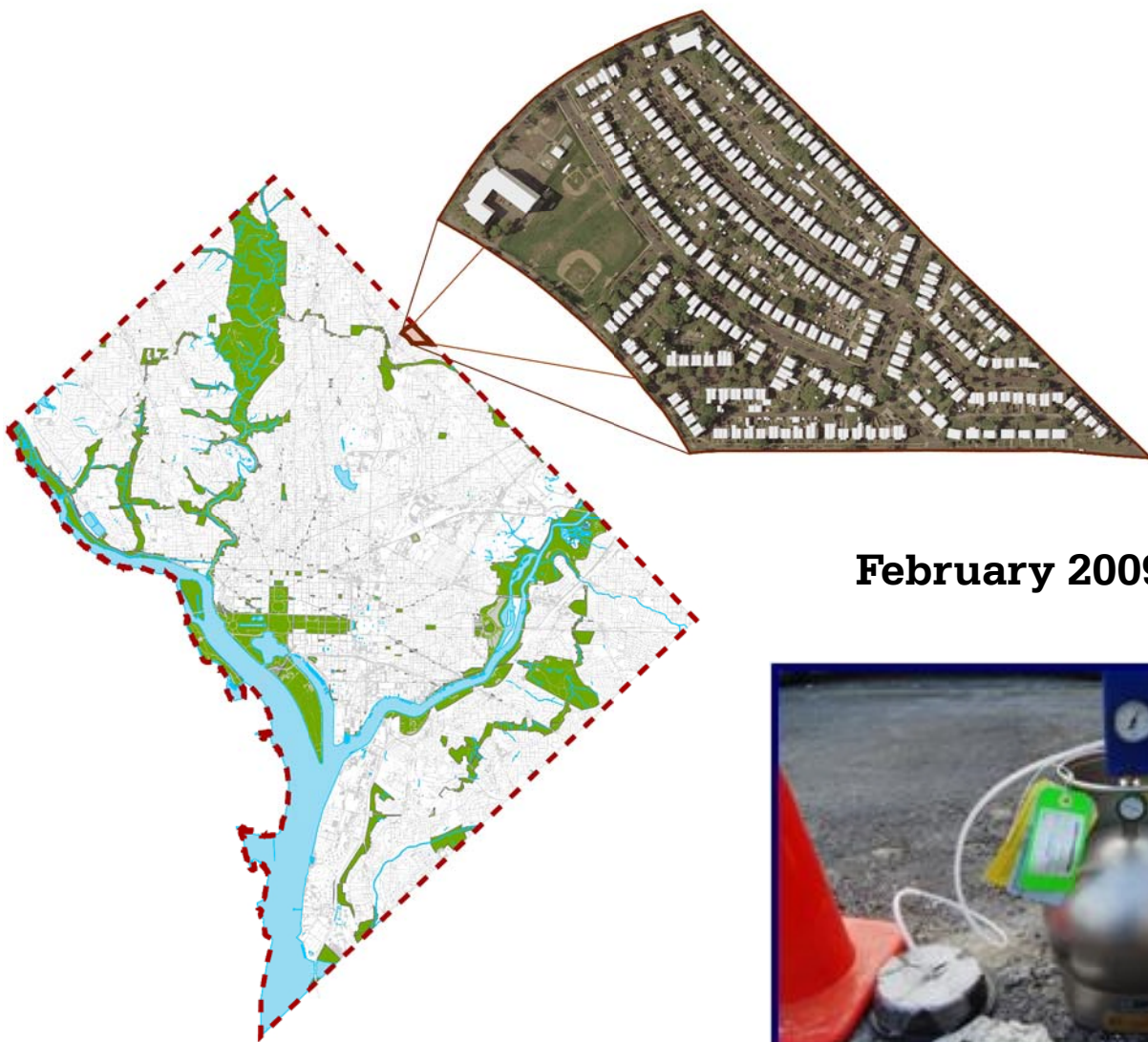


Riggs Park

Indoor Air, Sub-Slab Vapor, Soil and Groundwater Sampling and Analysis Report

Prepared for the DC Department of Environment
and DC Department of Health



February 2009

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S.S. Papadopoulos
& Associates, Inc.

CGS Chesapeake
GeoSciences, Inc.

**RIGGS PARK
INDOOR AIR, SUB-SLAB VAPOR, SOIL
AND GROUNDWATER SAMPLING AND
ANALYSIS REPORT**

Prepared for: The District of Columbia Department of
Health and the District of Columbia
Department of the Environment

Prepared by:



S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

February 2009

Executive Summary

This report presents results of a sampling program for indoor air, ambient outdoor air, sub-slab vapor, soil vapor, soil, and groundwater in the Riggs Park neighborhood of northeast Washington DC. This study was undertaken in 2007 and 2008 on behalf of the District of Columbia Department of Health and the District of Columbia Department of the Environment. The work was completed by S.S. Papadopoulos & Associates and its subcontractor Chesapeake GeoSciences. The investigation was prompted by a 1989 release of gasoline from a Chevron station on the corner of Eastern Ave. and Riggs Road in Chillum, Maryland. The plume of dissolved contamination from that release extends under the Riggs Park neighborhood for a distance of approximately 1400 feet. In addition to constituents associated with gasoline, other contaminants including tetrachloroethylene (PCE) have been detected persistently in groundwater under the neighborhood.

During the period from January through September 2008, the following samples were obtained: 128 indoor air samples from 115 homes; 39 samples of ambient outdoor air concurrent with the indoor air samples; 378 samples from sub-slab vapor monitoring ports in 106 homes, collected over three consecutive quarters; and 151 samples of subsurface vapors from outdoor vapor monitoring ports at 66 homes, collected during two consecutive quarters. In addition, 69 soil samples and 14 groundwater samples were collected from direct-push borings installed using Geoprobe equipment. All vapor samples were collected in 6-liter Summa canisters, and analyzed for volatile organic compounds via USEPA method TO-15 (modified). All soil and groundwater samples were analyzed for volatile organic compounds via USEPA method 8260.

Up to 68 individual parameters were analyzed in each vapor sample. Duplicate samples were sent to a secondary laboratory for confirmatory analysis. In the population of indoor air samples, forty-seven (47) different analytes were detected. Thirty-eight (38) analytes were detected in ambient air. For the subsurface samples, sixty-four (64) analytes were detected in the sub-slab samples, and forty-eight (48) were detected in the outdoor vapor monitoring port samples. Detection of any analytical parameter depends upon factors including the presence and concentrations of other compounds in each sample. In general, higher detection limits were associated with the outdoor soil vapor samples.

In the fourteen (14) groundwater samples, the compound most frequently detected was MTBE. Concentrations of MTBE observed in groundwater were consistent with those from the ongoing groundwater monitoring program. The majority of soil samples were collected above the water table and yielded non-detects in the analysis. One soil sample collected at the water table (28 ft depth) from the alley between Oglethorpe St. and Eastern Ave yielded detections of xylenes (6,100 ug/kg), naphthalene (3,000 ug/kg), and MTBE (3 ug/kg). These results are consistent with the presence of residual contamination from liquid-phase hydrocarbons (gasoline). This indicates that in addition to dissolved contamination, liquid phase gasoline had migrated from Maryland to the DC side of Eastern Ave. This location is within "Area B" targeted for remediation under USEPA's Final Remedy.

For each volatile organic compound in the TO-15 analyte list, and for each group of samples (ambient air, indoor air, sub-slab, and outdoor vapor monitoring port) the data population was examined. Statistical measures of the population were calculated for a select group of petroleum-related compounds (1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, toluene ethylbenzene, o-xylene, m,p-xylenes, MTBE, naphthalene, hexane, cyclohexane, and n-heptane), and chlorinated compounds (tetrachloroethylene (PCE), trichloroethylene, 1,1,1-trichloroethane, chloroform, chloromethane, and 1,4-dichlorobenzene). Maps of the indoor and subsurface distribution of these contaminants were also prepared. Many compounds detected in the TO-15 analyses are likely unrelated to any potential subsurface contamination (e.g. freons, various solvents and alcohol), and thus are not emphasized in the analysis.

Ambient air concentrations of benzene, toluene, and PCE are within ranges observed both at Washington DC's McMillan Reservoir, and within ranges reported in the literature for other urban environments. For the petroleum-related and chlorinated compounds cited above, it is noted that concentrations of most contaminants are higher in indoor air than in outdoor (ambient air), consistent with other studies showing that in-home sources of contaminants may dominate indoor air concentrations.

For each of the petroleum-related and chlorinated analytes cited above, the detected concentrations range over several orders of magnitude in each medium. The maximum benzene concentration detected in indoor air was $8.36 \text{ ug}/\text{m}^3$ (2.6 ppbV). The maximum benzene concentration detected in subsurface vapors was $24.9 \text{ ug}/\text{m}^3$ (7.8 ppbV). The maximum concentration of PCE detected in indoor air was $42.3 \text{ ug}/\text{m}^3$ (6.2 ppbV). The maximum concentration of PCE detected in subsurface vapors was $929 \text{ ug}/\text{m}^3$ (137.0 ppbV).

The contaminants observed in subsurface vapor samples are consistent with those detected in groundwater at the site. Where the petroleum-related and chlorinated compounds cited above are detected both indoors and in the sub-slab, the ratios of sub-slab vapor to indoor air concentrations range from 182 to 0.004. For each of the petroleum-related compounds, the maximum sub-slab to indoor air concentration ratio exceeds 1 (is higher in the sub-slab location than in indoor air) in at least 20% of the homes. The ratios exceed 10 for benzene, toluene, n-heptane, m,p-xylenes, and cyclohexane. Similar results are observed for the chlorinated compounds. For homes with tetrachloroethylene (PCE) detections in both the sub-slab and indoor air samples, the maximum sub-slab to indoor air concentration ratio exceeds 1 in 72% of the homes.

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List of Acronyms and Abbreviations

<i>ug/kg</i>	Microgram per kilogram
<i>ug / m³</i>	Micrograms per cubic meter
<i>ug/l</i>	Micrograms per liter
1,4-DCB	1,4-Dichlorobenzene
111-TCA	1,1,1-Trichloroethane
124-TMB	1,2,4-Trimethylbenzene
135-TMB	1,3,5-Trimethylbenzene
AOA	Identifier for an ambient outdoor air sample collected during this study
ATSDR	Agency for Toxic Substances and Disease Registry
BSEA	Building Sciences and Engineering Associates, Ltd.
BTEX	Benzene, toluene, ethylbenzene and toluene
CGS	Chesapeake GeoSciences, Inc.
COC	Contaminant(s) of Concern
COTR	Contracting Officer's Technical Representative
DC	District of Columbia
DDOE	District Department of Environment
DOH	Department of Health of the District of Columbia
DPE	Dual-phase extraction
GMP	Outdoor Vapor Monitoring Port (Geoprobe-Installed Monitoring Port), or the identifier for an outdoor vapor monitoring port sample collected during this study
INA	Identifier for an Indoor Air Sample collected during this study
MCL	Maximum Contaminant Level (a drinking water standard)
MDE	Maryland Department of the Environment
MEK	Methyl ethyl ketone (2-butanone)
MIBK	Methyl isobutyl ketone (4-Methyl-2-pentanone)
MTBE	Methyl-Tert-Butyl Ether
ND	Non-detect or not detected
PCE	Perchloroethylene, synonymous with Tetrachloroethylene and Tetrachloroethene
Perc	Perchloroethylene, synonymous with Tetrachloroethylene and Tetrachloroethene
PID	Photo-ionization detector
ppb	Parts per billion
ppbV	Parts per billion by volume
ppm	Parts per million
ppmV	Parts per million, by volume
PVMP	Identifier for a previously-installed sub-slab vapor monitoring port sampled during this study
QA/QC	Quality Control / Quality Assurance
QAPP	Quality Assurance Project Plan
RFP	Request for Proposal
SOW	Scope of Work or Statement of Work
SSP&A	S.S. Papadopoulos & Associates, Inc.

