These are typically cleaned, set, and provided by the laboratory. Soil vapor samples are typically collected in 1 or 6 liter canisters at a flow rate of 200 mL/min; however, lesser flow rates may be used in finer grainer soils.

3.14 Negative pressure (vacuum) gauge—oil-free and clean—to check canister vacuum. The vacuum gauges are typically provided by the laboratory. The laboratory may either provide one vacuum gauge to be used with all of the canisters, or a vacuum gauge for each canister to be left on during sample collection. Sometimes the canisters are fitted with built-in vacuum gauges that are not removable. Gauges sent by the laboratory are for field use only, and are an approximate measure of the actual vacuum. Regularly calibrated – and less rugged – vacuum gauges are used at the laboratory to measure vacuum before shipment and again after sample receipt.

3.15 Digital vacuum gauge with 0.25 percent accuracy at the -30 to 0 inches of mercury (inches Hg) range to accurately measure the initial and final Summa canister vacuum.

3.16 Shipping container, suitable for protection of canister(s) during shipping. Typically, strong cardboard boxes are used for canister shipment. The canisters should be shipped to the laboratory in the same shipping container(s) in which they were received.

4.0 System Set Up

4.1 Acquire all the necessary hardware and sampling equipment shown in **Figure 1**. Be sure to place the helium leak-check enclosure over the probe, remove the probe cap, and push the sample tubing through the hole in the enclosure cap before attaching the sampling manifold. It may be necessary to cut off the probe cap with tubing cutters if the hole in the enclosure cap is not large enough to accommodate the ferrule set. The nut and probe cap can be reused once sampling is complete. The ferrule set must be replaced. ***Do not connect the canister at this time***.

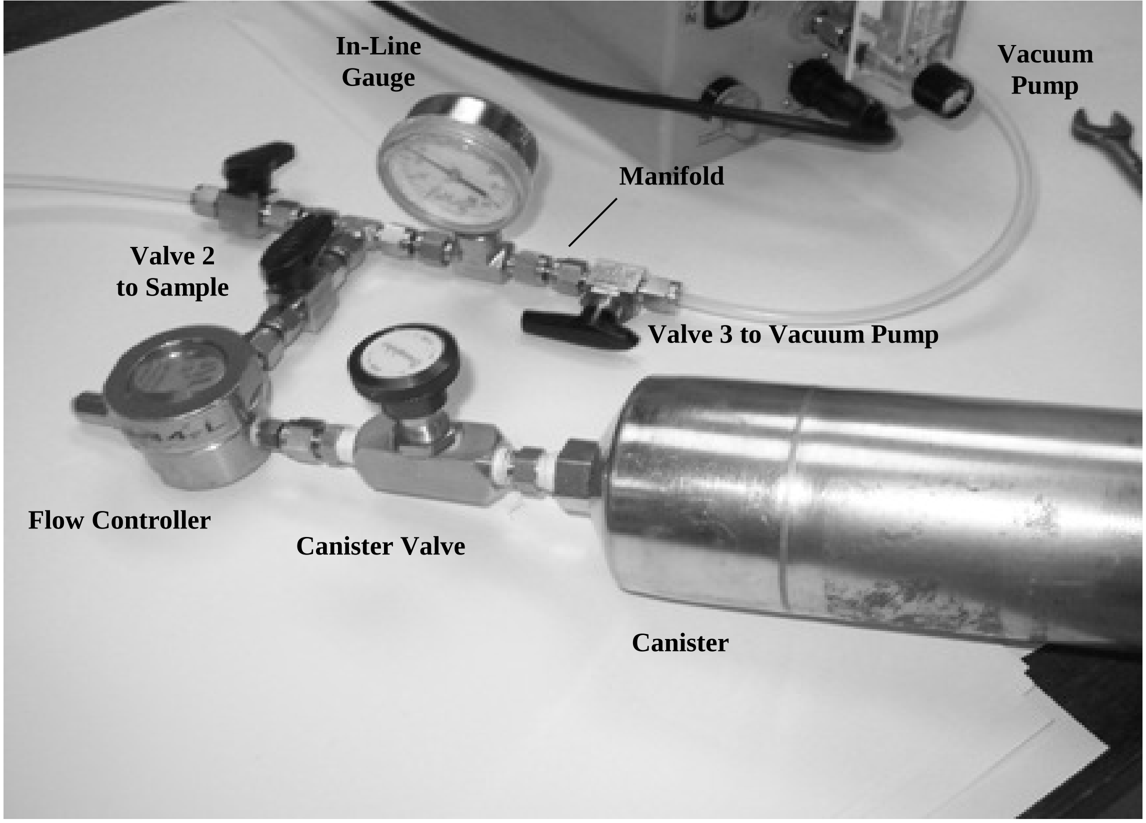
4.2 Adjust the purge system evacuation pump sampling rate to achieve the desired flow rate of 200 milliliters per minute (ml/min) or less. Flow rate measurements should be performed at the outlet of the vacuum pump prior to purging, either by using a suitable flow meter or by determining the amount of time required to fill a 1-liter gas sampling bag.

