REPORT

Phase 1 Sitewide Soil Vapor Investigation Report 221 Sunset Drive, Camdenton, Missouri

August 2017

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Acronyms and Abbreviations

bgs	below ground surface
CH2M	CH2M HILL Engineers, Inc.
1,1-DCA	1,1-dichloroethane
DCE	dichloroethene
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
MDHSS	Missouri Department of Health and Senior Services
MDNR	Missouri Department of Natural Resources
$\mu g/m^3$	micrograms per cubic meter
mg/kg	milligrams per kilogram
PCE	tetrachloroethene
PID	photoionization detector
ppb	parts per billion
scfm	standard cubic feet per minute
1,1,1-TCA	1,1,1-trichloroethane
TCE	trichloroethene
TOC	total organic carbon
VC	vinyl chloride
VISL	vapor intrusion screening level
VOC	volatile organic compound

SECTION 1

Introduction

This report presents the procedures and results associated with sitewide investigation activities related to the presence of volatile organic compounds (VOCs) in soil vapor at the facility located at 221 Sunset Drive (formerly 179 Sunset Drive) in Camdenton, Missouri (Figure 1-1).

1.1 Project Background

The facility at 221 Sunset Drive (formerly 179 Sunset Drive) in Camdenton, Missouri, was constructed in 1967 and produced aluminum and copper heat-transfer units. The facility was expanded four times (in 1970, 1973, 1979, and 1983) after it was constructed. Until 1990, the manufacturing processes included a vapor degreasing process that used trichloroethene (TCE). From 1990 through 1993, 1,1,1-trichloroethane (1,1,1-TCA) was used as part of the vapor degreasing process. In 1993, the 1,1,1-TCA was replaced with methylene chloride, which was used in facility operations until 1997 when the degreasing equipment was removed.

The building located at the facility underwent complete interior renovation in 1997, during which time the degreasing units were removed and recessed portions of the building floor were brought to grade. Between 1997 and March 2012, the facility produced radiators using a manufacturing process that did not include the use of chlorinated solvents. Facility operations ceased in March 2012 and the facility has been vacant since April 2012.

Investigations and remedial activities have been conducted at the facility since 1992. Activities that occurred before March 2015 are detailed in the RCRA Facility Investigation Report (CH2M HILL Engineers, Inc. [CH2M] 2009) and the Indoor Air and Subslab Sampling Quality Assurance Project Plan (CH2M 2013). The regulatory history and previous investigations conducted since March 2015 are presented in the Sitewide Investigation Work Plan (CH2M 2016a).

1.2 Phase 1 Sitewide Soil Vapor Investigation Scope and Objectives

The Phase 1 sitewide soil vapor investigation was conducted on the north and east side of the building to investigate the overall presence of VOCs related to former facility operations in soil vapor, soil, and groundwater, and to assess VOC migration pathways from the facility toward offsite properties. The drivers for this investigation were the results of the previous soil vapor and indoor air investigations conducted at the facility and in the adjacent residential area in 2015 and 2016 (CH2M 2016a).

The site-specific list of VOCs investigated included the following: 1,1,1-TCA, 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (DCE), cis-1,2-DCE, trans-1,2-DCE, methylene chloride (also referred to as dichloromethane), tetrachloroethene (PCE), TCE, and vinyl chloride (VC). The site-specific VOC list is based on chemicals used in past manufacturing processes (TCE, 1,1,1-TCA, and methylene chloride), chemicals detected in groundwater or soil during past investigations (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and 1,1-DCE), and other degradation products of 1,1,1-TCA and TCE (1,1-DCA, VC).

The Phase 1 sitewide soil vapor investigation data quality objectives (DQOs) were as follows:

- Assess the presence of potential vapor migration pathways.
- Assess the presence and distribution of VOCs in soil vapor within the potential migration pathways.
- Assess the presence of VOCs in soil and groundwater (if present) along potential vapor migration pathways.

The investigation activities are consistent with the work plan submitted to and approved by the Missouri Department of Natural Resources (MDNR) (CH2M 2016a). The investigation activities are also consistent with what MDNR and the Missouri Department of Health and Senior Services (MDHSS) communicated during the public meeting held in Camdenton, Missouri, on March 8, 2016, and in communications that MDNR and MDHSS have had with residents.

Phase 1 of the sitewide soil vapor investigation prioritized the evaluation of VOC migration pathways from the facility toward offsite properties and to assess the presence of VOCs in soil, groundwater, and soil vapor along potential migration pathways. The investigation findings were used to propose a recommended path forward herein.

SECTION 2

Investigation Activities

This section summarizes the approach and methods that were used as part of investigation activities completed north and east of the building to satisfy the sitewide investigation DQOs.

The following tasks were completed during the sitewide investigation:

- Soil boring advancement and soil sampling
- Monitoring well installation
- Groundwater sampling
- Vapor sampling
- Vacuum testing
- Surveying

Table 2-1 presents construction details of monitoring wells installed during the Phase 1 sitewide soil vapor investigation. Table 2-2 summarizes samples collected during the Phase 1 sitewide soil vapor investigation. Sample locations are presented in Figure 2-1. Construction details for monitoring wells installed during the Property No. 9 soil and groundwater investigation and sampled for soil vapor during the Phase 1 sitewide soil vapor investigation are included in the Property No. 9 Soil and Groundwater Investigation Technical Memorandum (CH2M 2016b).

The source area investigation sampling and analysis protocols were conducted in accordance with the Sitewide Investigation Work Plan (CH2M 2016a).

2.1 Investigation Approach

Soil borings were advanced during these investigation activities for the purposes of geologic logging, surface and subsurface soil sample collection, and monitoring well installation. Throughout the field investigation, field observations and results of select quick turn laboratory analytical results were reviewed to determine additional soil boring and monitoring well locations and intervals in which wells would be screened.

2.2 Soil Boring Advancement and Sampling

Twenty-one soil borings (SB-108D/S through SB-114 D/S, SB-115D, SB-116D/S, SB-117S, SB-118S, and SB-119D/S) were advanced using rotosonic drilling methods, and soil samples were collected from deep borings from the surface and subsurface soil cores. Drilling was conducted by Mateco Drilling, a state of Missouri-registered drilling firm. The soil borings were advanced through unconsolidated materials (soil and weathered bedrock) and terminated up to 8 feet into competent bedrock. Due to highly variable subsurface conditions, borings were advanced beyond the proposed maximum of 3 feet into competent bedrock to verify the presence and condition of bedrock.

Soil borings were continuously cored, logged, and screened by a qualified CH2M geologist. Soil cores were screened using a handheld photoionization detector (PID) capable of reading in parts per billion (ppb) concentrations of total VOCs (ppbRAE). Soil boring logs are presented in Appendix A.

2.2.1 Surface Soil Samples

Surface soil (0 to 1 foot below ground surface [bgs]) samples were collected from seven soil boring locations (SB-108D through SB-113D and SB-116D, Table 2-2). Surface soil samples were not collected from the remaining soil boring locations based on field observations, PID measurements, and data needs

to meet the DQOs. Surface soil samples were collected from either the depth exhibiting the highest PID reading or, in the case of no elevated PID readings, from 0.5 to 1 foot bgs.

Surface soil samples were collected using Terra Core sample kits, placed in an ice-bearing cooler, and submitted to CT Laboratories of Baraboo, Wisconsin, via FedEx priority overnight service using standard chain-of-custody procedures. Samples were analyzed for site-specific VOCs by U.S. Environmental Protection Agency (EPA) Method 8260C.

2.2.2 Subsurface Soil Samples

A minimum of three subsurface (greater than 1 foot bgs) soil samples were collected from each soil boring location (SB-117S, SB-118S, and SB-108D through SB-119D, Table 2-2). Subsurface soil samples were collected from the depths exhibiting the highest PID readings measured in soil cores collected from the boring. In soil borings where no elevated PID readings were observed, subsurface soil samples were collected from zones that visually appeared to have higher permeability (e.g., clayey sand, gravelly clay).