TAGA	Trace Atmospheric Gas Analyzer
TCE	Trichloroethylene, synonymous with Trichloroethene
TPH	Total Petroleum Hydrocarbons
TVH	Total Volatile Hydrocarbons in the C5 to C12 range
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VMP	Vapor Monitoring Port, or the identifier for a sub-slab vapor monitoring port sample collected during this study

REPORT

Section 1

Introduction

This report was completed by S.S. Papadopoulos & Associates, Inc. (SSP&A) on behalf of the District of Columbia Department of Health (DOH) and the District Department of Environment (DDOE). Chesapeake GeoSciences, Inc. (CGS), as subcontractor to SSP&A, contributed to the data collection and analysis. Additional reports to be completed under the planned scope of work include individualized reports distributed to each participating homeowner. Other reports previously completed and submitted under this contract are included in the Appendices.

The data presented herein were collected from January through September 2008 by staff of SSP&A and CGS. All samples collected for this study were obtained in and around homes in the Riggs Park neighborhood of northeast Washington DC. Additional data from previous investigations and other monitoring sites are cited where appropriate.

This work was completed under District of Columbia contract GS-10F-0426M, DC Task Order Number DCHC-2007-T-0022 and Purchase Order PO283733-KGO/DDOE/R0607/675-Riggs Park.

Purposes of this Study

A gasoline release from a Chevron station located at 5801 Riggs Road in Chillum, Maryland (Figure 1) was reported to the Maryland Department of the Environment (MDE) in October 1989. Under oversight of MDE, remedial activities including pump-and-treat and groundwater monitoring continued through 2001. At that time, it was reported that the plume of groundwater contamination had migrated across Eastern Avenue into the District of Columbia. In October 2001, U.S. Environmental Protection Agency (USEPA) Region III assumed responsibility for the site, providing oversight for Chevron's ongoing remedial activities. USEPA entered into a cooperative agreement with the U.S. Army Corp of Engineers (USACE) for additional data collection, including soil vapor monitoring. During site investigations, the presence of tetrachloroethylene (PCE) in soil and groundwater was also detected. EPA began to investigate the PCE contamination in 2002.

Under Chevron's and USEPA's oversight, soil vapor and indoor air samples were collected from homes in the Riggs Park community from 2002 through 2005. A number of investigations by, and on behalf of the U.S. Environmental Protection Agency (USEPA), the U.S. Army Corps of Engineers (USACE), and the Chevron Corporation were completed during this period. In February, 2006, the Council of the District of Columbia ordered additional in-home testing under Resolution 16-522.

The initial phase of the District's testing was completed by Building Sciences & Engineering Associates (BSEA) in 2006. A total of 97 homes were tested in the spring and

summer of 2006 for concentrations of volatile organic chemicals in indoor air. BSEA found that the indoor air PCE concentrations exceeded the outdoor air concentrations in 55% of homes tested. For benzene, the percentage of homes with greater indoor than outdoor concentrations was 72%. BSEA identified a number of uncertainties regarding the significance of these results, including the source of these vapors.

As a consequence of these results and BSEA's recommendations, the District of Columbia government decided to commission this Phase II Study. The goals of this Phase II study are to evaluate and further monitor for subsurface soil vapor intrusion to indoor air. In addition to further in-home testing, Phase II included installation of vapor monitoring ports and testing of vapors from in, around, and under homes.

Scope of Work

The initial Scope of Work (SOW) outlined for this Phase II study by DOH included 13 tasks. The details of these tasks and approaches to their completion are outlined in the Request for Proposal (RFP), the Work Plan and the Quality Assurance Project Plan (SSP&A, 2007). Upon completion of the sampling in September 2008, the SOW pertaining to the remaining reporting tasks was slightly modified. Responsibility for issuance of the Final Corrective Action Report now lies with DDOE, with support from SSP&A. In addition, the revised SOW encompasses a broader range of potential contaminants than originally planned.

SSP&A and its subcontractor were tasked with obtaining indoor air samples from up to 150 homes in the Riggs Park neighborhood, with concurrent ambient (outdoor) air samples. The study area is bounded by Riggs Road, NE, Eastern Avenue, NE, Kennedy Street, NE and Madison Street, NE (Figure 1). In addition, installation of sub-slab vapor monitoring ports was planned for each of these homes. (Sub-slab sampling provides a measurement of vapor concentrations present immediately under the home.) Sampling of sub-slab vapors was to be repeated for three calendar quarters. The Statement of Work also required installation of outdoor vapor monitoring ports at multiple depths. A total of 225 sub-slab and outdoor vapor monitoring ports were to be installed and sampled. During development of the Work Plan in December, 2007, the DOH's technical representative requested that outdoor vapor monitoring ports be installed in the second quarter, and that they be sampled for two consecutive quarters.

The project SOW specified that vapor analysis be completed by EPA method TO-15. The analyte list for method TO-15 includes over 60 analytes, and may vary between laboratories. The TO-15 analyte lists for the laboratories used in this project are included in the Work Plan and QAPP.

The Scope of Work also included the following requirements:

- Collection of soil and/or groundwater samples from outdoor vapor monitoring ports (GMPs) installed using Geoprobe equipment, and analysis via USEPA Method 8260

- Collection of duplicate vapor samples for analysis at a secondary laboratory for quality control purposes

This report addresses conditions in the Riggs Park neighborhood in the 2008 time frame. No attempt is made to extrapolate indoor air, sub-slab, or ambient air data collected during this study to indoor air concentrations in previous years. Nonetheless, some data necessarily point to contaminant migration that may have occurred at an earlier time. These issues are discussed where appropriate.

Section 2

Site History

In 1954, a Gulf service station was built and began operating at 5801 Riggs Road, Chillum, MD. Subsequently, after Gulf Oil Corporation merged with Chevron U.S.A., Inc., the Service Station became a Chevron-branded location. In June 1993, the service station was sold to an independent owner, with the land, buildings, underground storage tanks (USTs), and appurtenances included in the sale (Gannett Fleming, 2003a). This service station continues to operate at the present time. Currently it is branded as a Sunoco gasoline station.

Initial reports of a petroleum release from this station were filed with the Maryland Department of the Environment (MDE) in October, 1989 (Gannett Fleming, 2003a). An initial assessment and installation of the first monitoring wells were completed the following month. Following detection of liquid-phase gasoline product in monitoring wells, a product recovery system was installed on-site in 1990 with MDE oversight (Gannett Fleming, 2003a). Through 2001, a number of modifications to the groundwater and gasoline recovery systems were implemented, including installation of dual phase extraction (DPE) wells and soil vapor extraction wells (Gannett Fleming, 2003a, 2006). The DPE system was further expanded in January 2005.

In 2001, Chevron discovered that the gasoline-contaminated groundwater had migrated into the District under the Riggs Park neighborhood. Because the contaminated groundwater impacted two separate political jurisdictions (the State of Maryland and the District of Columbia), at the request of the District of Columbia City Council, USEPA assumed the lead investigatory role for the Facility (USEPA, 2007). A unilateral Administrative Order was issued by USEPA in December 2002 requiring Chevron to conduct further investigations, to perform interim measures to mitigate threats to human health and the environment, and to evaluate alternatives for corrective actions needed to protect human health and the environment (USEPA, 2007).

In 2002, Chevron implemented further investigation activities including direct push (Geoprobe) investigation and sampling for soils and groundwater, soil vapor sampling, and collection of ambient air and basement sump samples. Additional monitoring wells were installed in the District of Columbia to monitor the groundwater (Figure 2). In addition, in 2005, Chevron completed sampling of indoor air in selected homes. Sampling of groundwater and vapors under Chevron's oversight has continued through the present day.

During the summer of 2002, ongoing site investigations found PCE in groundwater commingled with gasoline-related contaminants. EPA concluded that the PCE was not related to the gasoline release, and therefore that the PCE contamination was not within the scope of EPA's RCRA corrective action investigation (USEPA, 2007). An investigation of the PCE contamination was therefore begun independently, under USEPA's Superfund Division. In the summer of 2002, EPA began sampling soil, groundwater and indoor air to investigate the source

of the PCE. In addition, USEPA requested that the Agency for Toxic Substances and Disease Registry (ATSDR) provide public health recommendations about the presence of PCE in the community.

Coincident with USEPA and Chevron investigations the District of Columbia DOH began investigations of indoor air. In the summer of 2006, DOH oversaw indoor air and ambient (outdoor) air testing for 97 homes in the Riggs Park neighborhood (BSEA, 2006). All indoor air samples were collected in Summa canisters for 24 hours. Summa canisters were placed in the basement of each residence. Due to conditions in the access agreements signed by the residents, some of these results remain confidential, i.e. the addresses of the homes in which each sample was collected have not been released. Subsequently, DOH collected 12 additional indoor air samples and two additional outdoor air samples in March of 2007.

In 2007, the USEPA issued its proposed remedy for the Chevron gasoline release (USEPA, 2007) and requested public comments. The proposed remedy consists of the following elements:

- continued operation of the existing groundwater remediation system in Maryland (Area A on Figure 2)
- expansion of the existing system by installing additional recovery wells at an angle across Eastern Ave. (Area B on Figure 2), and
- installation of individual vapor mitigation systems in homes above the plume where measured vapor concentrations exceed EPA's remedial standards for indoor air for
 - Benzene ($8 \text{ ug} / \text{m}^3$),
 - MTBE ($17 \text{ ug} / \text{m}^3$),
 - Xylenes ($100 \text{ ug} / \text{m}^3$),
 - Ethylbenzene ($1,000 \text{ ug} / \text{m}^3$), and
 - Toluene ($5,000 \text{ ug} / \text{m}^3$).

EPA's remedial standards represent the contaminant concentration that pose an excess lifetime cancer risk to 3.5 people in 100,000 for benzene or 1 in 100,000 people for MTBE. For the non-carcinogens toluene, ethylbenzene and the xylenes, levels were established by adopting the concentrations corresponding to a Hazard Quotient of one.

As noted by USEPA in their response to comments (USEPA, 2008a), the design objective of the existing and final remediation system is source removal, not hydraulic containment of the dissolved phase plume. Therefore, the capture zones of extraction wells do not encompass the entire 1,400-foot long dissolved phase plume. EPA anticipates that once the liquid gasoline source is eliminated, the dissolved phase plume will degrade rapidly to attain drinking water standards within a few years.

Based on comments received during the public comment period and evaluation of the remedy selection criteria, USEPA (2008a) modified the proposed remedy to include

- the installation of an independent remediation system on the District of Columbia side of Eastern Avenue (Area B on Figure 2), and
- the installation of an oxygen injection curtain to accelerate degradation of the dissolved phase plume (Area C on Figure 2).