4.3 If the sample will be collected over a period of time greater than 30 minutes a flow diversion valve (Swagelok® part# SS-4P4T) should be placed in-line between the probe and the manifold. Once purging has been completed, the flow diversion valve can be turned to the off position, allowing disconnection of the manifold and vacuum pump for use at another location, without the loss of purge integrity at the purged location.

4.4 Sampling canisters are evacuated prior to shipment by the laboratory. The vacuum will need to be verified in the field with the Digital Pressure Gauge **AND** the laboratory supplied vacuum gauge and properly recorded prior to use.

4.5 Attach the air pump to the sampling manifold and the Tedlar® bag to the air pump exhaust. See **Figure 2**. ***Do not attach the canister at this time.***

FIGURE 1
Sampling Manifold



5.0 Soil Vapor Sampling System Leak Checking and Purging Procedure

5.1 Physical Leak Check - Perform a leak check of the sample manifold system (**Figure 1**):

5.1.1 Make sure the vapor probe valve (valve #1) is closed and the sample valve (valve #2) is open.

5.1.2 Open the purge valve (valve #3) and start the vacuum pump. Verify that the flow is set to 200 ml/min.

5.1.3 Close the sample valve (valve #2) and achieve a vacuum gauge reading of 10 inches of mercury (inches Hg) or to a vacuum that will be encountered during sampling, whichever is greater.

5.1.4 A leak-free system will be evident by closing off the purge valve (valve #3), turning off the vacuum pump, and observing no loss of vacuum within the sampling manifold system for a period of 30 seconds. Repair any leaks prior to sample collection by tightening the fittings on the manifold. Re-test to make the sure the manifold passes the physical leak check before proceeding.

5.1.5 Record the leak check date and time on the Soil Vapor Sampling Log.

5.2 System Purge and Helium Leak Check - A purge of the soil vapor probe and sampling manifold system is required before taking each sample. The helium leak-check procedure is also performed during this step. This helium leak check will verify the integrity of the sampling adapter (or PRT adapter if using the Geoprobe® system) seal as well as the probe and ground interface. This is accomplished by doing the following steps:

5.2.1 Place the helium leak-check enclosure around the soil vapor probe to achieve a buildup of helium in the leak-check enclosure. The enclosure should not be tightly sealed and there should be an exhaust for the helium so pressure doesn't build up in the enclosure. Where the ground surface is soft, the helium leak-check enclosure is pressed down slightly into the ground surface. In situations where the ground surface is hard (for example, asphalt), apply a slight downward pressure to achieve a buildup of helium in the leak-check enclosure.

5.2.2 Start the flow of helium under the leak-check enclosure at 200 ml/min. Try to position the tube so the helium is directed at the interface between the probe and the ground. Let the helium fill the enclosure for a couple of minutes.

5.2.3 Turn the helium leak detector on while in outdoor air and ensure that the detector is not reading any helium before proceeding. Verify that the helium concentration inside the leak-check enclosure is >10 percent by placing the probe of the helium detector into the hole where the sample tubing comes out or under the enclosure wall. It is not necessary to verify that the helium concentration is 100%, as this may damage the detector.

5.2.4 Purging is carried out by pulling soil vapor through the system at a rate of 200 ml/min for a time period sufficient to achieve a purge volume that equals 3 to 5 dead volumes (internal volume) of the in-ground annular space, sample line, and sampling manifold system. When calculating the dead volume, be sure to take into account the inside diameter and length of the Teflon sample tubing, as well as the probe outside diameter and retraction distance for the annular space of temporary probes. For permanent probes, calculate the volume of the annular space using a nominal 30 percent porosity for the sand or glass bead pack. If, during the purge (or sampling), the vacuum exceeds 7 inches Hg, then reduce the pump flow rate. The system vacuum must stay below this level at all times to minimize the risk of inducing leaks or altering conditions in the subsurface.