Subsurface soil samples were collected using TerraCore sample kits, placed in an ice-bearing cooler, and submitted to CT Laboratories of Baraboo, Wisconsin, via FedEx priority overnight service using standard chain-of-custody procedures. Samples were analyzed for site-specific VOCs by EPA Method 8260C.

Fifteen bulk soil samples were collected for total organic carbon (TOC) analysis from SB-115D, SB-117S, SB-118S, and SB-119D, placed in an ice-bearing cooler, and submitted to CT Laboratories of Baraboo, Wisconsin, via FedEx priority overnight service using standard chain-of-custody procedures.

2.3 Monitoring Well Installation

A total of 21 monitoring wells were installed using rotosonic drilling methods (Figure 2-1). In general, the screened interval selected for the wells was based on visual observation of the soil cores during borehole installation, with zones of potentially higher permeability (coarser grain size) preferentially selected for well screens, since higher-permeability zones are more likely to contribute to soil vapor migration (McHugh et al. 2013). In addition, preference was given for well screen locations to zones that appeared to potentially contain perched groundwater, since groundwater migration may also affect soil vapor migration. Two monitoring wells were installed at nine of the soil boring locations where more than one saturated or higher-permeability interval was observed at vertically separate portions of the stratigraphy (e.g., upper and lower portion of soil horizon). One monitoring well was installed at the remaining three locations, shallow wells at SB-117S and SB-118S and a deep well at SB-115D. Table 2-1 presents the monitoring well construction details. The monitoring well completion diagrams are presented in Appendix B. Monitoring well certification records were completed and submitted to MDNR Geological Survey Program by the drilling subcontractor.

Following well installation, depth to groundwater and total well depth were measured in each monitoring well. These water level measurements revealed that naturally occurring water was not present in sufficient volumes to develop the newly installed monitoring wells, and well development was not performed. However, as noted in the following section, several wells installed during previous site activities did contain enough groundwater for purging and sampling.

2.4 Groundwater Sampling

Monitoring wells MW-102 and MW-106, installed during the Property No. 9 soil and groundwater investigation (CH2M 2016b), contained sufficient groundwater volumes for sample collection and were purged and sampled using low-flow sampling.

New monitoring wells installed as part of this field effort were dry or did not contain sufficient groundwater volumes for sample collection. Vapor samples were collected from these monitoring wells as described in Section 2.5.

Groundwater samples were placed in an ice-bearing cooler and submitted to CT Laboratories of Baraboo, Wisconsin, by overnight delivery using standard chain-of-custody procedures. Samples were analyzed for site-specific VOCs by EPA Method 8260C.

2.5 Vapor Sampling

Monitoring wells with screen intervals that were dry or had more than 2 feet of unsubmerged well screen were purged of vapor, field screened using a PID, and sampled to assess the presence of VOCs in soil vapor. Vapor samples were collected from each monitoring well except MW-102 and MW-106 because they had less than 2 feet of unsubmerged well screen. Vapor sampling activities were conducted on completed monitoring wells to assess the nature and extent of VOCs in soil vapor and to support decisions associated with additional boring locations.

Vapor sampling was completed by sealing off the monitoring well riser above the top of well screen using an inflatable packer, inserting 0.25-inch-diameter sample tubing through the packer to the midpoint of the exposed well screen, purging at least 3 volumes of vapor from the sealed portion of the well using a low-flow vacuum pump, and collecting a vapor sample when the minimum volume of air had been purged. Vapors purged were continuously monitored using a PID (ppbRAE), and multi-gas meter (MultiRAE or GEM 5000).

Vapor samples were collected in pre-purged laboratory-supplied canisters. Sample canisters were submitted to Applied Sciences Laboratory in Corvallis, Oregon, using standard chain-of-custody procedures and analyzed site-specific for VOCs by Method TO-15 Scan.

Vapor sampling details are presented in Appendix C.

2.6 Short-term Vacuum Testing

Short-term vacuum tests were conducted on new monitoring wells, using a methodology as generally described by McAlary et al 2010, to provide semi-quantitative information on the relative vapor transmissivity of the subsurface formation intercepted by the well screen. A vacuum pump was used to induce a vacuum on the monitoring wells and create subsurface vapor flow. The vacuum was incrementally increased over the duration of the test to monitor for changes in vapor flow at different vacuums. During the test, extracted vapor was monitored using a PID (ppbRAE) and landfill gas analyzer (GEM 5000). Vapor flow rate, temperature, and pressure (positive and negative) were also monitored. Vacuum influence was monitored at adjacent monitoring wells to evaluate interconnectivity of potential migration pathways. Vapor extracted during the vacuum test was treated using granular activated carbon prior to discharge to the atmosphere.

2.7 Surveying

Horizontal coordinates and vertical elevations were established for existing and newly installed monitoring wells by a Missouri-licensed land surveyor (Cochran Engineering and Surveying).
The elevations were established for both the top of well riser and ground surface and are presented in the Well Construction Diagrams in Appendix B.

2.8 Waste Management

Investigation-derived waste was segregated by media (soil, groundwater, and sampling materials) and containerized in steel 55-gallon drums. The drums were staged on concrete within the fenced portion of the site, and labeled. Waste was characterized as nonhazardous for disposal and transported and disposed of in accordance with applicable state and federal regulations.

SECTION 3

Results

This section presents the results of the Phase 1 sitewide soil vapor investigation. Laboratory analytical reports are provided in Appendix D, and the data quality evaluation report is presented in Appendix E.

In addition to the laboratory data collected during this investigation, soil, groundwater, and soil vapor data collected as part of the Property No. 9 soil and groundwater investigation (CH2M 2016b) and September 2016 quarterly residential vapor intrusion sampling (CH2M 2017) are presented on figures and/or are used for data assessment purposes in Sections 3 and 4.

A discussion of results, analytical data tables, laboratory reports, and data quality evaluation associated with the data are presented in the Property No. 9 Soil and Groundwater Investigation Technical Memorandum (CH2M 2016b) and Residential Vapor Intrusion Investigation – September 2016 Quarterly Event Results Technical Memorandum (CH2M 2017).

3.1 Soil Vapor

Soil vapor samples were collected from 27 wells installed during the Phase 1 sitewide soil vapor investigation and Property No. 9 soil and groundwater investigation. Soil vapor samples were analyzed for site-specific VOCs.

Table 3-1 presents soil vapor analytical results. Five VOCs (cis-1,2-DCE, PCE, trans-1,2-DCE, TCE, and VC) were detected in soil vapor samples. Table 3-2 summarizes the frequency of each VOC detected in soil vapor samples analyzed. VOCs were detected in each of the 27 soil vapor samples collected during this investigation. TCE was detected in each vapor sample. PCE, cis-1,2-DCE, trans-1,2-DCE, and VC were detected at frequencies of 1/27, 12/27, 2/27, and 1/27, respectively, in the soil vapor samples.

3.1.1 Shallow Soil Vapor

Figure 3-1 presents TCE results in shallow soil vapor samples from shallow monitoring wells (Table 3-1), as well as exterior soil vapor probes and sewer manholes (CH2M 2017). TCE detections in shallow soil vapor range from 5.84 J micrograms per cubic meter (µg/m^3) to 1,270,000 µg/m^3.

3.1.2 Deep Soil Vapor

Figure 3-2 presents TCE results in deep soil vapor samples from deep monitoring wells (Table 3-1). TCE detections in deep vapor ranged from 8,030 µg/m^3 to 726,000 µg/m^3. With the exception of one shallow and deep monitoring well pair (MW-113S and MW-113D, near the sewer line and MW-118S), TCE in shallower soil vapor (20 feet bgs or less) is at lower concentrations than TCE in deeper soil vapor (greater than 20 feet bgs).