In 2008, the ATSDR also released its Indoor and Outdoor Air Data Health Evaluation for PCE contamination in the Riggs Park neighborhood (U.S. Department of Health and Human Services, 2008). The public comment period for that report closed in May of 2008. Comments included those of the District of Columbia (Government of the District of Columbia, 2008a).

Section 3

Summary of Previous Investigations

In this section, the previous and ongoing investigations of soil, groundwater, and vapors at the Chillum gasoline and PCE release site are outlined. This section is intended as a brief reference to existing data sources and timeline of site activities. More detailed descriptions of each study can be found in the references cited.

Soil and Groundwater Investigations

The initial groundwater monitoring wells (MW-1 through MW-5) were installed on the station property by Chevron in 1989. Through the 1990s, additional wells were added and sampled. In addition to dissolved contamination in groundwater, liquid-phase petroleum was detected in a number of wells (Figure 3).

Following discovery of groundwater contamination in the District of Columbia in 2001, the groundwater monitoring program was expanded.

- Between 2001 and 2005, Chevron's consultants installed and collected groundwater samples from more than 200 direct-push (Geoprobe) sampling locations; (Figure 2)
- Between 2001 and 2005, Chevron's consultants installed and sampled approximately 75 additional groundwater monitoring wells (Figure 2)
- Periodic collection and analysis of groundwater samples from these wells has continued to the present time.

USEPA began to investigate the presence of PCE in groundwater in 2002.

- USEPA evaluated concentrations of PCE detected in groundwater during Chevron's 2002 Direct-Push Investigation (USEPA, 2002b), and from Summer 2004 monitoring well sampling (USEPA, 2004b)
- In September 2003, USEPA collected a small number of tap water samples and groundwater samples from direct-push borings for analysis (USEPA, 2003a).

Soil Vapor Investigations

Soil vapor recovery has been implemented as a remedial measure in the source area, and continued management of this system has included sampling and analysis of vapor samples. The following discussion, however, focuses primarily on soil vapors in and around the residential neighborhood, not on vapor extraction wells in the source area. These are vapors potentially associated with the plume of contaminated groundwater under the residential areas. Table 1 presents a summary of these previously collected data.

Chevron's consultants began investigating soil vapors in the Riggs Park neighborhood in 2002. These investigations included:

- From January through December 2002, Chevron conducted several phases of soil vapor and ambient air sampling (Gannett Fleming, 2003b); soil vapor samples were collected at multiple depths from 68 residential properties on Eastern Ave, Eighth Street, and Oglethorpe St.
- From March through August, 2004, Chevron collected soil vapor samples from direct-push location throughout the Riggs Park neighborhood; in addition 14 ambient air samples were collected in the neighborhood from February through April 2004
- In October 2004, Chevron collected a total of 24 soil vapor samples from 22 residential properties on Nicholson St., Eastern Ave, and Eighth St. All soil vapor sample locations were laterally within 3 feet of the building (Gannett Fleming, 2004, 2006).

USEPA began collecting soil vapor data as part of the Chillum PCE investigation. Sampling events included:

- In July 2003 sampling USEPA collected 11 soil vapor samples (U.S. Environmental Protection Agency, 2003a); an additional two samples were collected in September 2003
- Twenty-four (24) additional soil vapor samples (with associated ambient air samples) were collected from inside and outside Riggs Park homes in April 2004 (US Environmental Protection Agency, 2004b) for analysis via TO-15 in the EPA's Trace Atmospheric Gas Analyzer (TAGA) laboratory.

The USEPA and Chevron results were interpreted collectively by USEPA in 2004 (USEPA, 2004e). Benzene and MTBE concentrations in shallow soil (0 to 5 ft below the basement slab) were compared to Removal Action Levels of $220 \text{ ug} / \text{m}^3$ (benzene) and $1600 \text{ ug} / \text{m}^3$ (MTBE). None of the benzene or MTBE results in shallow soils were found to exceed these action levels (Figure 4).

As part of the concurrent PCE investigation, USEPA also evaluated PCE soil vapor concentrations with regard to EPA's Removal Action Level of $630 \text{ ug} / \text{m}^3$ in air (USEPA, 2003b). This level was subsequently reduced to $310 \text{ ug} / \text{m}^3$ (USEPA, 2004g). Subsurface PCE results from four of the initial twelve homes tested were above action levels, requiring additional indoor air testing. Additional testing and analysis in 2004 (USEPA, 2004d) confirmed soil vapor samples results in exceedance of EPA soil vapor action levels, warranting additional indoor sampling.

Indoor Air Investigations

Indoor air sampling and investigation have been completed using both Summa canisters USEPA's on-site TAGA laboratory.

Chevron Studies

Indoor and ambient air samples were collected by Chevron's consultants:

- From April through July 2005, Chevron collected indoor air samples from 21 locations and ambient air samples from 18 locations on Nicholson and Oglethorpe St.
- During 2007, Chevron's consultant collected indoor air, ambient air, and sub-slab vapor samples from a single home that had been identified by USEPA as a target for re-sampling (Gannett Fleming, 2007b).

USEPA required Chevron to use the gasoline plume boundaries as a selection criterion for identifying homes to be sampled for subsurface vapor intrusion (USEPA, 2007). The results are included with those reproduced on Table 1. Chevron's consultants concluded that the indoor air analytical results indicated non-detect or very low levels of hydrocarbons. The levels were below the EPA Target Indoor Air Action Levels and were similar to those observed in ambient air (Gannett Fleming, 2006).

USEPA Studies

USEPA investigations of indoor air date back to 2003.

- In April 2003 EPA sampled indoor air in four homes using Summa canisters (U.S. Environmental Protection Agency, 2003a)
- A larger program of indoor air sampling using Summa canisters was completed in July 2003. Forty-six indoor air samples were collected on the basement and first floor levels (Appendix F in Gannett Fleming, 2005)
- Nearly 60 additional indoor air samples were collected in April 2004 from the basement and first floors (US Environmental Protection Agency, 2004a).
- Subsequent indoor air sampling by EPA has also been directed at individual homes suspected of having elevated levels of VOCs.

Between 2003 and 2005, EPA's Superfund Removal program collected soil vapor and indoor air samples from 35 homes in Riggs Park for its PCE investigation. The U.S. Army Corps of Engineer (USACE), on behalf of EPA, also generated split /quality control data (USEPA, 2007). The minimum and maximum results for selected compounds are included with those on Table 1. The maximum benzene concentration detected was $13 \text{ ug} / \text{m}^3$. The maximum PCE concentration was $23 \text{ ug} / \text{m}^3$.

DOH/BSEA Studies

Independent sampling of indoor and outdoor air was completed by the District of Columbia Department of Health.

- In 2006, the DC Department of Health oversaw indoor and ambient air testing for 97 homes (BSEA, 2006)

- Subsequently, follow-up testing was completed in 12 homes in March 2007.

The first phase of DOH indoor air sampling was completed during the Summer of 2006 (BSEA, 2006). Indoor air samples were collected in 97 homes, together with contemporaneous ambient air samples. The results are summarized in Table 1. The maximum benzene detected was $26.8 \text{ ug}/m^3$. The maximum PCE detected was $38.9 \text{ ug}/m^3$. In this data set, 74% of the benzene detections and 62% of the PCE detections were qualified with a "J" value. Results flagged with a "J" are between the method detection limit and the reporting limit, and are considered estimated values.

The USEPA statistically evaluated the indoor air data collected from the initial 97 homes (USEPA, 2007). They concluded that there are elevated benzene and MTBE vapor concentration in homes above the gasoline plume as compared to homes situated outside the plume boundaries, consistent with the likelihood of subsurface vapor intrusion associated with the gasoline plume. Based on USEPA's review of 151 indoor air samples they identified up to 5 homes above the gasoline plume where measured vapor concentration have exceeded EPA's remediation standards.

Section 4

Current Site Conditions

A number of site investigations have been completed at the Riggs Park site since groundwater contamination was identified in 1989. The following discussion relies primarily upon site investigation documents produced by Chevron and its consultants, as well as the USEPA and the USACE.

Geology

The Riggs Park neighborhood and the Riggs Road Chevron are located within the Coastal Plain Physiographic Province. The Site overlies the Cretaceous Patuxent Formation, a fluvial non-marine deposit that directly overlies Precambrian and early Paleozoic bedrock and dips gently to the east to southeast (Gannett Fleming, 2006).

At the site, the Patuxent Formation is estimated to be 50 to 100 feet thick. Bedrock was apparently encountered in one direct-push location, GP-14BR, located in the alley between Oglethorpe Street and Eastern Avenue, at a depth of approximately 78 feet. Bedrock may also have been encountered at 24.5 ft during the attempted installation of well MW-34C, located along Kennedy Street. The bedrock type is not known (Gannett Fleming, 2006).

Investigations at the Site indicated that silty sands comprised approximately 75 percent of the materials encountered, while well-sorted sands comprised less than ten percent. The well-sorted sand layers could not be correlated among boreholes. They were therefore believed to be local in nature and not widespread (Gannett Fleming, 2006). Of 23 soil samples submitted for laboratory particle size testing, 14 were classified as silty sand (SM), while five other samples were given dual classifications including SM and one other class (i.e., either poorly graded sand [SP], clayey sand [SC], or well graded sand [SW]). Two samples were classified SP, and two samples were classified as cohesive soils sandy silt (ML) or silty clay (CL-ML) (Gannett Fleming, 2006).

Gannett Fleming (2006) identified a deposit of gray to black clay that could be correlated between boreholes south of the Service Station. The northern edge of this deposit is located south of Eastern Avenue. Based on boring logs, the thickness of this deposit is believed to be six to ten feet; although most borings did not extend beneath the clay. This clay area is asymmetrical in shape, approximately 200 feet in breadth and 700 feet in length, with its longest axis running approximately parallel to the primary direction of groundwater flow.

Topography and Hydrology

The elevation of the Riggs Pak neighborhood generally decreases from north to south toward Nicholson Street, and from the west toward Nicholson Street (Figure 5). The former Chevron station is situated at an elevation of approximately 170 ft elevation above sea level.

The lowest point in this area, the intersection of Eastern Ave. and Kennedy Street is at an elevation of approximately 100 ft. The decrease in elevation is accomplished through a series of terraces corresponding to Nicholson and Oglethorpe streets and their parallel alleys, with steeper grades between.

Groundwater in the Riggs Park area is under unconfined, or water table conditions. The primary source of recharge is precipitation, although man-made sources such as leaking water mains or storm sewers may also contribute. As in many unconfined systems, the general trend of groundwater flow is from areas of higher elevation (recharge areas) toward areas of lower elevation (discharge areas).

Review of historic aerial photographs determined that prior to construction of the residential neighborhood in the 1950s, a tributary to Northwest Branch was located in the vicinity of present-day Nicholson and Kennedy Streets and flowed to the southeast (Gannett Fleming, 2006). At the current time, a storm sewer is situated along Nicholson Street. Field observations by Gannett Fleming during the dry summer of 2002 revealed that the storm sewer buried beneath Nicholson Street contained continuously flowing water. This was interpreted as evidence that the buried storm sewer has replaced the former stream as the groundwater discharge zone in this area (Gannett Fleming, 2006). The current conceptual model for contaminant transport at the site includes discharge of contaminants from the groundwater system along this storm sewer line.