5.2.5 Open the sample valve (valve #2) and the purge valve (valve #3) and start the purge pump. Verify that the flow rate is still 200 ml/min.

5.2.6 To start the soil vapor probe purge, simultaneously open the vapor probe valve (valve #1) and close the sample valve (valve #2), and start timing.

5.2.7 If there is shallow groundwater in the area, carefully watch the tubing as the pump is turned on. If water is observed in the sample tubing, **shut the pump off immediately**. Soil vapor collection will not be feasible if the probe is in contact with water.

5.2.8 Connect the helium detector to the enclosure exhaust to confirm that helium is present in the enclosure during purging. It is optional to measure the helium concentration within the enclosure (see Step 5.2.12). Make sure that the helium detector is exposed to ambient air and "zeros out" before measuring the purged soil vapor in Step 5.2.12.

5.2.9 During the last 5 minutes of the purge (or the entire purge time if less than 5 minutes), attach a gas sampling bag to the purge pump exhaust and open the bag's valve. This bag/sample will be used for analysis of helium using the leak detector.

5.2.10 If the vacuum gauge reads >7 inches Hg during the purge, then close the purge valve (valve #3) and monitor the vacuum in the manifold and probe. If there is no noticeable change in vacuum after a minute, then there is an insufficient amount of soil vapor to collect a sample and the vacuum is too great to collect a soil vapor sample. Several factors can cause this situation. Consult with the project manager and take corrective action.

5.2.10.1 The soil formation is too "tight" (i.e., high clay or moisture content). Try using a lower flow rate. (temporary or permanent probe)

5.2.10.2 The soil formation is too tight. Try a different depth or location. (temporary probe)

5.2.10.3 With a temporary probe system, the expendable tip may not have released when the drive rod was retracted. Try retracting the probe a little further, or use a long, thin rod to poke the tip loose.

5.2.10.4 If water is visible in the flexible soil vapor tubing, **stop the purging immediately**. It is not possible to take a soil vapor sample at that depth or location.

5.2.11 At the end of the calculated purge time and after the system is verified to be leak free, close the purge valve (valve #3), close the valve to the gas sampling bag, and turn off the pump. Do not open the purge valve again. Doing so will result in loss of the purge integrity and will require re-purging.

5.2.12 Attach the gas sampling bag to the helium detector using a piece of flexible silicone or rubber tubing and open the valve. **The helium concentration in the purged soil vapor must be less than 1 percent of what it was in the helium enclosure during purging to pass the leak test** (10,000 parts per million by volume [ppmv] if the helium concentration was 100 percent) **(verify that this limit is consistent with appropriate project-specific regulatory guidance)**. Calculate what 1 percent of the helium concentration was in the enclosure from the measured concentration in Step 7.2.6. If the probe fails the leak check then corrective action is required. This includes first checking the fittings and connections and trying another purge and leak check. It may also be necessary to remove the soil vapor probe and re-install it in a nearby location.

Note: **Helium leak detectors may be sensitive to high concentrations of methane or other atmospheric gasses.** If these are expected to be present in the subslab soil vapor, then caution should be used with this technique, as false-positive readings may be encountered during leak testing. Use a multi-gas meter to determine whether methane is present in subslab soil vapor. The false-positive "helium" concentration should be measured in the soil vapor prior to applying helium in the enclosure so it can be compared with the helium concentration in the purged soil vapor during the leak test.

5.2.13 At the end of the purge and after the system is verified to be leak-free, close the purge valve (valve #3). Do not open it again. Doing so will result in loss of the purge integrity and will require re-purging. Turn off the helium leak detector.

5.2.14 The purged soil vapor in the Tedlar bag can be screened with the field meters.

5.2.15 Record the purge and leak check information on the Soil Vapor Sampling Log.

6.0 Sample Collection

6.1 Clean sampling protocols must be followed when handling and collecting samples. This requires care in the shipping, storage, and use of sampling equipment. Cleanliness of personnel who come in contact with the sampling equipment is also important: for example, no smoking, eating, or drinking; no perfumes or deodorants; and no dry-cleaned clothing. Canisters should not be transported in vehicles with gas-powered equipment or fuel cans. Sharpie-type markers should not be used for labeling or note-taking during sampling.