3.1.3 Soil Vapor along the Sewer Line

Figure 3-3 presents TCE results in vapor samples collected from monitoring wells (Table 3-1), as well as exterior soil vapor probes and manholes (CH2M 2017) near and along the sanitary sewer line. TCE concentrations in soil vapor are generally higher in monitoring wells and exterior soil vapor probes than in sewer manholes because samples collected from sewer manholes are likely exposed to atmospheric conditions. The TCE concentrations detected in soil vapor at the greatest concentrations along the sewer line are east of the facility (MW-118S at 1,270,000 µg/m^3) and near the Bent Tree manhole (MW-105 at 726,000 µg/m^3).

3.1.4 Vacuum Testing Results

Table 3-3 presents the estimated soil vapor flow rates from the vacuum testing performed. The flow rates were generally between 1 and 4 standard cubic feet per minute (scfm), with flow rates as high as 25 scfm and 35 scfm at MW-118S and MW-113D, respectively. These data may be useful for future remedial action planning.

3.2 Soil

Table 3-4 presents the analytical results for the seven surface soil samples analyzed for site-specific VOCs. The only VOC detected in surface soil was methylene chloride in two samples. Methylene chloride was used at the site from 1993 through 1997. However, it is also known to be a common laboratory solvent and a laboratory-related contaminant often detected during VOC analyses (EPA 1998). Methylene chloride was not detected in soil vapor or groundwater samples analyzed during this field effort. Given the length of time that has passed since this VOC was used at the site, its lack of detection in other site media, and the propensity of VOCs to readily volatilize from surface soil, the detections of methylene chloride in these two samples may be due to inadvertent laboratory contamination. However, it is noted that the current (June 2017) EPA Regional Screening Level (RSL) for methylene chloride for industrial soil is 320 milligrams per kilogram (mg/kg) (EPA 2017). Thus, the two concentrations detected (0.0563 J and 0.075 J mg/kg) are over 4,000 times lower than risk-based concentrations for industrial receptors. Therefore, the results for the surface soil samples do not indicate the potential for causing unacceptable risks to human health.

Table 3-5 presents VOC results for subsurface soil samples. Subsurface soil samples were collected from greater than 1 foot bgs to as deep as 62 feet bgs. Three VOCs (cis-1,2-DCE, methylene chloride, and TCE) were detected in subsurface soil samples collected during this investigation (Table 3-5). For the three detected VOCs, the frequency of detection for soil samples analyzed is presented in Table 3-2.

Results from TOC samples collected are presented in Table 3-6. Reported TOC values ranged from 72.1 mg/kg to 80,000 mg/kg. Generally, TOC concentrations were greater in shallower soils (13 feet bgs or less) compared to deeper soils (15 feet bgs or more). This pattern is consistent with TOC vertical distribution patterns previously found to occur naturally (Jobbagy and Jackson 2000).

Figure 3-4 presents TCE results in surface and subsurface soil from the Phase 1 sitewide soil vapor investigation. The highest TCE concentrations were observed in the subsurface soil to the east of the former manufacturing building. TCE concentrations in subsurface soil ranged from 0.0116 J to 1.26 mg/kg.

3.3 Groundwater

Groundwater was present in two monitoring wells (MW-102 and MW-106) in sufficient volume during the sitewide investigation to sample for analysis of site-specific VOCs. Six VOCs (1,1-DCA, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, TCE, and vinyl chloride) were detected in groundwater samples collected (Table 3-7). Table 3-2 presents frequency of VOC detections in groundwater samples collected from monitoring wells during the Phase 1 sitewide soil vapor investigation (Table 3-7) and the Property No. 9 soil and groundwater investigation (CH2M 2016b).

Figure 3-5 presents TCE results in groundwater samples from the Phase 1 sitewide soil vapor investigation, Property No. 9 soil and groundwater investigation (CH2M 2016b), and September 2016 quarterly residential vapor intrusion sampling event (CH2M 2017).

The highest concentrations of TCE are observed in MW-101 (April 2016) and MW-106 (April and October 2016), which are adjacent to sanitary sewer manholes. Sufficient groundwater was not present in MW-101 to sample in October 2016.

SECTION 4

Conceptual Site Model

This section presents the current understanding of the conceptual site model based on findings from the Phase 1 sitewide soil vapor investigation, portions of the Property No. 9 soil and groundwater investigation (CH2M 2016b), and September 2016 quarterly residential VI investigation results (CH2M 2017).

4.1 Geology and Hydrogeology

Boring logs (Appendix A) and survey data from the sitewide investigation were compiled to generate subsurface cross-sections of the site. Cross-section transects are presented in Figure 4-1. Cross section transects depicting generalized/simplified representations of subsurface geologic conditions beneath the site are presented in Figures 4-2 through 4-4.

The site topography slopes down from east to west and slopes down away from the former manufacturing facility in north and south directions. The general stratigraphy of the site consists of stiff clay with a varying sand and chert component at or near land surface, followed by one or more strata of greater coarseness and permeability (e.g., sand with a varying silt, clay, or chert component) overlying a limestone bedrock. The shallow clay ranges in thickness from a few feet to greater than 20 feet. Clay is often present within the underlying sand horizons as thin stringers or lenses. Permeable discontinuous chert layers are present in horizons as isolated lenses and thin layers. Weathered limestone interlayered with clay and sand is present approaching the bedrock contact. Interlayered clay, chert, and sand are present in areas where the bedrock contact dips downward (Figures 4-2 and 4-3). Bedrock consists of moderately weathered to fresh limestone with low to moderate fracture density and varying chert component. Bedrock was encountered at depths ranging from 21 feet bgs (MW-110D) to 61 feet bgs (MW-115D).

No evidence of a groundwater aquifer was observed during drilling. Groundwater observed within the core during drilling was the result of isolated perched groundwater within small discontinuous permeable zones. Groundwater was observed in monitoring wells near the sewer line. Groundwater located near the sewer line appears to be a result of water leaking from portions of the sewer line or manholes and collecting within the relatively loose unconsolidated backfill material and within localized deeper permeable soil horizons. Groundwater is present in the bedrock that underlies the soil (Secor 2003). Previous investigation findings define two groundwater zones in bedrock, the perched zone and the deep zone. The perched zone ranges from 110 to 180 feet bgs. The deep zone is separated from the overlying perched zone by an interval of rock containing clay that typically ranges between 30 and 40 feet thick.

Water was observed consistently in several of the exterior soil vapor probes screened within the clay horizon. Small-diameter probes installed within low-permeability clay often act as a wick, drawing out small volumes of groundwater trapped within the pore space of the clay. Water drawn out from the clay combined with condensation inside the probe resulted in an inability to collect soil vapor from many of the shallow probes.

4.2 Nature and Extent of VOCs

The nature and extent of VOCs in soil vapor, soil, and groundwater is presented in the following subsections.

4.2.1 Soil Vapor

VOCs were detected in each of the 27 soil vapor samples collected during this investigation. TCE was detected in each vapor sample and at significantly greater concentrations than other VOCs detected in soil vapor. Cis-1,2-DCE, trans-1,2-DCE, and VC (biodegradation products of TCE) were detected at frequencies of 12/27, 2/27, and 1/27, respectively, in the soil vapor samples. The detections of these TCE degradation products occurred in samples in which TCE was also detected, suggesting a direct linkage between these degradation products and TCE. PCE was detected in one of 27 soil vapor samples. Although not a degradation product of TCE, PCE is known to have been a contaminant in commercial TCE products during the period in which TCE was used at the site (Murphy and Morrison 2015). The vapor sample in which PCE was detected contained a significantly greater TCE concentration than PCE concentration.

Neither 1,1,1-TCA nor methylene chloride, both of which were used at the site during some periods of operation, nor degradation products of these two VOCs were detected in soil vapor samples.

These data indicate that TCE is the primary VOC present in soil vapor and poses the greatest potential for vapor migration.