The direction of shallow groundwater flow generally follows the topography (Figure 6). Consequently groundwater flows from the Riggs Road Chevron station across Eastern Ave. toward Nicholson Street. East of 8th street, however, groundwater flow on the Maryland side of Eastern Ave. is approximately parallel to Eastern Ave. The existing remediation system at the former Chevron station impacts the elevation of the water table and flow direction of groundwater, although these effects are limited to the immediate vicinity of the remediation system.

Because of the topographic variation across the site, the depth to groundwater also varies. Near the former Chevron station on Riggs Road, the depth to groundwater is approximately 40 ft (Figure 7). The depth to groundwater decreases with the topographic trends so that along Nicholson and parts of Oglethorpe Streets the depth to groundwater may only be three to four feet. Many homes in this area are built with sumps and sump pumps in the basement to prevent flooding with groundwater. Water from these sumps was sampled by Gannett Fleming in 2002 and 2005 (Gannett Fleming, 2006).

Extent of Free Product and Source Area

Liquid-phase hydrocarbons (LPH), or free-product gasoline has been detected in 18 monitoring wells in the vicinity of the release area (Figure 3; Gannett Fleming, 2006). With one exception, all of these wells are located on the Maryland side of Eastern Ave. The one exception

is well MW-18 on the south side of Eastern Ave. Gannett Fleming (2006) reported that free product was detected in this well only once, in 2002. Dissolved concentrations of some gasoline components, and TPH-GRO have remained at the ppm level in this well through 2007 (Gannett Fleming, 2007a).

Since the start of petroleum recovery operations in 1990, more than 4,500 gallons of total hydrocarbons have been removed from the source area (Gannett Fleming, 2006). Source area remediation is ongoing, and will include an expansion of activities to the DC side of Eastern Ave. with installation of the final remedy (USEPA, 2008).

Extent of Groundwater Contamination

The extent of groundwater contamination in the Riggs Park neighborhood has been described in a number of key sources. For information on petroleum-related compounds, the following sources were relied upon:

- Gannett Fleming Inc. 2003. Description of Current Conditions Report
- Gannett Fleming Inc. 2006. Site Investigation Report, former Chevron Facility 122208, 5801 Riggs Road, Chillum, Maryland
- Gannett Fleming Inc. 2007 and 2008. Groundwater Monitoring Data in Electronic Format (122208_analytical_11-26-07.xls, 122208_GW_Data_12-08-08.xls). Data Provided to DDOE and DOH by Gannett Fleming
- U.S. Army Corp of Engineers. 2004 to 2006. Maps of Benzene and MTBE in shallow and deep groundwater
- US Environmental Protection Agency, 2007. Statement of Basis - Chevron Gasoline Release at Chillum, Maryland.

Groundwater monitoring wells installed by Chevron are screened either across the water table (shallow wells) or deeper in the water-bearing zone (deep wells). Consequently, maps of the groundwater contamination are reported as either shallow or deep. Gasoline-related contamination is present in both intervals.

Figures 8 and 9 represents the concentrations of benzene in groundwater in the water table and deeper levels from September 2005, based upon samples collected from groundwater monitoring wells. Prior direct-push investigations in 2002 had found concentrations of benzene in exceedance of MCLs extending across a larger portion of the Riggs Park Neighborhood. In particular, samples collected from direct-push locations GP-154a and GP-155a (near the current location of the MW-33 cluster on Nicholson St.) exhibited benzene concentrations up to a maximum value of 1,320 ug/l.

Figures 10 and 11 illustrate the benzene concentrations in groundwater in March 2008 as depicted by the USACE, on behalf of the USEPA. It is important to note that benzene contamination is present outside the contoured area on Figure 10. The USACE's minimum contour interval is 5 ug/l, but they excluded benzene concentrations as high as 51 ug/l from the contoured area on the Maryland side of Eastern Ave. This exclusion represents USACE's

judgment that these detections in shallow groundwater originate from a different source than the rest of the benzene plume.

Figures 12 and 13 illustrate the extent of MTBE in monitoring wells as mapped in 2005 (Gannett Fleming, 2006). Figures 14 and 15 illustrate the MTBE distribution in groundwater as mapped in 2008 by the USACE. In contrast to Figure 11, the USACE has depicted MTBE results in shallow groundwater monitoring wells on the Maryland side of Eastern Ave. (southeast of 8th street) as part of a contiguous plume of MTBE contamination.

For information on the extent and concentrations of PCE in groundwater, the following sources of information were relied upon:

- USEPA, 2002a. Perc Groundwater Results, Deep - Chevron Spring 2002 Direct Push Sampling Round
- USEPA, 2002b. Perc Groundwater Results, Shallow - Chevron Spring 2002 DP Sampling Round
- USEPA, 2004b. Perc Groundwater Results - Chevron July 2004 Sampling Round
- USEPA, 2004c. Perc Groundwater Results - Chevron May 2004 Sampling Round
- Gannett Fleming Inc. 2008. Groundwater Monitoring Data in Electronic Format (122208_GW_Data_12-08-08.xls). Data Provided to DDOE and DOH from Gannett Fleming.

The 2002 mapping results are reproduced as Figures 16 and 17. While these are not the most recent data, they include all of the direct-push locations that were sampled, and therefore show a higher density of sampling than monitoring well data from subsequent years. Only limited data on PCE in groundwater have been provided for the period following 2004. PCE data for 2008, however, indicate that that maximum concentrations of PCE under the Riggs Park neighborhood range up to 43 ug/l, with the maximum concentrations generally observed in the deeper groundwater for the MW-25, MW-27, MW-44, MW-31, and MW-33 well pairs.

Table 2 presents a summary of the compounds reported as detected in groundwater for the period from 1989 to 2008. As noted above, however, this summary is based upon a limited data set. No PCE results, for example, were available for the period from 2005 to 2008.

Section 5

Project Methods and Materials

In this section, the timeline, methods and materials used to complete this project are reviewed. Additional information on the analytical methods, QA/QC procedures and other aspects of the project can be found in the Work Plan and QAPP (SSP&A, 2007).

Timeline

The contract for the Riggs Park Vapor Intrusion Study and Corrective Action Plan was awarded to S.S. Papadopoulos & Associates on October 18, 2007. The kickoff meeting with DOH staff, including DOH's technical representative (COTR) took place on October 25, 2007. As indicated on Figure 18, the project proceeded as follows:

- Preparation of the Work Plan and Field Readiness Documents from October 25th 2007 to January 8, 2008
- Residents were contacted, and Access Agreements collected in several phases during the period from December 13th 2007 to March 14, 2008
- First Quarter (Q1) VMP Installation and Sampling were completed during the period from January 14th to April 4th, 2008
- First Quarter analytical results were forwarded to DOH on June 24, 2008
- Second Quarter (Q2) GMP Installation was completed during the period from April 1st to May 20th, 2008
- Second Quarter (Q2) Sampling was completed during the period from April 15th through June 27, 2008
- Second Quarter analytical results were forwarded to DOH on July 22, 2008
- Third Quarter (Q3) Sampling was completed during the period from July 15th to September 12, 2008
- Third Quarter analytical results were forwarded to DDOE on October 17, 2008, with an updated and final data set provided on November 4, 2008

Activities

As noted earlier in this report, the primary site activities for this project included:

- Indoor/outdoor air sampling in 115 homes (Table 2)
- Sub-slab and outdoor vapor port installation and sampling at 118 homes

The following tasks were undertaken as part of the sample collection process:

Contacting Homeowners and Obtaining Access Agreements

All sampling for this project was completed on private property in the Riggs Park neighborhood. Testing was voluntary, and signed access agreements were required from all

participants prior to sampling. The information packets and access agreements sent to residents are reproduced in Appendix A. Signatures only of homeowners, not renters or other residents, were accepted for participation in this study.

Potential sampling locations were initially based upon results of the prior DOH study (BSEA, 2006). The initial target homes were the 97 homes sampled in 2006, and the co-slab homes of the 53 highest priority homes identified for re-sampling. After contacting these homeowners, additional sampling targets were identified.

Over 300 homes were contacted and provided with information packets for review. Of these, 144 residents returned signed access agreements with a positive response. Ten additional homeowners returned access agreements declining to participate in the study. Of these 144 potential participants, some subsequently declined to participate, and others were either unable, or unwilling to schedule sampling appointments. Ultimately, indoor air samples were collected from 115 homes. Another three homeowners were either unable or unwilling to participate in the 3-day indoor air sampling protocol, but did agree to installation of outdoor GMPs on their property. Subsurface samples were therefore collected from a total of 118 homes.

Pre-VMP Installation Survey

Prior to installation of sub-slab VMPs, a survey of the basement area was completed to determine the presence of pre-existing VMPs, evidence for past flooding, and general suitability for VMP installation. Sub-slab VMPs were not installed in homes in which there was evidence of past flooding due to high groundwater levels or in which the owner expressed significant concern over such flooding. In addition, VMPs were not installed in some homes where the groundwater was known to be shallow and close to the slab elevation (e.g. parts of Nicholson Street). At these homes outdoor VMPs were installed instead during the second quarter. The completed survey forms are found in Appendix B. To maintain anonymity of information about specific homes, Appendix B is marked as confidential.

Pre-Indoor Air Sampling Survey

As per recommended procedures (USEPA, 2002), home surveys were completed prior to indoor air sampling. The purpose of these surveys was to collect information on resident demographics, home construction, and resident activities that might influence indoor air results (e.g. smoking or recent renovations), and to identify chemicals that might interfere with the indoor air testing. All chemicals identified were collected in bins, and removed to an outside location at least 24 hours before sampling began. The completed home survey forms are found in Appendix C. To maintain anonymity of information about specific homes, Appendix C is marked as confidential.

Sub-Slab Vapor Monitoring Port Installation

The methods for installing VMPs were based on USEPA's November 2002 Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance) and the USEPA Region 3 Standard Operating Procedures (SOP) for "Construction and Installation of Permanent Sub-Slab Soil Gas Wells" (USEPA, 2004f).

During installation of the sub-slab VMPs, an electric hammer drill was used to drill core holes through the concrete basement floor of the home. The sub-slab VMPs were then built using 1/4-inch OD stainless steel tubing, and Swagelok[®] fittings with Teflon tubing attached to each assembly. Expansive concrete was used to seal the VMPs into the concrete floor. When water was encountered in any sub-slab hole during installation or purging for sampling, the boring was abandoned by sealing with expansive concrete grout.

The project Work Plan called for collection of soil samples during VMP installation. Because of the difficulty and disruption associated with collection of these samples, with the COTR's prior approval, soil samples were not collected from the sub-slab locations.

The majority of ports were screened within the soil/fill immediately below the concrete slab. In some homes, duplicate VMPs were installed to assist in evaluation of sub-slab vapor heterogeneity. In selected homes, additional ports were also installed to a depth of approximately 2.5 ft. Some existing VMPs from previous studies were encountered in the basements. When possible, the depths of these ports were measured. Some of these were sampled during subsequent sampling events. These samples are annotated as PVMPs (for pre-existing VMPs).