6.2 The air sampling canisters are certified clean and evacuated by the laboratory to approximately 29 to 30 inches Hg vacuum. Initial canister vacuums that are less than certified by the laboratory are a potential indication of leakage that could affect the accuracy of analytical results. Care should be used at all times to prevent inadvertent loss of canister vacuum. Never open the canister's valve unless the intent is to collect a sample or check the canister vacuum with an attached gauge.

6.3 Verify that the canister has sufficient initial vacuum for sampling. Measure the initial canister vacuum using an external vacuum gauge as described below:

6.3.1 Remove the protective cap from the valve on the canister. Make sure the canister knob is closed!

6.3.2 Measure the initial canister pressure using a digital vacuum gauge. Open the canister knob and record the reading. Close the canister knob and remove the digital vacuum gauge.

6.3.3 If using assigned analog vacuum gauges (one for each canister), attach the vacuum gauge to the canister, and then attach the flow controller.

6.3.4 Do not sample using a canister without sufficient initial vacuum. Be advised that sampling data may be flagged or rejected from canisters with low initial vacuum (less than 28 inches Hg). Low initial vacuum could create a low bias in analytical results due to air leakage. While there is also a smaller risk that air leakage could introduce contaminants into the canister, the primary concern is the low bias to analytical results; this bias is within the range of analytical variability allowed with the EPA Method TO-15 (±30 percent) for initial vacuums >24 inches Hg. The table presented in Paragraph 6.3.5 identifies the field team's response based on the initial vacuum reading for a canister. In addition, this table also identifies the potential bias to results at different initial canister vacuums.

6.3.5 Use the following table to determine when to use canisters based on initial vacuum readings.

Initial Vacuum Reading	Potential Error in Analytical Results Due to Leakage	Field Team Response
>30 to 28 inches Hg	Up to -10% error	Use canister for sampling – no limitations on use.
>26 to 28 inches Hg	Up to -21% error	Use canister for sampling if necessary; replace canister with a spare if spares are available.
>24 to 26 inches Hg	Up to -30% error	Sampling with canister is not advisable. Contact project manager and obtain direction before sampling with this canister. Be advised that qualifiers may be applied to analytical results sampled with canisters with vacuums less than 26 inches Hg.
<24 inches Hg	>-30% error	Do not use this canister for sampling. Analytical results will be rejected.

6.4 Attach the canister to the flow controller and then connect the flow controller to the sample valve (valve #2) on the sampling manifold. Open the sample valve (valve #2).

6.5 Before collecting the sample, confirm that the sampling system valves are set as follows: (1) the purge valve (valve #3) is confirmed to be closed; (2) the vapor probe valve (valve #1) is open; and (3) the sample valve (valve #2) is open.

6.6 Slowly open (counter-clockwise) the canister's knob approximately one full turn.

6.7 Each sampling canister that is left unattended should be clearly marked with a sign that includes contact information for a point of contact.

6.8 After sampling for the appropriate amount of time (determined from project instructions), close the sample valve (valve #2) and the canister's knob. If the canister has a built-in or assigned vacuum gauge, allow the canister to fill until the vacuum reaches 2 to 10 inches Hg for 6-liter canisters and 2 to 5 inches Hg for 1-liter canisters and record the final pressure. Remove the canister from the sampling manifold.

6.9 Measure the final canister pressure using the same digital vacuum gauge used to measure initial canister pressure. Open the canister knob and record the reading. Close the canister knob and remove the digital vacuum gauge.

6.10 If using a single laboratory provided external vacuum gauge, re-attach it, open the canister knob, and record the final vacuum. Close the valve, remove the gauge, and replace and tighten the cap on the canister. Ideal final vacuum in the canister is between 2 and 10 inches Hg. More than 10 inches Hg of vacuum can greatly increase reporting limits; however, a small amount of vacuum should be left in the canister so the laboratory can confirm that the canister was not opened during shipment.