With a few exceptions, soil vapor concentrations demonstrated a vertical gradient, with soil vapor VOC concentrations collected from the shallowest intervals (well screen intervals ranging from 3.5 to 4.5 feet bgs to 7.9 to 8 feet bgs; such as from exterior soil vapor probes that yielded soil vapor samples) generally lower than in soil vapor collected from nearby or collocated shallow monitoring wells. Shallow wells (well screen intervals ranging from 3.7 to 8.7 feet bgs to 10 to 20 feet bgs), in turn, typically had lower VOC concentrations in soil vapor than collocated deeper wells (well screen intervals ranging from 10 to 20 feet bgs to 28 to 38 feet bgs). The only location where this pattern of shallower soil vapor concentrations being lower than deeper concentrations was not observed was in one sampling location (MW-113S and MW-113D).

The highest TCE concentrations detected in onsite (MW-118S [adjacent to a sewer manhole east of the facility] at 1,270,000 µg/m^3) and offsite (MW-105 [Bent Tree manhole] at 726,000 µg/m^3) soil vapor were collected from vapor sampling locations near the sewer lines. The concentrations of cis-1,2-DCE along the sewer line (MW-118S, MW-110S, and MW-105) indicate that some degree of anaerobic biodegradation is occurring, since cis-1,2-DCE is known to be produced through reductive dechlorination of TCE. This biodegradation is likely due to reducing subsurface geochemical conditions created by wastewater releases from adjacent sewer lines.

4.2.2 Soil

Other than several low-level detections of methylene chloride, VOCs were not detected in surface soil at the facility or in a nearby residential yard sampled during the Property No. 9 soil and groundwater investigation (CH2M 2016b). TCE concentrations were detected in subsurface soil between 9 feet and 46 feet below ground surface below the current (June 2017) EPA RSL for industrial soil (1.9 mg/kg; EPA 2017). Generally, TCE detections in soil were collocated with high TCE soil vapor concentrations at those locations. The extent of onsite subsurface soil containing detectable TCE outside of the former production building was limited to the east side of the facility (near and south of the sewer line along Mulberry Drive at SB-112D, SB-118S, SB-113D, and SB-114D) and northwest side of the facility (SB-109D, SB-108D, and SB-115D).

4.2.3 Groundwater

Groundwater was present in, and TCE concentrations were detected in groundwater samples from, monitoring wells near sewer lines (MW-101, MW-102, MW-104, and MW-106) in April and/or October 2016. Some of the detected concentrations exceeded the site-specific vapor intrusion screening level (VISL) (CH2M 2016b).[1]

Groundwater has been sampled from exterior soil vapor probes (SV01 through SV11) for three quarters, when present (CH2M 2017). The exterior soil vapor probes are screened in shallow clay. VOCs have primarily been not detected or below the health-based levels for residential groundwater.

The current conceptual site model is that there is not a continuous groundwater aquifer present above the competent bedrock found at approximately 30 to 40 feet bgs at this site. Groundwater observed and sampled to date appears to originate from leaking sewer lines or sewer manholes (MW-101, MW-102, MW-104, and MW-106) and possibly infiltrated rainwater (SV01 through SV11). Groundwater sampled from bedrock during previous investigations demonstrated TCE was consistently above the federal Maximum Contaminant Level for drinking water standards in both perched and deep zones (Secor 2003).

4.3 Soil Vapor Sources and Migration Pathways

The investigation was not intended to identify all of the source(s) of TCE detected in soil vapor. However, the available data suggest that the sewer line is a likely conduit from which TCE releases to the environment occurred. Lines of evidence supporting this include the detection of the highest VOC vapor concentrations occurring at sampling points near the sewer lines or manholes, higher VOC soil gas concentrations occurring in shallower sampling points than deeper sampling points at locations near sewer lines, and the detection of TCE biodegradation products, such as cis-1,2-DCE, primarily in samples near sewer lines or manholes.

With the exception of shallower soil vapor along the sewer line, higher TCE concentrations in soil vapor were detected in deeper wells compared to collocated shallower wells installed during the Phase 1 sitewide soil vapor investigation. The deeper wells are generally screened near the top of bedrock. The available data suggest that TCE detected in groundwater present in bedrock or related sources of that contamination may also be contributing to TCE detected in soil vapor (Secor 2003).

The geologic borings and soil vapor sampling activities indicate that discrete zones of preferential vapor migration are present in the subsurface. Beneath the surficial soil, a shallow clay layer with relatively low permeability is present across the site. Many of the soil vapor probes installed within this clay have been unable to provide soil vapor samples and have often been found to be filled with water. Generally, the characteristics of this shallow clay layer make it somewhat resistant to soil vapor migration. Beneath the shallow clay layer are several stratigraphic units with coarser grained material (sand and chert) that more readily yield soil vapor samples that contain elevated VOCs. These zones are shown in the geologic cross-sections presented in this section. The more permeable zones are intermixed with less permeable zones (Figures 4-2 through 4-4). Within these zones, the primary migration pathway appears to be laterally. The overlying clay layer appears to significantly inhibit although not completely eliminate upward vertical vapor migration.

Approximately 18 cubic yards of soil impacted by TCE was removed from the Bent Tree manhole (adjacent to MW-105) in December 2010 by Golder Associates, a City of Camdenton contractor (Golder Associates 2011). However, TCE in soil vapor was detected in well MW-105, adjacent to this soil removal

[1] The site-specific VISLs were calculated using the most recent version of the VISL Calculator (Version 3.5.1), which incorporates the May 2016 RSLs for residential air. Although EPA updated the RSL table in June 2017, the VISL Calculator has not yet been updated. However, none of the indoor air RSLs for the site-specific VOCs changed in the June 2017 update. Therefore, the site-specific VISLs reflect the most recent (June 2017) RSLs.

location, at 726,000 ug/m^3. This indicates that the contaminated soil removal activity may have been incomplete and residual soil contamination at this location represents an ongoing source of TCE to soil vapor. The detection of TCE in a groundwater sample from well MW-106, collocated at this location with MW-105, provides corroborating data suggesting that a residual source of TCE contamination remains at this location.

The highest TCE soil vapor concentration detected during the investigation (1,270,000 µg/m^3) was collected from a shallow location adjacent to the sewer line onsite, at MW-118S. Given the high TCE levels in soil gas, this area may warrant further investigation in the future to assess whether this area may represent or be associated with a residual contamination source zone.

The investigation data show that upward migration of soil vapor in the subsurface appears to be generally limited, with shallower soil gas samples often showing lower VOC concentrations than collocated deeper samples. This is believed to be likely due to the presence of the low-permeability clay soil directly below the ground surface at the facility and in the surrounding area. Lower-permeability soils have been shown to be less conducive to soil vapor migration. In addition, the consistent accumulation of water within many of the shallow soil gas probes indicates that there is considerable moisture present within the clay. Higher soil moisture has also been found to inhibit vapor migration through soil, because vapor diffusion coefficients decrease rapidly with increasing water content (Tillman and Weaver 2007). Together, the low-permeability nature of the clay along with the significant moisture content of the clay combine to create a formation that limits the amount of upward vapor migration.

The overlying shallow clay may also be limiting the degree to which atmospheric pressure gradients, such as those created by storm fronts and other weather conditions, induce pressure-driven vapor migration. Based on the cumulative geologic and laboratory analytical data collected to date, it appears that vapor migration at the site is occurring primarily within the deeper, more permeable stratigraphic zones, and is being driven primarily by chemical diffusion.

SECTION 5

Conclusions and Path Forward

The DQOs defined in the Sitewide Investigation Work Plan (CH2M 2016a) and summarized in Section 1.2 were met as follows:

- Potential vapor migration pathways (zones of greater permeability) were identified in the subsurface through the installation of, and soil vapor sampling from, monitoring wells.
- The nature and distribution of VOCs in soil vapor within the potential migration pathways was determined through the collection of soil vapor samples from monitoring wells and analysis for site-specific VOCs.
- The presence of VOCs in soil and groundwater along potential vapor migration pathways was determined by soil and groundwater sampling and laboratory analysis for site-specific VOCs.