Outdoor Vapor Monitoring Ports

During the second quarter of this study, Outdoor Vapor Monitoring Ports (GMPs) were installed using a track-mounted Geoprobe-model 54LT direct push equipment. As per the work plan (SSP&A, 2007) each GMP was constructed in the boring using a 1/4-inch OD stainless steel screen point and small diameter Teflon tubing. A glass bead filter medium was placed around the screen point and a portion of the tubing. The remainder of the annular space around the tubing was back-filled with bentonite followed by native soil. For each VMP, the tubing was extended above the ground surface, capped, and coiled within the surface completion. Surface completions consisted of blank PVC casings with a PVC cap. The soil core extracted during the deepest geoprobe push at each location was described, and the depth to water and/or soil saturation was noted, if present.

For each boring location, a soil and/or groundwater sample was collected for VOC analysis by USEPA Method 8260 at the deepest point of the push. At some locations, refusal or the target push depth was encountered before groundwater was reached. In these cases, soil samples were collected from the bottom of the core sample. When a saturated zone was

encountered, a sample of the saturated soil was collected for analysis, and a water sample was collected if sufficient water was produced in the hole.

Locations for the GMPs were based upon suitability of homes for indoor VMP installation, first quarter sampling results and previous investigation data. Some homes were identified for GMP installation because VMP installation was precluded. Locations for additional GMPs were generally identified as those homes with the highest concentrations of benzene, and/or PCE in previous sampling. GMPs were placed as close to each home as practical within the property boundary. In many cases, access to the property was limited by fences, ledges or other structures. If access to the front, side, or back yard was not possible, the GMP was completed in the alley behind the home. Depths for the geoprobe VMPs were based upon the estimated depth to groundwater at each location.

During the third quarter of sampling, some shallow GMPs were replaced using hand auger equipment. These were GMPs that did not produce adequate vapor samples due to water saturation of the soil in the screened interval and several that were damaged or paved-over subsequent to initial installation and sampling. These Q3 GMP replacements were installed at depths of 1 to 2 feet bgs. All other construction details were the same as those built using the Geoprobe equipment.

Sampling and Analysis Methods

Pre-evacuated, cleaned, and certified summa canisters and associated regulators were obtained from two laboratories

- Spectrum Analytical (the primary laboratory), and
- Pace Analytical (the secondary laboratory).

Each canister was delivered directly to Chesapeake GeoSciences, and returned to the laboratory with chain of custody records by staff of Chesapeake GeoSciences. Because of the large number of Spectrum Analytical canisters used during each week of sampling, these were delivered by truck and picked up by laboratory staff at the offices of Chesapeake GeoSciences in Columbia, MD. All canisters were used within the holding times appropriate to ensure maintenance of the laboratory vacuum.

Vapor samples were analyzed using the Modified EPA Method TO-15 Low Level consistent with EPA/625/R-96/010b, METHOD TO-15 "Determination of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry." The TO-15 analyte lists and MDLs for each of the two analytical laboratories are included as appendices in the Work Plan (SSP&A, 2007). Spectrum Analytical's original TO-15 analyte list included 61 parameters. Over the course of the study, additional analytes were added to the list, increasing the total to 68.

Soil and groundwater samples were analyzed by Phase Separation Science laboratories. Sample containers, as specified in the Work Plan, were obtained from the laboratory. After

collection, these samples were shipped via express carrier to the laboratory in chilled coolers with chain of custody documentation. Soil and groundwater samples were analyzed via USEPA Method 8260.

For each target home, every attempt was made to sample indoor air and vapor monitoring ports simultaneously. In some cases, however, due to equipment issues (typically regulator flow rates that did not meet QC criteria) the indoor air and VMP samples may not have been collected on the same day. The actual sample date for each sample is reported in the results section of this report.

Indoor Air Sampling

Each indoor sampling event required three visits to the home on sequential days. On the first day, the field crew (2-person minimum) completed a pre-sampling survey form, and removed from the home chemicals with potential to interfere with the sampling. During surveying of the home, the ppb-RAE PID device was used to screen the home and identify any specific hot spots that might indicate indoor sources of VOCs.

On the second day of sampling, the field crew returned to place the Summa canister(s). All indoor air samples were collected from the basement or lowest level of the homes in pre-evacuated 6-liter certified summa canisters. The samples were fitted with regulators calibrated to 24 hours. During placement of the canisters, PID readings were recorded near the canister, and the location noted on the field sheets. When the regulator valve was opened, the time and date were noted on the field sheets, together with the starting canister vacuum. After opening of the valve, the field crew waited for 5 to 10 minutes to observe the progress of the vacuum gage. If an unacceptable rate of vacuum loss was noted, the equipment was replaced.

On the third day, the field crew returned to retrieve the canister as close as possible to 24-hours after placing the canister. The time and date were noted on the field form together with the final vacuum of the regulator.

One duplicate indoor air sample was collected for every 10 regular indoor air samples. The duplicate samples (submitted to the independent laboratory for comparative analysis) were noted on all field sheets with the same information as the primary samples.

Ambient Air Sampling

At least one ambient air sample was collected for each day during which indoor air samples were obtained. During the primary period of indoor air sample collection (the first quarter of sampling) two ambient air samples were collected each day of indoor air sampling.

Locations for the ambient air samples were selected randomly from amongst the homes scheduled for that day. The canister was fitted with a 24-hour regulator, and typically situated in

a backyard, away from any obvious VOC sources. All other procedures for record keeping and chain of custody were the same as for the indoor air samples. Although each ambient air sample is identified with a home identification number, that number is solely intended as a record of the sampling location; ambient air samples were intended to represent ambient air for the entire neighborhood for the day of collection. One duplicate ambient air sample was collected for every 10 regular ambient air samples.

Vapor Monitoring Port Samples

Collection of sub-slab vapor monitoring port (VMP) samples and outdoor vapor monitoring port (GMP) samples was accomplished in two-day sampling visits. During the initial visit, downhole readings of ambient PID levels were collected with the ppb-RAE PID and noted on the field sheets (see Appendices).

Canisters were attached to the VMP and GMP locations using Teflon tubing. The tubing was discarded after a single use. When duplicate samples were required, a T-junction was used to connect the VMP or GMP to both canisters. On the second day, the field crew returned to retrieve the canister as close as possible to 24-hours after placement. The time and date were noted on the field form together with the final vacuum of the regulator. If the total sampling time exceeded 24 hours, the sample is annotated in the results section of this report.

Section 6

Results

In this section of the report, the sampling results are reported by medium and sample type. Some information on the statistics of each data population is also provided. A summary of the samples collected is provided in Tables 3 and 4. Completed sampling forms can be found in Appendices D through G. Laboratory Data Sheets can be found in Appendices H through N. Quarterly monitoring reports can be found in Appendix O.

Analytical methods at the primary laboratory included standard TO-15 GC/MS analysis, as well as TO-15 analysis with selected ion monitoring (TO-15 SIMS). For some analytes with high concentrations, the greater sensitivity of the SIMS method yielded results flagged with an "E" qualifier indicating an estimated value. In these cases, if the standard TO-15 method produced an unqualified result, the standard TO-15 result is reported here. All laboratory results, flagged and otherwise, can be found in the Appendices.

For consistency with previous reports, analytical results for the target compounds are presented in units of micrograms per cubic meter (ug / m^3). Results for the Total Volatile Hydrocarbons (C5-C12), however, were reported by the laboratory in units of parts per million, by volume (ppmV). Because there is no single molecular weight associated with the TVH parameter that can be used to convert to ug / m^3 , these results are presented in ppmV.

Total Volatile Hydrocarbons (C5-C12) is a calculated parameter indicating the overall presence of volatile compounds. It does not reflect the presence or absence of a single compound. In the following discussions, the term "compounds" is used to describe analytical parameters, although it is recognized that TVH does not represent a single compound. Similarly, the m- and p-xylenes are reported as a single analytical result, although they represent two different chemical compounds.

Detection of any specific compound or its discussion below does not necessarily indicate a risk to human health or the environment associated with that compound. Potential risks from these results are not discussed in this report.

Ambient Air Samples (AOA)

Thirty-nine (39) ambient air samples were collected during Q1, Q2, and Q3 sampling events. Each sample was collected concurrent with at least one indoor air sampling event. Although each ambient air sample is labeled with a home identification number, that ID number is solely intended a record of the sampling location; these samples are intended to represent ambient air for the entire neighborhood for the day of collection.

The complete list of analytes detected in the ambient air samples is included in Table 5. Statistical measures describing the data populations are presented in Tables 6 and 7. A total of 38 analytes were detected. Those detected in greater than 50% of the samples were:

- Ethanol
- Isopropyl alcohol
- Toluene
- Chloromethane
- Trichlorofluoromethane (Freon 11)
- Acetone
- Benzene
- m,p-Xylene
- Total Volatile Hydrocarbons C5-C12
- 2-Butanone (MEK)
- Dichlorodifluoromethane (Freon12)
- Methylene chloride
- Hexane
- n-Heptane

A graphic representation of the data in Table 4 is presented in Figures 19 through 22, illustrating the range of detections of selected compounds. The complete data populations are depicted graphically in Appendix O.

Indoor Air Samples (INA)

A total of 128 indoor air samples were collected at 115 homes. Some of these samples from the first quarter of sampling exhibited elevated detection limits for certain compounds that did not meet the project's quality criteria. Following discussions with the laboratory, analytical procedures were modified and repeat samples were collected from those homes. All analytical results are presented in the Appendices.

The complete list of analytes detected in the indoor air samples is included in Table 5. A total of 47 were detected. Those detected in more than 50% of the samples were:

- Ethanol
- Isopropyl alcohol
- Toluene
- Acetone
- Chloromethane
- Total Volatile Hydrocarbons C5-C12
- Benzene
- Dichlorodifluoromethane (Freon12)

- 2-Butanone (MEK)
- m,p-Xylene
- Hexane
- Trichlorofluoromethane (Freon 11)
- Ethyl acetate
- n-Heptane

A graphic representation of these data is presented in Figure 20.

Sub-Slab Vapor Monitoring Ports (VMPs)

A total of 378 sub-slab vapor samples were collected during the first, second and third quarters of this study. These were collected from 106 homes, and are listed in Tables 3 and 4. A total of 64 analytes were detected in the sub-slab samples (Table 5). Those detected in greater than 50% of the samples were:

- Acetone
- Total Volatile Hydrocarbons C5-C12 (ppmV)
- Trichlorofluoromethane (Freon 11)
- 2-Butanone (MEK)
- Tetrachloroethene
- Toluene
- Ethanol
- Dichlorodifluoromethane (Freon12)
- Isopropyl alcohol
- Benzene
- 2-Hexanone (MBK)
- Chloroform
- 1,4-Dichlorobenzene
- n-Heptane
- Ethyl acetate
- m,p-Xylene

A graphic representation of the data in Table 5 is presented in Figure 21.

Outdoor Vapor Monitoring Ports (GMPs)

A total of 151 samples were collected from the outdoor vapor monitoring ports (GMPs) installed at 66 homes. A total of 48 analytes were detected in the GMP samples. Those detected in more than 50% of the samples were:

- Total Volatile Hydrocarbons C5-C12 (ppmV)
- Acetone
- Carbon disulfide
- Ethanol
- Isopropyl alcohol
- 2-Butanone (MEK)
- Propene
- Toluene
- 2-Hexanone (MBK)

A graphic representation of these data is presented in Figure 22.

Soil Samples

Locations of the soil samples collected during outdoor vapor monitoring ports (GMPs) installation are shown in Figure 23 and Table 8. Of the 69 soil samples collected, 19 were collected from saturated soil – either the water table or a perched zone of groundwater. These are indicated on Figure 23.