6.11 Consult with the project manager and the project specific VI senior technical consultant (STC) before submitting the sample to the laboratory if a final vacuum greater than 10 inches Hg, or less than 2 inches Hg are encountered. Use the following table for guidance to determine how to address final vacuum measurements:

Final Vacuum Reading	Field Team Response
< 2 inches Hg	Contact Project Manager and project VI STC before submitting sample. Notify analytical laboratory to report their laboratory-measured pressure and to get direction from the Project Manager before analyzing sample.
> 2 inches Hg and <10 inches Hg	Submit sample for analysis - no limitations on data use
>10 inches Hg	Contact Project Manager and project VI STC before submitting sample. Verify final vacuum with the analytical laboratory before analysis.

6.12 Canisters with no vacuum left (i.e., 0 inches Hg) should not be analyzed. Contact the Project Manager and project VI STC before submitting a sample with a final vacuum of 0 inches Hg to determine the appropriate course of action. One option is to verify the final vacuum with the analytical laboratory. If there is vacuum remaining in the canister according to the laboratory vacuum gauge, the Project Manager and/or project VI STC may direct the analytical laboratory to analyze the sample.

6.13 The analytical laboratory should be directed to not analyze a sample showing a final vacuum of 0 inches Hg (as measured by the laboratory), and to notify the Project Manager and obtain further guidance regarding that sample.

6.14 Record the sampling date, times, canister identification (ID), flow controller ID, vacuum gauge ID(s), and any other observations pertinent to the sampling event on the Soil Vapor Sampling Log. Also record the weather conditions (temperature, barometric pressure, precipitation, etc.) during sampling.

6.15 Fill out all appropriate documentation (sampling forms, sample labels, chains of custody, sample tags, etc.).

6.16 Disassemble the sampling system.

6.17 For permanent probes, replace the probe cap and make sure it is securely in place. For temporary probes, remove the probe and abandon the bore hole.

7.0 Altitude Correction

7.1 Air pressure decreases with elevation. Therefore, a canister evacuated at a laboratory located at sea level will show a lower vacuum measurement at a higher altitude. Generally, a 1,000-foot rise in elevation corresponds to a 1 inch Hg drop in pressure OR a 1 inch Hg decrease in measured vacuum. For example, a canister evacuated to 30 inches at sea level and used at 3,000 feet would show an initial vacuum of 27 inches Hg.

7.2 If you plan to sample at altitude, be sure to inform the laboratory ahead of time so they adjust the flow controllers accordingly.

7.3 If sampling is being conducted at higher elevations, verify the elevation difference between the analytical laboratory and field location and determine the associated decrease in measured vacuum.

7.3.1 Calculate the pressure difference between the laboratory and field location as follows: Difference from Sea Level (field) – Difference from Sea Level (laboratory). Use the Altitude Correction Table attached to this SOP.

7.3.2 Subtract the pressure difference determined in Section 7.3.1 from allowable initial vacuum levels (Section 6.3.5) and final vacuum levels (Section 6.11) to determine appropriate initial and final vacuum levels.

8.0 Sample Handling and Shipping Procedure

8.1 Fill out all appropriate documentation (chain of custody, sample tags) and return canisters and equipment to the laboratory

8.2 The canisters should be shipped back to the laboratory in the same shipping container in which they were received. The samples should not be cooled during shipment. DO NOT put ice in the shipping container.

8.3 When packing the canisters for shipment, verify that the valve (just past finger-tight) and valve caps are snug (1/4 turn past finger tight), and use sufficient clean packing to prevent the valves from rubbing against any hard surfaces. Never pack the canisters with other objects or materials that could cause them to be punctured or damaged. Ensure that flow controllers and gauges are separately and adequately wrapped to prevent damage.

8.4 **Do not place sticky labels or tape on any surface of the canister.**

8.5 Place a custody seal over the openings to the shipping container.

8.6 Make sure to insure the package for the value of the sample containers and flow controllers if corporate card policy does not cover this.

8.7 Ship canisters for overnight delivery. NOTE: If sampling on a Friday, ensure the laboratory accepts samples on Saturdays (you do not want the canisters sitting on some loading dock (or worse) for 3 days).

9.0 Quality Control

9.1 Laboratories supplying canisters must follow the performance criteria and quality assurance prescribed in U.S. Environmental Protection Agency (EPA) Method TO-14/15 for canister cleaning, certification of cleanliness, and leak checking. SOPs are required.