TCE (and its associated degradation products) is the site-specific VOC that is most widely present and has the greatest potential for vapor migration. VOC concentrations in surface soil are below residential health-based levels of concern.[2] TCE concentrations in subsurface soil were, in some cases, above the industrial health-based level of concern.[2] The presence of groundwater and detectable TCE concentrations in groundwater was limited to near sewer lines (MW-101, MW-102, MW-104, and MW-106). Detectable concentrations of TCE are present in soil vapor in more permeable zones along the northern and eastern facility boundaries and along sewer lines. TCE concentrations in soil vapor were generally greater in the deeper more permeable zones, but the highest TCE concentrations in soil vapor were detected near sewer lines (MW-118S and MW-105 [Bent Tree manhole]), which is a likely source and migration pathway identified. The investigation data show upward migration of soil vapor in the subsurface is inhibited by the low-permeability clay soil directly below the ground surface.
The investigation was not intended to identify all of the source(s) of TCE detected in soil vapor, but did identify the sewer lines as a likely conduit from which TCE releases to the environment occurred.

The recommended path forward is to perform an investigation beneath the former manufacturing building to identify additional potential sources(s) of TCE detected in soil vapor at the facility boundary and along sewer lines. An addendum to the Sitewide Investigation Work Plan (CH2M 2016a) will define the scope and objectives of the proposed investigation beneath the former manufacturing building.

[2] Health-based levels were developed by EPA based on current toxicity information for human health protection. EPA has determined that these levels are protective of individuals who may be exposed to chemicals through ingestion, dermal contact, and inhalation. Levels are available at https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017.
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SECTION 6

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Tables

Table 2-1. Well Construction Details

Phase 1 Sitewide Soil Vapor Investigation Report

221 Sunset Drive, Camdenton, Missouri

Location ID	Designation	Total Boring Depth (feet bgs)	Diameter (inches)	Material	Well Screen Slot (inches)	Screen Length (feet)	Well Screen Interval (feet bgs)			Surface Completion	Measured Total Well Depth (feet btoc)
MW-108D	Deep	31.0	2	SCH40 PVC	0.02	10	20	-	30	Flush	30.22
MW-108S	Shallow	16.1	2	SCH40 PVC	0.02	5	10	-	15	Flush	15.00
MW-109D	Deep	27.0	2	SCH40 PVC	0.02	10	16	-	26	Flush	26.08
MW-109S	Shallow	11.0	2	SCH40 PVC	0.02	5	5	-	10	Flush	9.72
MW-110D	Deep	21.0	2	SCH40 PVC	0.02	10	10	-	20	Flush	19.96
MW-110S	Shallow	11.0	2	SCH40 PVC	0.02	5	5	-	10	Flush	9.20
MW-111D	Deep	23.0	2	SCH40 PVC	0.02	10	12	-	22	Flush	22.09
MW-111S	Shallow	13.0	2	SCH40 PVC	0.02	5	7	-	12	Flush	11.63
MW-112D	Deep	31.5	2	SCH40 PVC	0.02	10	20	-	30	Flush	29.81
MW-112S	Shallow	12.0	2	SCH40 PVC	0.02	5	6	-	11	Flush	10.70
MW-113D	Deep	23.0	2	SCH40 PVC	0.02	5	16	-	21	Flush	20.72
MW-113S	Shallow	13.0	2	SCH40 PVC	0.02	5	7	-	12	Flush	11.64
MW-114D	Deep	31.0	2	SCH40 PVC	0.02	10	20	-	30	Flush	29.91
MW-114S	Shallow	19.0	2	SCH40 PVC	0.02	10	8	-	18	Flush	17.71
MW-115D	Deep	37.0	2	SCH40 PVC	0.02	10	25	-	35	Flush	34.79
MW-116D	Deep	31.0	2	SCH40 PVC	0.02	10	20	-	30	Flush	30.18
MW-116S	Shallow	16.0	2	SCH40 PVC	0.02	5	10	-	15	Flush	14.88
MW-117S	Shallow	16.0	2	SCH40 PVC	0.02	10	5	-	15	Flush	14.62
MW-118S	Shallow	16.0	2	SCH40 PVC	0.02	10	5	-	15	Flush	14.62
MW-119D	Deep	41.0	2	SCH40 PVC	0.02	10	28	-	38	Flush	40.24
MW-119S	Shallow	21.0	2	SCH40 PVC	0.02	10	10	-	20	Flush	20.16

Notes:

bgs = below ground surface

btoc = below top of casing

SCH40 PVC = Schedule 40 polyvinyl chloride

Table 2-2. Sampling and Analysis Summary

Phase 1 Sitewide Soil Vapor Investigation Report

221 Sunset Drive, Camdenton, Missouri

Soil Boring Samples

Location ID	VOC Method 8260C Surface (0-1 ft bgs)	VOC Method 8260C Subsurface (> 1 ft bgs)	Subtotal	Total Organic Carbon (Lloyd Kahn Method)
SB-108D	1	3	4	0
SB-109D	1	3	4	0
SB-110D	1	3	4	0
SB-111D	1	3	4	0
SB-112D	1	3	4	0
SB-113D	1	3	4	0
SB-114D	0	4	4	0
SB-115D	0	6	6	6
SB-116D	1	3	4	0
SB-117S	0	3	3	3
SB-118S	0	3	3	3
SB-119D	0	3	3	3

Monitoring Well Samples

Location ID	Sample Type	(VOC Method 8260B)[1]	(VOC Method TO-15)[2]
MW-108S	Soil Vapor	0	1
MW-108D	Soil Vapor	0	1
MW-109S	Soil Vapor	0	1
MW-109D	Soil Vapor	0	1
MW-110S	Soil Vapor	0	1
MW-110D	Soil Vapor	0	1
MW-111S	Soil Vapor	0	1
MW-111D	Soil Vapor	0	1
MW-112S	Soil Vapor	0	1
MW-112D	Soil Vapor	0	1
MW-113S	Soil Vapor	0	1
MW-113D	Soil Vapor	0	1
MW-114S	Soil Vapor	0	1
MW-114D	Soil Vapor	0	1
MW-115D	Soil Vapor	0	1
MW-116S	Soil Vapor	0	1
MW-116D	Soil Vapor	0	1
MW-117S	Soil Vapor	0	1
MW-118S	Soil Vapor	0	1
MW-119S	Soil Vapor	0	1
MW-119D	Soil Vapor	0	1
MW-100	Soil Vapor	0	1
MW-101	Soil Vapor	0	1
MW-102	Groundwater	1	0
MW-103	Soil Vapor	0	1
MW-104	Soil Vapor	0	1
MW-105	Soil Vapor	0	1
MW-106	Groundwater	1	0
MW-107	Soil Vapor	0	1

Notes:

ft bgs = feet below ground surface

VOC - volatile organic compound

[1] Groundwater samples collected only if a well yielded water at the time of sampling.

[2] Vapor samples collected if well screen was not fully submerged in water.