Compounds detected in the soil samples were

- Acetone
- m,p-Xylenes
- Methyl-t-butyl ether
- Naphthalene
- o-Xylene

Acetone, in addition to occurring naturally as a metabolic by-product, is a common laboratory contaminant in soil and groundwater analyses, and may not be representative of actual soil contamination. Acetone was detected in 3 locations. The other compounds detected in soil were found in a single sample collected from the alley between Oglethorpe St. and Eastern Ave at a depth of 28 ft. The depth to water at this location was approximately 25 ft after the hole filled with water. From a depth of about 24 to 28 ft, the geoprobe core was characterized by high PID readings.

Concentrations of these compounds in that sample were:

- m,p-Xylenes 4,000 ug/kg
- o-Xylene 2,100 ug/kg
- Naphthalene 3,000 ug/kg

Detection of these compounds at this location is consistent with the presence of residual gasoline in the "smear zone." A "smear zone" is an area of soil contamination formed when

liquid phase gasoline (which is less than dense than water) has migrated atop the water table and been "smeared" across the soil with rising and falling water levels. These detections suggest that liquid-phase gasoline from the release at 5801 Riggs Road migrated at least as far as this location.

The location of this soil contamination is within Area B identified by USEPA for additional remedial measures in its Final Decision and Response to Comments on the Chillum Gasoline Release (see Figure 1 in USEPA, 2008). While no benzene was detected in soil from this location, it is important to note that USEPA recognizes that the shallow groundwater benzene plume did extend at least this far in 2008 (Figure 10). Subsequent data for wells MW-24a and MW-24b confirm the presence of the other dissolved BTEX constituents (toluene, ethylbenzene and xylenes) through 2008.

Groundwater Samples

Fourteen groundwater samples were collected from the geoprobe borings described above (Table 8). The compounds detected were:

- Acetone
- Chloroform
- Methyl-t-butyl ether (MTBE)
- Tetrachloroethene (PCE)

Chloroform is a laboratory and industrial solvent, as well a common byproduct of water chlorination. It may be present in urban groundwater due to use of public water supplies for watering of lawns and other activities that discharge treated water to the ground (Ivahnenko and Zogorski, 2006).

The most commonly detected compound in groundwater samples was MTBE, which was detected in more than half of the samples (Table 9). The presence of MTBE in these shallow groundwater samples is generally consistent with the known maximum extent of shallow groundwater contamination. The location of the highest concentration (83 ug/l) in the area between Oglethorpe and Nicholson Streets is also consistent with previous mapping (Figures 12-15). The low-concentration detections on the order of 2-8 ug/l northeast and northwest of 6th street, were not reported for the shallow groundwater in 2008 (Figure 14).

The detection of PCE is also generally consistent with the previously reported distribution of contaminants in the shallow groundwater. The two monitoring wells situated closest to the PCE detection in groundwater are MW-27A and MW-44A. Sampling results from these two wells in 2008 yielded 5.9 ug/l and 6.2 ug/l respectively. The PCE detection at location S199 was 7 ug/l.

Data Validation

An important part of the data collection effort was Quality Control / Quality Assurance (QA/QC) and data validation. Methods for QA/QC are addressed more fully in the Quality Assurance Project Plan (QAPP) included with the Work Plan (SSP&A, 2007).

Field QA/QC

During data collection, every effort was made to ensure that field activities conformed with the data quality objectives of this project, and that data were collected according to the required protocols. Substantial emphasis was placed on appropriate installation of VMPs, sampling protocols, and field record keeping. All field notes are reproduced in the Appendices to this report. Key information recorded for each sample included

- the exact sample location(s),
- Summa canister and regulator ID numbers,
- times and vacuums during canister placement and pickup,
- PID calibration data
- any other information that might have impacted sample collection.

Laboratory QA/QC

The Quality Assurance Manual for Spectrum Analytical Inc. is included as an Appendix to the QAPP. The other two laboratories used for this project also maintain detailed QA manuals. At all stages of this project, the Project Managers from SSP&A and CGS were in contact with the analytical laboratories to ensure that laboratory procedures were in compliance with the project and laboratories' QA/QC procedures.

Independent Laboratory Duplicates

As per the work plan, a duplicate sample was collected for at least ten percent of vapor samples (Table 10). These duplicates were sent to Pace Analytical Laboratories for analysis via method TO-15 (modified). The analyte lists for method TO-15 (modified) for the primary and secondary laboratories vary somewhat (see SSP&A, 2007), but include all of the target compounds required in the original scope of work and work plan, with similar nominal detection limits.

Figure 24 illustrates the correspondence between data from the primary and secondary laboratories for selected compounds. Many of the compounds are present at concentrations close to the detection limits. All non-detects are plotted at $0.1 \text{ ug} / \text{m}^3$ on Figure 24 (except for TVH, for which they are plotted at 10 ppbV). As seen on Figure 24, for all the compounds illustrated, there is a positive correlation between the results from the two laboratories. The data are generally distributed about the 1:1 line, with greater scatter apparent at lower concentrations. Detection limits from the secondary lab are generally higher than those reported from the

primary lab. Consequently, at low concentrations, the correspondence between the laboratories is more variable.

Spatial Duplicates (VMPs)

The concentrations of any compound in samples from a single home are expected to exhibit some variation. These variations may occur over time (temporal variation) or by sampling location (spatial variation). In fourteen (14) homes, more than one sub-slab VMP was installed. These VMPs were installed to the same depth, but in different parts of the basement for each home. They serve as spatial duplicates to provide a check upon the consistency of the sampling results, and the potential for subsurface heterogeneity to influence the sampling results. For each home with multiple VMPs, each VMP was sampled on the same schedule, and analytical results were obtained from the same laboratory.

A comparison of results from duplicate VMPs is presented in Figure 25. These results represent a selection of the compounds most frequently detected. As can be seen from these diagrams, there is a positive correlation between results from the paired VMPs. This indicates that subsurface concentrations of contaminants are correlated for the same home, regardless of VMP location. While subsurface heterogeneity exists, and may impact individual measurements, these data suggest that it is generally not sufficient to be the primary factor impacting sampling results at the scale of individual homes.

Section 7

Evaluation of Air and Vapor Sample Results

As described above, many compounds were detected in the vapor and air samples. Thirty-eight (38) compounds were detected in the ambient air samples and 64 were detected in the sub-slab samples. A smaller number of compounds were detected in the soil and groundwater samples.

The number of compounds detected does not by itself indicate the relative degree of contamination. Detection of any analytical parameter depends upon a number of factors including the detection limit for each sample. The detection limit is itself influenced by the analytical method, the presence of other compounds and their concentrations in each sample.

Appendix O contains cumulative frequency diagrams for each analyte. In these diagrams, for each group of samples (e.g. indoor air, ambient air, sub-slab vapor monitoring ports and outdoor vapor monitoring ports) the complete set of results is sorted by value, and plotted in ascending order. Non-detect results are plotted at the value of the detection limit, and are indicated by open symbols. Detections are indicated by filled symbols. A review of these curves indicates that for each parameter, the lowest detection limits are generally associated with the sub-slab VMP samples, and the highest with the outdoor GMP samples. The higher detection limits for the GMP samples likely originate in part from preferential placement of the GMPs. They were installed at depths closer to potentially contaminated groundwater than were most VMPs, and for many compounds of interest, the highest concentrations are observed in the GMP samples (see below). In addition, the higher detection limits in some GMP samples may reflect anomalously high concentrations of acetone, tetrahydrofuran, and 2-butanone (MEK) and carbon disulfide. These compounds are unlikely to represent actual subsurface conditions, and may reflect factors associated with construction of the GMPs. Nonetheless, the detection limits for benzene and PCE, for example, are as low as 0.1 ppbV, and population of compounds detected is similar to that for the VMP samples.

Figure 26 illustrates the analytes detected in ambient and indoor air samples. Forty-seven (47) analytes were detected in indoor air, and 38 were detected in ambient outdoor air. Two compounds were detected in ambient air, but not indoor air. Those two compounds (trans-1,3-dichloropropene and 1,2,4-trichlorobenzene) were only detected in a single ambient air sample. The 11 compounds detected in indoor air, but not ambient air, were detected in no more than 3 indoor samples each. Overall, these results indicate that the population of compounds detected in indoor and ambient air samples are similar.

The frequency of detection between the indoor and ambient air data populations, varies between the two data sets. For example:

- cyclohexane was detected in about 27% of the indoor air samples, but in fewer than 3% of the ambient air samples

- Carbon tetrachloride was detected in 26% of the ambient air samples, but only 6% of the indoor air samples
- 1,4-dichlorobenzene was detected in 49% of the indoor air samples, but only 10% of the ambient air samples
- Ethyl acetate was detected in 61% of the indoor air samples, but only 10% of the ambient air samples
- Methylene chloride was detected in 72% of the ambient air samples, but only 46% of the indoor air samples
- Naphthalene was detected in 21% of the indoor air samples, but in none of the ambient air samples
- Trichlorofluoromethane (Freon 11) was detected in 100% of the ambient air samples, but only 73% of the indoor air samples.

Figure 27 illustrates a similar comparison between the indoor air samples and the sub-slab vapor monitoring port samples. Sixty-four (64) analytes were detected in the sub-slab samples, and 47 were detected in the indoor air samples. Only one compound, 1,3-butadiene detected in indoor air was not detected in the sub-slab samples. (Butadiene was detected in 7% of the indoor air samples.) There are 18 analytes that were detected in the sub-slab VMPs that were not detected in any indoor air samples. Of these, n-butyl benzene (in 17% of the sub-slab samples) occurred most frequently (see note on Table 5 regarding frequency of testing for compounds added to the TO-15 list). Overall, these results indicate that the population of compounds detected in indoor and sub-slab samples are very similar.

The frequency of detection between these data populations, however, are not identical. For example,

- Carbon disulfide was detected in 31% of the sub-slab VMP samples, but only 4% of the indoor air samples
- Carbon tetrachloride was detected in 30% of the sub-slab VMP samples, but only 6% of the indoor air samples
- Chloroform was detected in 58% of the sub-slab VMP samples, but only 24% of the indoor air samples.
- Chloromethane was detected in 95% of the indoor air samples, but only 23% of the sub-slab samples.
- Ethylbenzene was detected in 31% of the indoor air samples, but only 13% of the sub-slab samples
- Hexane was detected in 75% of the indoor air samples, but only 40% of the sub-slab samples
- 2-Hexanone (MBK) was detected in 60% of the sub-slab air samples, but only 7% of the indoor air samples
- Methylene chloride was detected in 46% of the indoor air samples and 25% of the sub-slab samples
- Naphthalene was detected in 21% of the indoor air samples but only 2% of the sub-slab samples

- The m,p-xlyenes were detected in 78% of the indoor air samples, but only 50% of the sub-slab samples
- PCE (tetrachloroethene) was detected in 95% of the the sub-slab samples, but only 31% of the indoor air samples
- 1,1,1-Trichloroethane was detected in 37% of the the sub-slab samples, but only 10% of the indoor air samples
- Trichloroethene (TCE) was detected in 26% of the the sub-slab samples, but only 6% of the indoor air samples
- 1,1,2-Tirchlorotrifluoroethane (Freon 113) was detected in 44% of the the sub-slab samples, but only 8% of the indoor air samples.