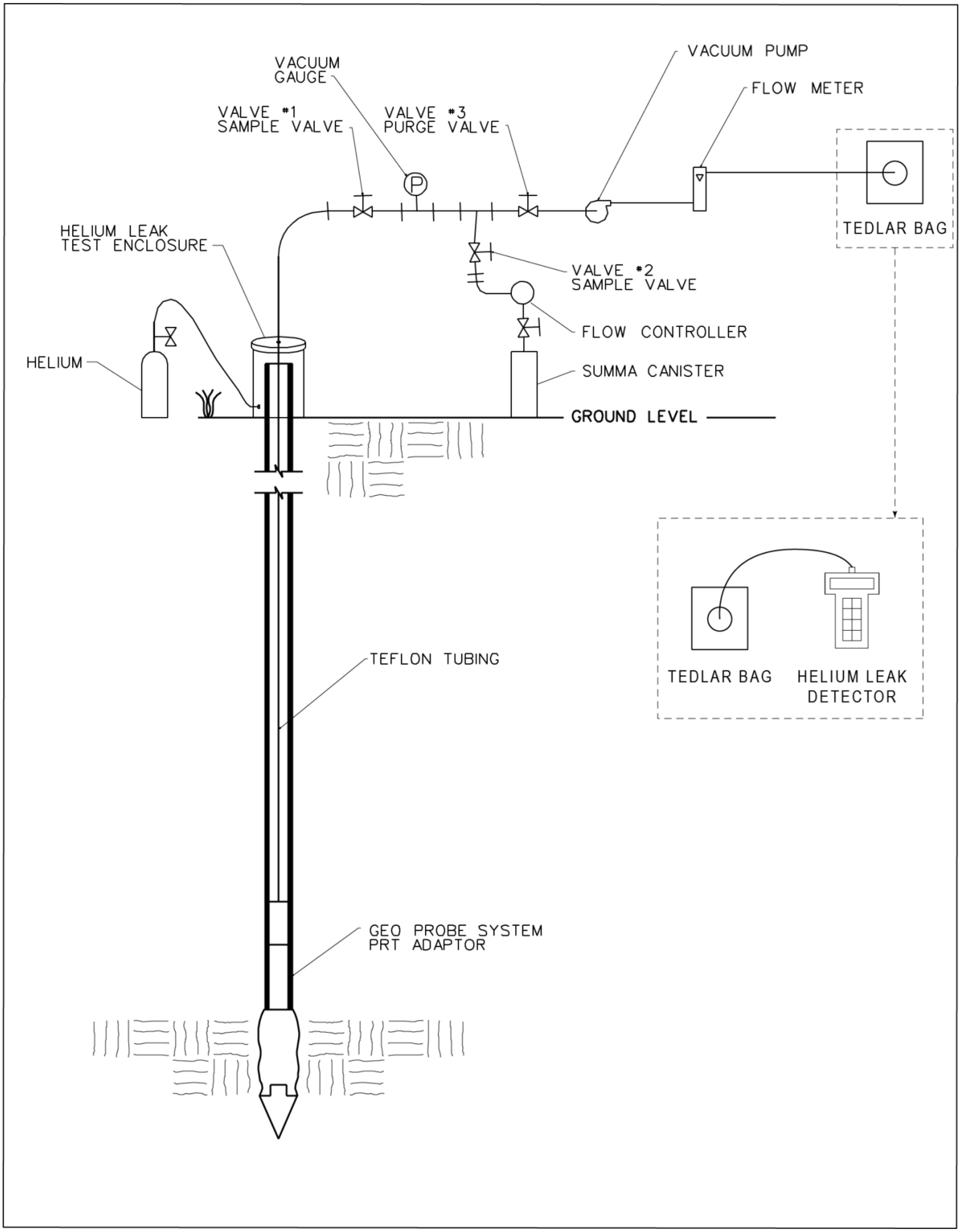
9.2 Laboratories supplying flow controllers must follow the performance criteria and quality assurance prescribed in EPA Method TO-14/15 for flow controller cleaning and adjustment. SOPs are required.