Table 3-1. Soil Vapor Sampling Results

Phase 1 Sitewide Soil Vapor Investigation Report

221 Sunset Drive, Camdenton, Missouri

Location ID	Sample ID	Date	Well Screen Interval (feet bgs)			Chemical: 1,1,1-Trichloroethane	1,1-Dichloroethane	1,1-Dichloroethene	cis-1,2-Dichloroethene	Methylene Chloride	Tetrachloroethene	trans-1,2-Dichloroethene	Trichloroethene	Vinyl Chloride
Shallow Soil Vapor														
MW-100	MW100-SV-6.3-16.3-092816	9/28/2016	6.3	-	16.3	502 U	373 U	365 U	**4680**	3200 U	624 U	365 U	**56300**	235 U
MW-103	MW103-SV-3.7-8.7-092916	9/29/2016	3.7	-	8.7	65.5 U	48.6 U	47.6 U	**42.3 J**	417 U	81.4 U	47.6 U	**7260**	30.7 U
	MW103-SV-3.7-8.7-092916-FD	9/29/2016	3.7	-	8.7	65.5 U	48.6 U	47.6 U	**28.7 J**	417 U	81.4 U	47.6 U	**7540**	30.7 U
MW-104	MW104-SV-3.7-5.7-092916	9/29/2016	3.7	-	5.7	11.3 U	8.4 U	8.23 U	**19.2**	72.1 U	14.1 U	8.23 U	**150**	5.3 U
MW-107	MW107-SV-4.7-14.7-093016	9/30/2016	4.7	-	14.7	11.8 U	8.73 U	8.55 U	8.55 U	74.9 U	14.6 U	8.55 U	**5.84 J**	5.51 U
MW-108S	MW108S-SV-10-15-101116	10/11/2016	10	-	15	74.4 U	55.2 U	54 U	54 U	474 U	92.4 U	54 U	**5260 J**	34.8 U
MW-109S	MW109S-SV-5-10-100316	10/3/2016	5	-	10	76 U	56.4 U	55.3 U	**24.3 J**	484 U	94.5 U	55.3 U	**2800**	35.6 U
MW-110S	MW110S-SV-5-10-100416	10/4/2016	5	-	10	1300 U	963 U	944 U	**4560**	8270 U	1610 U	944 U	**134000**	608 U
MW-111S	MW111S-SV-7-12-100516	10/5/2016	7	-	12	68.3 U	50.6 U	49.6 U	49.6 U	435 U	84.9 U	49.6 U	**3510**	32 U
MW-112S	MW112S-SV-6-11-100516	10/5/2016	6	-	11	31.8 U	23.6 U	23.1 U	23.1 U	202 U	39.5 U	23.1 U	**3120**	14.9 U
MW-113S	MW113S-SV-7-12-100316	10/3/2016	7	-	12	2190 U	1620 U	1590 U	1590 U	13900 U	2720 U	1590 U	**255000**	1020 U
MW-114S	MW114S-SV-8-18-100216	10/2/2016	8	-	18	347 U	257 U	252 U	252 U	2210 U	431 U	252 U	**49500**	163 U
MW-116S	MW116S-SV-10-15-101216	10/12/2016	10	-	15	68.3 U	50.6 U	49.6 U	49.6 U	435 U	**39.1 J**	49.6 U	**8680**	32 U
MW-117S	MW117S-SV-5-15-101616	10/16/2016	5	-	15	20 U	14.8 U	14.5 U	14.5 U	127 U	24.8 U	14.5 U	**2180**	9.36 U
MW-118S	MW118S-SV-5-15-101616	10/16/2016	5	-	15	11600 U	8600 U	8430 U	**231000**	73900 U	14400 U	8430 U	**1270000**	5430 U
MW-119S	MW119S-SV-10-20-101716	10/17/2016	10	-	20	21.9 U	16.3 U	15.9 U	15.9 U	140 U	27.2 U	15.9 U	**2550**	10.3 U
	MW119S-SV-10-20-101716-FD	10/17/2016	10	-	20	21.9 U	16.2 U	15.9 U	15.9 U	139 U	27.2 U	15.9 U	**2530**	10.2 U
Deep Vapor Samples														
MW-101	MW101-SV-23.7-33.7-092816	9/28/2016	23.7	-	33.7	871 U	646 U	633 U	**59300**	5550 U	1080 U	**4270**	**132000**	**460**
MW-105	MW105-SV-10.7-20.7-092916	9/29/2016	10.7	-	20.7	5550 U	4120 U	4030 U	**130000**	35300 U	6900 U	**1890 J**	**726000**	2600 U
MW-108D	MW108D-SV-20-30-100516	10/5/2016	20	-	30	1390 U	1030 U	1010 U	1010 U	8830 U	1720 U	1010 U	**116000**	650 U
MW-109D	MW109D-SV-16-26-100316	10/3/2016	16	-	26	5610 U	4160 U	4070 U	**1380 J**	35700 U	6970 U	4070 U	**447000**	2630 U
MW-110D	MW110D-SV-10-20-100416	10/4/2016	10	-	20	1310 U	972 U	952 U	**1750**	8340 U	1630 U	952 U	**145000**	614 U
MW-111D	MW111D-SV-12-22-100516	10/5/2016	12	-	22	1170 U	865 U	847 U	847 U	7420 U	1450 U	847 U	**9180**	546 U
MW-112D	MW112D-SV-20-30-100516	10/5/2016	20	-	30	2020 U	1500 U	1470 U	1470 U	12900 U	2510 U	1470 U	**255000**	946 U
MW-113D	MW113D-SV-16-21-100116	10/1/2016	16	-	21	497 U	369 U	361 U	**278 J**	3170 U	618 U	361 U	**91800**	233 U
MW-114D	MW114D-SV-20-30-100216	10/2/2016	20	-	30	2940 U	2180 U	2130 U	**1540 J**	18700 U	3650 U	2130 U	**360000**	1380 U
MW-115D	MW115D-SV-25-35-101316	10/13/2016	25	-	35	73.8 U	54.8 U	53.6 U	53.6 U	470 U	91.8 U	53.6 U	**8030**	34.6 U
MW-116D	MW116D-SV-20-30-101216	10/12/2016	20	-	30	207 U	154 U	150 U	150 U	1320 U	257 U	150 U	**31400**	97 U
MW-119D	MW119D-SV-28-38-101716	10/17/2016	28	-	38	139 U	103 U	101 U	101 U	883 U	173 U	101 U	**16600**	65 U
	MW119D-SV-28-38-101716-FD	10/17/2016	28	-	38	139 U	103 U	101 U	101 U	883 U	173 U	101 U	**16800**	65 U

Notes:

Results are presented in micrograms per cubic meter ($\mu g/m^3$).

Bold result indicates that the chemical was detected at the value reported.

J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

U = The analyte was analyzed for but was not detected above the reported sample quantitation limit.

bgs = below ground surface

Table 3-2. Frequency of VOC Detections in Soil Vapor, Soil, and Groundwater

Phase 1 Sitewide Soil Vapor Investigation Report

221 Sunset Drive, Camdenton, Missouri

Chemical	Frequency of Detection	Number Of Results	Number Of Detects	Number Of Non-Detects	Minimum Detect	Maximum Detect	Minimum Non-Detect	Maximum Non-Detect	Result Units
Soil Vapor									
Tetrachloroethene	3.7%	27	1	26	39.1	39.1	14.1	14400	µg/m^3
Vinyl Chloride	3.7%	27	1	26	460	460	5.3	5430	µg/m^3
trans-1,2-Dichloroethene	7.4%	27	2	25	1890	4270	8.23	8430	µg/m^3
cis-1,2-Dichloroethene	44.4%	27	12	15	19.2	231000	8.55	1590	µg/m^3
Trichloroethene	100%	27	27	0	5.84	1270000	NA	NA	µg/m^3
Surface Soil									
Methylene Chloride	28.6%	7	2	5	56.3	75	87	140	µg/kg
Subsurface Soil									
cis-1,2-Dichloroethene	5%	40	2	38	98.9	387	37	82	µg/kg
Methylene Chloride	25%	40	10	30	33.5	96.3	82	160	µg/kg
Trichloroethene	37.5%	40	15	25	11.6	1260	37	72	µg/kg
Groundwater									
1,1-Dichloroethane	16.7%	6	1	5	0.032	0.032	0.1	0.1	µg/L
Tetrachloroethene	16.7%	6	1	5	0.18	0.18	0.1	0.1	µg/L
1,1-Dichloroethene	50%	6	3	3	0.22	0.5	0.1	0.1	µg/L
trans-1,2-Dichloroethene	50%	6	3	3	1	2.1	0.1	0.1	µg/L
Vinyl Chloride	50%	6	3	3	0.2	0.63	0.1	0.1	µg/L
cis-1,2-Dichloroethene	83.3%	6	5	1	0.082	270	0.1	0.1	µg/L
Trichloroethene	100%	6	6	0	0.12	140	NA	NA	µg/L

Notes:

NA = Not applicable

µg/kg = micrograms per kilogram

µg/L = micrograms per liter

µg/m^3 = micrograms per cubic meter

Table 3-3. Soil Vapor Flow Rates

Phase 1 Sitewide Soil Vapor Investigation Report

221 Sunset Drive, Camdenton, Missouri

Well ID	**Average flow[1] (SCFM)**			**Average Flow[2] (SCFM)**	
Differential Pressure (in. W.C.) -->	**@ -1**	**@ -2**	**@ -3**	**@ -1**	**@ -3**
MW-105	3.98	1.44	0.51	--	--
MW-108D	1.94	2.49	3.15	--	5.70
MW-109S	8.45	10.89	14.89	--	--
MW-109D	2.01	3.24	2.02	--	--
MW-110D	3.64	5.35	3.06	4.03	3.99
MW-111D	3.53	5.22	9.63	4.85	12.85
MW-112S	1.86	2.54	0.74	--	--
MW-112D	2.40	2.29	2.82	--	--
MW-113S	2.04	2.97	1.98	--	--
MW-113D	22.58	27.48	35.12	--	--
MW-114S	4.04	3.76	3.14	--	--
MW-114D	2.38	2.75	3.30	--	--
MW-115D	2.93	3.34	3.43	--	--
MW-117S	3.62	2.97	5.65	--	--
MW-118S	31.62	27.17	23.85	--	25.33

Notes:

in. W.C. = inches of water column (differential pressure)

SCFM = standard cubic feet per minute

-- = flow rate not calculated

1 "Hg = 0.49 psi

ID of 2-inch SCH 80 = 2.067 inches

Flow Coefficient (K) = 0.64

Specific gravity of air @ 60°F = 1.000

[1]Flow rate calculated using readings collected from a Dwyer DS-300 Flow Sensor

[2] Flow rate calculated using readings collected from a TSI Veloci Calc Plus 8360 flow sensor

Maximum manifold flow rate (not attached to well) = ~130 SCFM

Table 3-4. Surface Soil Sampling Results

Phase 1 Sitewide Soil Vapor Investigation Report

221 Sunset Drive, Camdenton, Missouri

			Chemical:	**1,1,1-Trichloroethane**	**1,1-Dichloroethane**	**1,1-Dichloroethene**	**cis-1,2-Dichloroethene**	**Methylene Chloride**	**Tetrachloroethene**	**trans-1,2-Dichloroethene**	**Trichloroethene**	**Vinyl Chloride**
			Screening Level	**3600**	**16**	**100**	**230**	**320**	**39**	**2300**	**1.9**	**1.7**
Location ID	**Sample ID**	**Date**	**Depth (feet bgs)**									
SB-108D	SB108D-SO-1-093016	9/30/2016	1	0.071 U	0.071 U	0.071 U	0.071 U	0.14 U	0.071 U	0.071 U	0.071 U	0.071 U
SB-109D	SB109D-SO-1-100116	10/1/2016	1	0.057 U	0.057 U	0.057 U	0.057 U	0.11 U	0.057 U	0.057 U	0.057 U	0.057 U
SB-110D	SB110D-SO-1-100216	10/2/2016	1	0.047 U	0.047 U	0.047 U	0.047 U	0.094 U	0.047 U	0.047 U	0.047 U	0.047 U
SB-111D	SB111D-SO-1-100316	10/3/2016	1	0.05 U	0.05 U	0.05 U	0.05 U	0.099 U	0.05 U	0.05 U	0.05 U	0.05 U
SB-112D	SB112D-SO-1-100416	10/4/2016	1	0.043 U	0.043 U	0.043 U	0.043 U	0.087 U	0.043 U	0.043 U	0.043 U	0.043 U
SB-113D	SB113D-SO-1-092716	9/27/2016	1	0.05 U	0.05 U	0.05 U	0.05 U	**0.0563 J**	0.05 U	0.05 U	0.05 U	0.05 U
SB-116D	SB116D-SO-1-101116	10/11/2016	1	0.063 U	0.063 U	0.063 U	0.063 U	**0.075 J**	0.063 U	0.063 U	0.063 U	0.063 U

Notes:

Results are presented in milograms per kilogram (mg/kg).

Bold result indicates that the chemical was detected at the value reported.

Screening Level = June 2017 Industrial Soil Regional Screening Levels (Hazard Index = 0.1) (mg/kg)

J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

U = The analyte was analyzed for but was not detected above the reported sample quantitation limit.

bgs = below ground surface

Table 3-5. Subsurface Soil Sampling Results
Phase 1 Sitewide Soil Vapor Investigation Report
221 Sunset Drive, Camdenton, Missouri