Figure 28 illustrates a comparison between the sub-slab vapor monitoring port samples and those collected from the outdoor vapor monitoring ports (GMPs). Forty-eight analytes were detected in the outdoor GMP samples, compared to 64 in the sub-slab samples. As noted above, detection limits for the GMP samples were generally higher than those for the VMP samples. Consequently, compounds at low concentration may have been detected more frequently in the VMP sample population than in the GMP sample population.

Bearing these issues in mind, it is noted that:

- Benzene was detected in 67% of the sub-slab VMPs, but only 12% of the GMPs
- MTBE was detected in 11% of the GMPs, but only 5% of the sub-slab VMPs
- Carbon disulfide was detected in 95% of the GMPs, but only in 31% of the VMPs
- 1,4-dichlorobenzene was detected in 56% of the sub-slab VMPs, but only 11% of the GMPs
- Dichlorodifluoromethane (Freon 12) was detected in 94% of the sub-slab VMP samples, but only 43% of the GMP samples
- Ethyl acetate was detected in 50% of the sub-slab VMPs, but only 21% of the GMPs
- Methylene chloride was detected in 25% of the sub-slab VMPs, but only in 3% of the GMPs
- Propene was detected in 82% of the GMP samples, but only 14% of the sub-slab VMP samples.
- Tetrachloroethene (PCE) was detected in 95% of the VMP samples, but only 29% of the GMP samples
- Tetrahydrofuran was detected in 25% of the VMP samples, but only 9% of the GMP samples
- 1,1,1-Trichloroethane (111-TCA) was detected in 37% of the VMP samples, but only 4% of the GMP samples
- Trichlorofluoromethane (Freon 11) was detected in 95% of the sub-slab VMPs, and only 25% of the GMPs
- 1,1,2-trichlorotrifluoroethane (Freon 113) was detected in 44% of the VMPs, but only 3% of the GMPs.

As discussed above, installation of VMPs was not possible in some homes. Consequently, for these homes, outdoor GMPs were installed instead. Nonetheless, several studies have shown that there can be a significant difference in soil vapor concentrations below and adjacent to buildings (Hers et al., 2001). Concerns over false negative results from exterior soil vapor sampling has limited its use in determining vapor intrusion problems (Boyer, 2004). Exterior soil gas sampling may be an appropriate part of an indoor vapor intrusion study, when for example, occupants are (as in some Riggs Park homes) not receptive to drilling a hole in the slab (Boyer, 2004). While the elevated detection limits may mask some low concentrations of contaminants in the outdoor vapor samples, it is important to note that the maximum concentrations of many compounds were also detected in the GMPs.

Compounds Likely Unrelated to Subsurface Contamination

While it is not the intent of this report to exclude from consideration potential contaminants, there are a number of compounds detected that are unlikely to be related to subsurface contamination. These are compounds that are commonly detected in ambient and/or indoor air, and are unlikely to provide information about the subsurface environment. For example, the chlorofluorocarbons (CFCs)

- Dichlorodifluoromethane (Freon 12)
- 1,2-Dichlorotetrafluoroethane (Freon 114)
- Trichlorofluoromethane (Freon 11)
- 1,1,2-Trichlorotrifluoroethane (Freon 113)

are widely disseminated, common, and relatively persistent chemicals in the atmosphere. Studies have shown the presence of these chemicals in the ambient air and subsurface. Pankow et al. (2003) found average values of these compounds in semi-rural and urban areas consistent with values observed here.

Similarly, the compounds ethyl acetate, 4 ethyl-toluene, and the alcohols are excluded from further discussion, as they are not typical of the groundwater or soil contaminants observed in the Riggs Park neighborhood. Finally, some common solvents acetone, MEK, MIBK, carbon disulfide, and tetrahydrofuran are excluded because they may represent laboratory or sampling contamination, and are not indicative of groundwater contamination. Propene, a compound that exists in a vapor-phase at ambient conditions, appears to be preferentially observed in the GMP samples, and is not known to be associated with gasoline-related contamination at the site. It is also excluded from further discussion.

Data Population Analysis

Tables 6 and 7 presents summary statistics for selected analytes grouped by common sources or characteristics. These groupings are not intended to represent an evaluation of provenance. Cyclohexane, for example, is a compound found in gasoline. It is also, however, a

common laboratory solvent and component of gasoline exhaust. Similar limitations apply to all these compounds – each has multiple uses, and potential sources. The grouped compounds are as follows:

Petroleum-Related Compounds

- Benzene
- Toluene
- Ethylbenzene
- Xylenes (m,p- and o-)
- Naphthalene
- MTBE
- Trimethylbenzenes (1,2,4- and 1,3,5-)
- Cyclohexane
- Hexane
- n-heptane

Chlorinated Solvents

- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- 1,1,1-Trichloroethane (111-TCA)
- Chloroform
- Chloromethane
- 1,4-Dichlorobenzene

In Table 6, each sample population – the Ambient Air, Indoor Air, Sub-Slab VMP Samples, and Outdoor GMP Samples, are addressed separately. In its Risk Assessment Guidance, the USEPA recommends that the average concentration of a compound be used to represent a reasonable estimate of the concentration likely to be contacted over time. Because of the uncertainty associated with estimating the true average concentration at a site, the USEPA recommends that the 95 percent Upper Confidence Limit (UCL) of the arithmetic mean should be used (USEPA, 1992, 2002d).

In this study, the USEPA software ProUCL 4.0 was used to calculate UCLs for the ambient air data. Some of the data populations were determined by ProUCL to exhibit lognormal or gamma distributions, and thus are suitable for calculation of the UCL via parametric methods. The data distributions for other data sets were not determined to display a discernible distribution. For these datasets, the UCL was calculated via non-parametric methods. When more than one non-parametric method was suitable for UCL calculation, the highest estimate of the UCL is cited. Generally, the variation in UCL value calculated using different methods was small ($<1 \text{ ug} / \text{m}^3$).

Figures 29 and 30 illustrates the range of values detected in vapor samples for selected compounds. On each chart, the filled bars represent the interquartile range for each set of detections. The interquartile range represents the data between the 25th to 75th percentiles when all values are ranked in ascending order. Observations about these data populations include:

- For the selected petroleum-related compounds,
 - the concentration values for each compound range over several orders of magnitude
 - all but naphthalene and MTBE were detected in ambient air
 - the maximum concentrations and 75th percentile concentrations for indoor air samples generally exceed those from the ambient air samples
 - for each compound, the maximum concentrations and 75th percentile concentrations are generally associated with the GMP data
 - the minimum detections are generally associated with sub-slab VMP samples
- For the selected chlorinated solvents,
 - the concentration values for each compound range over several orders of magnitude
 - all the compounds were detected in each of the four sample groups (indoor air, ambient air, VMPs, and GMPs)
 - For TCE, 111-TCA, chloroform, and chloromethane, the maximum detections were in the VMP samples
 - The maximum concentrations of 1,4-dichlorobenze are found in the indoor air samples
 - For PCE, the maximum concentrations and 75th percentile concentrations are similar in both the VMP and GMP sample populations; these exceed the maximum and 75th percentile values for indoor air and ambient air.

Comparison of Ambient Air Data from Other Studies

Many of the results cited above for ambient air are consistent with data from other studies of urban environments. For example, the 95% UCL of the mean benzene concentrations in this study was $1.1 \text{ ug} / \text{m}^3$. In comparison, a 2003 study found the average benzene concentration in highly urbanized areas in Massachusetts, California, and New Jersey to range from 0.4 to $3.5 \text{ ug} / \text{m}^3$ in 1999 to 2000 (Pankow et al., 2003). While sampling methods in that study utilized adsorbent cartridges rather than Summa canisters, a number of studies have cited a good correspondence of results between these two types of samples (Aleksic et al., 2005, Spicer 1986 cited in Wallace, 2001, Jia et al., 2008a).

Similarly, a California Air Resources Board study (California Air Resources Board, 1992) found the median values of benzene to range from 0.77 to $1.1 \text{ ug} / \text{m}^3$. Closer to the Riggs

Park neighborhood, the average result of 60 ambient benzene samples collected at the McMillan Reservoir in Washington DC in 2005 was $0.92 \text{ ug} / \text{m}^3$ (DDOE, pers. Comm.)

For toluene, which was detected in 100% of the ambient air samples, the 95% UCL of the mean value of $2.5 \text{ ug} / \text{m}^3$ is consistent with the Pankow et al. (2003) mean values ranging from 1.5 to $10.2 \text{ ug} / \text{m}^3$. The 2005 mean concentration for toluene at the McMillan reservoir was $1.94 \text{ ug} / \text{m}^3$.

PCE was detected in 28% of the ambient air samples collected for this study. The range of detected values (0.61 to $4.95 \text{ ug} / \text{m}^3$) and the 95% UCL of the mean value ($1.1 \text{ ug} / \text{m}^3$) are consistent with values observed at the MacMillan Reservoir from 2000 to 2007. Mean concentrations reported in Pankow et al. (2003) ranged from 0.26 to $2.3 \text{ ug} / \text{m}^3$.

Comparison of Vapor Data to Previous Studies

Comparison of the data on Tables 1 and 5 illustrates the relationships between the current data set, and data collected in previous studies. For example:

- For indoor air samples
 - The maximum benzene detected in this study was $8.36 \text{ ug} / \text{m}^3$; this result is within the range of indoor (basement) values obtained from previous Riggs Park studies:
 - the maximum value detected in the USEPA/Chevron studies was $13 \text{ ug} / \text{m}^3$
 - the maximum reported for the BSEA 2006 study was $26.8 \text{ ug} / \text{m}^3$
 - the maximum value observed in winter 2007 studies by DOH was $6.6 \text{ ug} / \text{m}^3$
 - The maximum value of MTBE detected in this study ($1.77 \text{ ug} / \text{m}^3$) is lower than the maximum reported in other studies 25.0 to $63.5 \text{ ug} / \text{m}^3$
 - The maximum concentration of PCE detected ($42.31 \text{ ug} / \text{m}^3$) is higher than that reported from previous data sets ($23.1 \text{ ug} / \text{m}^3$, $38.9 \text{ ug} / \text{m}^3$, and $3.3 \text{ ug} / \text{m}^3$), although in a similar range
- For Subsurface (VMP and GMP samples)
 - The maximum detections of benzene ($24.9 \text{ ug} / \text{m}^3$), toluene ($173.7 \text{ ug} / \text{m}^3$), MTBE ($667.4 \text{ ug} / \text{m}^3$), and PCE ($929.0 \text{ ug} / \text{m}^3$) are all lower than the maximum reported in previous USEPA/Chevron studies; this may reflect inclusion of samples at depths and geographic locations closer to the source areas in those studies than sampled here

- The maximum concentrations for the xylenes (270.2 and 189.9 $\mu\text{g}/\text{m}^3$) in this study are higher than those reported in previous USEPA/Chevron studies.

Comparison of Indoor Air Data to Ambient Air Data

As can be seen in Figures 29 and 30, the interquartile range and maximum concentrations for many compounds are higher in the indoor air samples than in the ambient air samples. This relationship by itself does not, however, serve as evidence for vapor intrusion from subsurface sources. There are many possible sources of indoor VOCs that may influence concentrations measured indoors.