10.0 Attachments

10.1 *Exterior Soil Vapor Probe Installation and Sampling Log - Canister Method*

10.2 *Altitude correction table*

Figure 2 Soil Vapor Sampling System



Altitude Correction Table

Elevation (ft)	Pressure (in Hg)	Difference from Sea-Level (in Hg)	Elevation (ft)	Pressure (in Hg)	Difference from Sea-Level (in Hg)
0	29.92	0	1500	28.37	1.553
50	29.87	0.053	1550	28.32	1.603
100	29.81	0.106	1600	28.27	1.653
150	29.76	0.159	1650	28.22	1.703
200	29.71	0.212	1700	28.17	1.753
250	29.66	0.265	1750	28.12	1.803
300	29.60	0.317	1800	28.07	1.853
350	29.55	0.370	1850	28.02	1.903
400	29.50	0.422	1900	27.97	1.953
450	29.45	0.474	1950	27.92	2.002
500	29.39	0.527	2000	27.87	2.052
550	29.34	0.579	2050	27.82	2.101
600	29.29	0.631	2100	27.77	2.151
650	29.24	0.683	2150	27.72	2.200
700	29.19	0.735	2200	27.67	2.249
750	29.13	0.787	2250	27.62	2.298
800	29.08	0.838	2300	27.57	2.347
850	29.03	0.890	2350	27.52	2.396
900	28.98	0.941	2400	27.47	2.445
950	28.93	0.993	2450	27.43	2.494
1000	28.88	1.044	2500	27.38	2.543
1050	28.82	1.095	2550	27.33	2.591
1100	28.77	1.147	2600	27.28	2.640
1150	28.72	1.198	2650	27.23	2.688
1200	28.67	1.249	2700	27.18	2.736
1250	28.62	1.299	2750	27.14	2.785
1300	28.57	1.350	2800	27.09	2.833
1350	28.52	1.401	2850	27.04	2.881
1400	28.47	1.452	2900	26.99	2.929
1450	28.42	1.502	2950	26.94	2.977

Note: use the following equation to calculate atmospheric for altitudes not shown on this table:

$P = P_o \exp(-35.523 \times 10^{-6} y)$, where P is the pressure at the desired elevation, P_o is the atmospheric pressure at sea level, and y is the desired elevation. Source: NASA, 1996. *Elevation Correction Factor for Absolute Pressure Measurements*. NASA Technical Memorandum 107240.

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Sheet ___ of ___

Vapor Intrusion Best Practices
Exterior Soil Vapor Probe Installation and Sampling Log - Canister Method

Project Info

Project Name: .... **Project # :** ....

Sampler Name: .... **Date:** ....

Site

Identification: ....

Address: ....

Site Information:

Describe ground cover ....

Depth to groundwater (feet below ground surface) ....

Describe vadose zone soil type(s) ....

Was a soil boring log completed? .... Was a probe diagram completed? ....

Soil Vapor Probe Installation, Purging, Leak Checking, & Sampling Log

Sample location (describe and show in diagram)		
Probe and Sample Identification (field ID)		
Probe Installation	Date and time	
	Depth of hole drilled (feet below ground surface)	
	Bottom of probe screen (feet below ground surface)	
	Length of probe screen (inches)	
	Width of probe screen (inches)	
	Dead volume - including screen, sand pack, and tubing (mL)	
Manifold Leak Check	Leak check (sampling manifold) - Pass/No Pass	
Probe Purge	Purge rate (mL/min)	
	Purge start time	
	Helium concentration in shroud (%)	
	Purge vacuum (" Hg)	
	Purge completion time	
Helium Leak Check*	Helium concentration in purged soil vapor (%)	
	Pass or Fail?	

Field Analysis (optional)	O_2 (%)	
	CO_2 (%)	
	CO (ppm)	
	H_2S (ppm)	
	CH_4 or LEL (%)	
	Total VOCs (ppmv)	
Canister Sampling	Canister ID	
	Flow controller ID	
	Pressure gauge ID (optional)	
	Sampling rate or period (mL/min or hours)	
	Sample start date and time	
	Initial canister pressure (" Hg)	
	Sampling vacuum (" Hg)	
	Sample completion date and time	
	Final canister pressure (" Hg)	

* The soil vapor probe passes the helium leak check if the measured helium concentration in the purged soil vapor is less than 1% of the measured helium concentration in the shroud. Do NOT collect a soil vapor sample if the probe fails the helium leak test. (multiply % by 10,000 to convert to ppm)

Weather conditions during sampling: ....

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Observations and Comments: ....

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