For example, attached garages are potential sources of BTEX (Dodson et al., 2008; Jia et al., 2008b; Batterman et al., 2006) as would be any gasoline-containing items such as lawnmowers. Other sources of indoor air contamination include recent renovations, indoor smoking, building materials, furnishings, cleaning products, insecticides, hobby supplies, etc. The degree of contamination itself can be related to rates of window/door opening and ventilation rates (Jia et al., 2008b). A USEPA study (Sack et al., 1992) evaluated 1159 common household products for 31 VOCs. Xylenes were among the most common chemicals detected. Other chemicals typically found in relatively high concentrations included PCE and toluene. Sources of BTEX included automotive products, household cleaners/polishes, and fabric and leather treatments (Sack et al., 1992). PCE may be elevated in indoor air when freshly dry-cleaned clothes are stored indoors (Tichenor et al., 1990).

Because these effects are well known, the indoor air sampling protocol required that household chemicals be removed 24 hours prior to sampling. Nonetheless, such removal cannot completely eliminate the impacts of these indoor sources. It is known that sinks such as wallboard, ceiling tile, carpet, and upholstery are important in controlling VOC concentrations over extended periods (Hers et al., 2001; Tichenor et al., 1990). Similarly, seasonal variations in ambient air concentrations in urban communities can have an impact on contaminant concentrations in indoor air (Jia, et al., 2008b).

Geographic Distribution of Data

The geographic distributions of indoor air and subsurface vapor data are depicted on Figures 31 through 34. The zones depicted as Areas 1 to 6 are those used by BSEA in their initial study of the Riggs Park neighborhood on behalf of DOH (BSEA, 2006). For each of the selected contaminants the color scale for concentration ranges are scaled to the maximum values detected in either medium.

As noted above, air and soil vapor concentration data may vary over time as well as by location. For the subsurface data, the maximum value detected at each home is indicated on these maps.

Key observations include the following:

- For the petroleum-related compounds (Figures 31 and 32),
 - With the exception of MTBE, all compounds were detected in the indoor air of each of the six zones.
 - All compounds were detected in at least one location in the subsurface vapor of each of the six zones.
- For the chlorinated compounds (Figures 33 and 34)
 - All compounds were detected in the indoor air of each of the six zones.
 - All compounds were detected in at least one location in the subsurface vapor of each of the six zones.

The highest subsurface concentrations for several compounds were observed in GMP samples southwest of Nicholson Street. Other subsurface detections were also noted in the portion of the study area southwest of Nicholson street. The currently accepted conceptual model for groundwater flow at this site is that groundwater discharge point for the Chevron plume occurs at the storm sewer along Nicholson street. If these results are confirmed, it suggests that the conceptual model for groundwater flow and plume migration may need to be modified, or that there is an additional source of gasoline-related contaminants affecting these portions of the neighborhood.

Section 8

Information from Home Surveys

Prior to indoor air sampling, each homeowner completed a detailed survey form. Household chemicals were identified, and these were removed for 24 hours prior to testing. Some of the information on those survey forms may potentially inform the results of the indoor air testing. These results are summarized on Table 11.

Briefly, key results can be summarized as follows. Of the 115 homes for which indoor air sampling was completed:

- Smokers (occasional or regular) were resident in 21 homes
- Dry cleaned clothes had been present in more than 20 homes within the last several weeks
- Seven homes have an attached garage
- Gas cans, or lawnmowers with gas tanks were stored in the outdoor sheds of 7 homes, and in two homes with attached garages
- None of the residents cited a visit by an exterminator in the past year
- Three residents reported that a household member worked with solvents currently or in the past (car painting, furniture repair)
- About 30 homeowners reported some home repairs or renovations within the six months prior to the home survey and indoor air sampling
- Twenty-two (22) homeowners reported roof repairs or replacement within the past year
- Basement sumps were reported to currently or commonly have water in them, in four homes
- Five basements were equipped with previously installed VMPs from other studies.

Section 9

Ratios of Subsurface to Indoor Air Concentrations

One measure of the potential for vapor intrusion into a home is the observed ratio of contaminant concentrations between the subsurface and the indoor air.

We can define this ratio as $\frac{Conc_{ss}}{Conc_{INA}}$ where

$Conc_{ss}$ is the subsurface concentration (max value), and

$Conc_{INA}$ is the indoor air concentration.

This definition is the inverse of the vapor/vapor attenuation factor (AF) commonly used in vapor intrusion guidance and studies (e.g. USEPA, 2002c). Other definitions of attenuation factor, including groundwater to indoor air AF are also used in evaluating vapor intrusion.

A previous study cited by USEPA (USEPA, 2002c) found that for homes with greater indoor air than subsurface vapor concentrations of chlorinated solvents, the sub/slab to indoor air ratios ranged from more than 0.1 to less than 0.001. These observations are consistent with the more recent work by McDonald and Wertz (2007) for chlorinated solvents in a New York State residential neighborhood.

Figures 35 and 36 illustrate the ratios of sub-slab to indoor air concentrations for each of the 115 homes which was fitted with a sub-slab VMP. Outdoor GMP data are excluded from this analysis. The maximum value for the sub-slab concentrations are used in these analyses. As can be seen from these graphs

- For both the petroleum-related and chlorinated compounds, the ratio of sub-slab concentrations to indoor air concentrations depends on the individual home and sampling result
- For the petroleum-related compounds, the sub-surface to indoor air ratios range from 182 to .006,
 - ratios are less than 1 for most samples
- The highest ratio is associated with measurements of m,p-Xylylene
- for each of the petroleum-related compounds, the sub-slab concentrations exceed the indoor air concentrations in at least 20% of homes
- For the chlorinated compounds, the sub-slab to indoor air ratios range from 144 to 0.004
- For PCE, the ratio for subsurface to indoor air is greater than 1 for about 72% of the homes.
- Ratios of 10 and higher were observed for 1,4-dichlorobenzene, chloroform, and PCE.

These results indicate that for some compounds concentrations in the sub-slab are higher than in the homes, setting up a positive concentration gradient from the subsurface to indoor air. Of course, these results exclude homes without VMPs, and are impacted by factors such as variable detection limits in the sub-slab and indoor air samples. To evaluate the evidence for vapor intrusion and/or risk posed by these concentrations, an individualized home-by home analysis is required.

Section 10

Conclusions

The following conclusions summarize the key points discussed in previous sections of this report:

- Shallow groundwater samples collected from 14 locations yielded detections of PCE and MTBE; MTBE was detected in more than half of the samples at concentrations consistent with previous studies
- A soil sample collected at the water table in the alley between Oglethorpe Street and Eastern Ave. is consistent with the presence of residual liquid-phase gasoline; this result provides additional evidence for migration of liquid-phase gasoline to the District of Columbia side of Eastern Ave
- Analyses of the air and vapor samples indicates that the population of volatile compounds detected via TO-15 analyses are similar amongst the 4 data populations.
 - In the 39 ambient air sample population, a total of 38 analytes were detected at least once
 - In the 128 indoor air sample population, a total of 47 analytes were detected at least once
 - In the 378 VMP vapor samples, a total of 64 analytes were detected at least once
 - In the 151 GMP vapor samples, a total of 48 analytes were detected at least once
- Ambient air concentrations of benzene, toluene, and PCE are within ranges observed both at Washington DC's McMillan Reservoir, and within ranges reported in the literature for other urban environments
- Many compounds detected in the TO-15 analyses are likely unrelated to subsurface contamination sources. These include
 - freons
 - various solvents and alcohols
 - anomalous concentrations of acetone, MIBK, tetrahydrofuran, propene, and carbon disulfide in GMP samples
- For the suite of 13 petroleum-related compounds that occur frequently in the vapor sample populations, the following observations can be made
 - the concentration values for each compound range over several orders of magnitude
 - the maximum values and 75th percentile values for indoor air samples generally exceed those from the ambient air samples
 - the maximum values and maximum 75th percentile values are generally associated with the GMP data
 - the minimum detections are generally associated with sub-slab VMP samples
 - With the exception of MTBE, all compounds were detected in the indoor air of each of the six geographic zones in the Riggs Park neighborhood.

- All compounds were detected in at least one location in the subsurface vapor of each of the six geographic zones in the Riggs Park neighborhood
- The maximum benzene concentration detected in indoor air was $8.36 \text{ ug} / \text{m}^3$
- The maximum benzene concentration detected in subsurface vapors was $24.9 \text{ ug} / \text{m}^3$.
- For the 6 selected chlorinated compounds that occur frequently in the vapor sample populations the following observations can be made:
 - the concentration values for each compound range over several orders of magnitude
 - all the compounds were detected in each of the four sample groups (indoor air, ambient air, VMPs, and GMPs)
 - For PCE, the maximum concentrations and 75th percentile concentrations are similar in both the VMP and GMP sample populations; these exceed the maximum and 75th percentile values for indoor air and ambient air
 - All compounds were detected in indoor air in at least one location in each of the six geographic zones in the Riggs Park neighborhood
 - All compounds were detected in subsurface vapors in at least one location in each of the six geographic zones in the Riggs Park neighborhood
 - The maximum concentration of PCE detected in indoor air was $42.3 \text{ ug} / \text{m}^3$
 - The maximum concentration of PCE detected in subsurface vapors was $929 \text{ ug} / \text{m}^3$.
- For homes at which compounds were detected both indoors and in the sub-slab samples:
 - for the petroleum-related and chlorinated compounds, the ratios of sub-slab to indoor air concentrations range from 182 to 0.003 for individual homes
 - for each of the petroleum-related compounds, the sub-slab concentrations exceed the indoor air concentrations in at least 20% of homes
 - for the chlorinated compounds chloroform, 111-TCA, 14-dichlorobenzene and PCE, the maximum sub-slab concentration exceed the indoor air concentration in at least 20% of the homes
 - the concentration of PCE is greater in the sub-slab than in the indoor air in about 72% of the homes

Discussion and Recommendations

The information presented above provides an overview of the analytical results from this sampling program. As noted, the intent of this report was not to exclude any analytes from the analysis. Nonetheless, some compounds that are widespread in the atmosphere (e.g. the freons) are not central to the potential impact of groundwater contamination on the Riggs Park neighborhood. Other compounds, such as the alcohols, propene, and carbon disulfide, may reflect some aspect of subsurface contamination and/or its metabolism by microbes. Because of

the potential of these compounds to originate from many potential sources, however, any linkage between them and existing groundwater contamination must be explored further.

Similarly, no attempt was made in this report to subtract or otherwise account for ambient air concentrations of the compounds of interest. The limited comparisons cited in this report between these data and other urban air studies suggest that the ambient air concentrations of volatile organic compounds are similar to those observed in other U.S. urban areas.

Finally, no attempt was made in this report to determine the levels at which contaminants present in indoor air that appear to be present in subsurface vapor pose unacceptable cancer or non-cancer risk.

The following recommendations are based upon the above analyses:

- These data should be used to complete a risk-assessment for the Riggs Park neighborhood on a home-by-home basis, using all relevant compounds in order to establish what risk, if any, exists for the residents
- Considering the results from subsurface sampling southwest of Nicholson street (beyond the presumed groundwater discharge zone), additional sampling may be helpful
- Should results suggesting subsurface contamination southwest of Nicholson Street be confirmed, the current conceptual model of contaminant transport should be reviewed to determine if
 - The Nicholson street storm sewer is an effective discharge point for all groundwater contamination and/or if
 - Other potential sources of subsurface contamination exist southwest of Nicholson street.

Section 11

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