Location ID	Sample ID	Date	Chemical: Screening Level Depth (feet bgs)	1,1,1-Trichloroethane 3600	1,1-Dichloroethane 16	1,1-Dichloroethene 100	cis-1,2-Dichloroethene 230	Methylene Chloride 320	Tetrachloroethene 39	trans-1,2-Dichloroethene 2300	Trichloroethene 1.9	Vinyl Chloride 1.7
SB-108D	SB108D-SO-13-093016	9/30/2016	13	0.055 U	0.055 U	0.055 U	0.055 U	0.11 U	0.055 U	0.055 U	**0.0168 J**	0.055 U
SB-108D	SB108D-SO-24-093016	9/30/2016	24	0.076 U	0.076 U	0.076 U	0.076 U	0.15 U	0.076 U	0.076 U	**0.0527 J**	0.076 U
	SB108D-SO-24-093016-FD	9/30/2016	24	0.083 U	0.083 U	0.083 U	0.083 U	0.17 U	0.083 U	0.083 U	**0.0501 J**	0.083 U
SB-108D	SB108D-SO-34-093016	9/30/2016	34	0.047 U	0.047 U	0.047 U	0.047 U	0.094 U	0.047 U	0.047 U	0.047 U	0.047 U
SB-109D	SB109D-SO-5-100116	10/1/2016	5	0.058 U	0.058 U	0.058 U	0.058 U	0.12 U	0.058 U	0.058 U	0.058 U	0.058 U
SB-109D	SB109D-SO-21-100116	10/1/2016	21	0.044 U	0.044 U	0.044 U	0.044 U	0.088 U	0.044 U	0.044 U	**0.028 J**	0.044 U
SB-109D	SB109D-SO-24-100116	10/1/2016	24	0.052 U	0.052 U	0.052 U	0.052 U	0.1 U	0.052 U	0.052 U	**0.0182 J**	0.052 U
SB-110D	SB110D-SO-6.5-100216	10/2/2016	6.5	0.052 U	0.052 U	0.052 U	0.052 U	0.1 U	0.052 U	0.052 U	0.052 U	0.052 U
SB-110D	SB110D-SO-9-100216	10/2/2016	9	0.072 U	0.072 U	0.072 U	0.072 U	0.14 U	0.072 U	0.072 U	0.072 U	0.072 U
SB-110D	SB110D-SO-17-100216	10/2/2016	17	0.046 U	0.046 U	0.046 U	0.046 U	0.092 U	0.046 U	0.046 U	0.046 U	0.046 U
SB-111D	SB111D-SO-8-100316	10/3/2016	8	0.057 U	0.057 U	0.057 U	0.057 U	0.11 U	0.057 U	0.057 U	0.057 U	0.057 U
SB-111D	SB111D-SO-17-100316	10/3/2016	17	0.043 U	0.043 U	0.043 U	0.043 U	0.086 U	0.043 U	0.043 U	0.043 U	0.043 U
	SB111D-SO-17-100316-FD	10/3/2016	17	0.056 U	0.056 U	0.056 U	0.056 U	0.11 U	0.056 U	0.056 U	0.056 U	0.056 U
SB-111D	SB111D-SO-20-100316	10/3/2016	20	0.044 U	0.044 U	0.044 U	0.044 U	0.089 U	0.044 U	0.044 U	0.044 U	0.044 U
SB-112D	SB112D-SO-19-100416	10/4/2016	19	0.052 U	0.052 U	0.052 U	0.052 U	0.1 U	0.052 U	0.052 U	0.052 U	0.052 U
SB-112D	SB112D-SO-27-100416	10/4/2016	27	0.041 U	0.041 U	0.041 U	0.041 U	0.082 U	0.041 U	0.041 U	**0.0423**	0.041 U
SB-112D	SB112D-SO-34-100416	10/4/2016	34	0.082 U	0.082 U	0.082 U	0.082 U	0.16 U	0.082 U	0.082 U	**0.267**	0.082 U
SB-113D	SB113D-SO-15-092716	9/27/2016	15	0.055 U	0.055 U	0.055 U	0.055 U	**0.054 J**	0.055 U	0.055 U	**0.0116 J**	0.055 U
SB-113D	SB113D-SO-17-092716	9/27/2016	17	0.052 U	0.052 U	0.052 U	0.052 U	**0.0636 J**	0.052 U	0.052 U	**0.0207 J**	0.052 U
SB-113D	SB113D-SO-21-092716	9/27/2016	21	0.037 U	0.037 U	0.037 U	0.037 U	**0.0335 J**	0.037 U	0.037 U	0.037 U	0.037 U
SB-114D	SB114D-SO-2.5-092816	9/28/2016	2.5	0.06 U	0.06 U	0.06 U	0.06 U	**0.0785 J**	0.06 U	0.06 U	0.06 U	0.06 U
SB-114D	SB114D-SO-10-092816	9/28/2016	10	0.066 U	0.066 U	0.066 U	0.066 U	**0.0963 J**	0.066 U	0.066 U	**0.0164 J**	0.066 U
SB-114D	SB114D-SO-22-092816	9/28/2016	22	0.069 U	0.069 U	0.069 U	0.069 U	**0.0632 J**	0.069 U	0.069 U	**0.0507 J**	0.069 U
SB-114D	SB114D-SO-27-092816	9/28/2016	27	0.077 U	0.077 U	0.077 U	0.077 U	**0.0962 J**	0.077 U	0.077 U	**0.244**	0.077 U
SB-115D	SB115D-SO-10-101216	10/12/2016	10	0.041 U	0.041 U	0.041 U	0.041 U	0.082 U	0.041 U	0.041 U	0.041 U	0.041 U
	SB115D-SO-10-101216-FD	10/12/2016	10	0.04 U	0.04 U	0.04 U	0.04 U	0.081 U	0.04 U	0.04 U	0.04 U	0.04 U
SB-115D	SB115D-SO-26-101216	10/12/2016	26	0.057 U	0.057 U	0.057 U	0.057 U	0.11 U	0.057 U	0.057 U	0.057 U	0.057 U
SB-115D	SB115D-SO-32-101216	10/12/2016	32	0.05 U	0.05 U	0.05 U	0.05 U	0.1 U	0.05 U	0.05 U	0.05 U	0.05 U
SB-115D	SB115D-SO-46-101216	10/12/2016	46	0.055 U	0.055 U	0.055 U	0.055 U	0.11 U	0.055 U	0.055 U	**0.034 J**	0.055 U
SB-115D	SB115D-SO-57-101216	10/12/2016	57	0.056 U	0.056 U	0.056 U	0.056 U	0.11 U	0.056 U	0.056 U	0.056 U	0.056 U
SB-115D	SB115D-SO-62-101216	10/12/2016	62	0.05 U	0.05 U	0.05 U	0.05 U	0.1 U	0.05 U	0.05 U	0.05 U	0.05 U
SB-116D	SB116D-SO-15-101116	10/11/2016	15	0.042 U	0.042 U	0.042 U	0.042 U	**0.0686 J**	0.042 U	0.042 U	0.042 U	0.042 U
SB-116D	SB116D-SO-18-101116	10/11/2016	18	0.062 U	0.062 U	0.062 U	0.062 U	**0.0951 J**	0.062 U	0.062 U	0.062 U	0.062 U
SB-116D	SB116D-SO-26-101116	10/11/2016	26	0.044 U	0.044 U	0.044 U	0.044 U	**0.068 J**	0.044 U	0.044 U	0.044 U	0.044 U
SB-117S	SB117S-SO-2-101516	10/15/2016	2	0.051 U	0.051 U	0.051 U	0.051 U	0.1 U	0.051 U	0.051 U	0.051 U	0.051 U
SB-117S	SB117S-SO-5-101516	10/15/2016	5	0.061 U	0.061 U	0.061 U	0.061 U	0.12 U	0.061 U	0.061 U	0.061 U	0.061 U
SB-117S	SB117S-SO-13-101516	10/15/2016	13	0.058 U	0.058 U	0.058 U	0.058 U	0.12 U	0.058 U	0.058 U	0.058 U	0.058 U
	SB117S-SO-13-101516-FD	10/15/2016	13	0.058 U	0.058 U	0.058 U	0.058 U	0.12 U	0.058 U	0.058 U	0.058 U	0.058 U
SB-118S	SB118S-SO-9-101616	10/16/2016	9	0.064 U	0.064 U	0.064 U	**0.387**	0.13 U	0.064 U	0.064 U	**1.26**	0.064 U
SB-118S	SB118S-SO-11-101616	10/16/2016	11	0.051 U	0.051 U	0.051 U	0.051 U	0.1 U	0.051 U	0.051 U	**0.0143 J**	0.051 U
SB-118S	SB118S-SO-15-101616	10/16/2016	15	0.059 U	0.059 U	0.059 U	**0.0989**	0.12 U	0.059 U	0.059 U	**0.468**	0.059 U
SB-119D	SB119D-SO-15-101516	10/15/2016	15	0.068 U	0.068 U	0.068 U	0.068 U	0.14 U	0.068 U	0.068 U	0.068 U	0.068 U
SB-119D	SB119D-SO-19-101516	10/15/2016	19	0.067 U	0.067 U	0.067 U	0.067 U	0.13 U	0.067 U	0.067 U	0.067 U	0.067 U
SB-119D	SB119D-SO-32-101516	10/15/2016	32	0.045 U	0.045 U	0.045 U	0.045 U	0.089 U	0.045 U	0.045 U	0.045 U	0.045 U

Notes:
Results are presented in milligrams per kilogram (mg/kg).
Bold result indicates that the chemical was detected at the value reported.
Screening Level = June 2017 Industrial Soil Regional Screening Levels (Hazard Index = 0.1) (mg/kg)
J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample
U = The analyte was analyzed for but was not detected above the reported sample quantitation limit.
bgs = below ground surface

Table 3-6. Total Organic Carbon Sample Results

Phase 1 Sitewide Soil Vapor Investigation Report

221 Sunset Drive, Camdenton, Missouri

Location ID	Sample ID	Date	Depth (feet bgs)	Chemical:	Total Organic Carbon (mg/kg)	Percent Moisture (percent)
SB-115D	SB115D-SO-10-101216	10/12/2016	10		**38100 J**	**12.8**
	SB115D-SO-10-101216-FD	10/12/2016	10		**20600 J**	**11.7**
SB-115D	SB115D-SO-26-101216	10/12/2016	26		**463**	**21.3**
SB-115D	SB115D-SO-32-101216	10/12/2016	32		**349**	**19.8**
SB-115D	SB115D-SO-46-101216	10/12/2016	46		**212**	**28.3**
SB-115D	SB115D-SO-57-101216	10/12/2016	57		**72.1 J**	**10.5**
SB-115D	SB115D-SO-62-101216	10/12/2016	62		**3850**	**1.2**
SB-117S	SB117S-SO-13-101516	10/15/2016	13		**57600 J**	**21.4**
	SB117S-SO-13-101516-FD	10/15/2016	13		**29600 J**	**23.2**
SB-117S	SB117S-SO-2-101516	10/15/2016	2		**26900**	**14**
SB-117S	SB117S-SO-5-101516	10/15/2016	5		**20200**	**8.9**
SB-118S	SB118S-SO-11-101616	10/16/2016	11		**80000**	**15.7**
SB-118S	SB118S-SO-15-101616	10/16/2016	15		**5850**	**13.7**
SB-118S	SB118S-SO-9-101616	10/16/2016	9		**638**	**29.8**
SB-119D	SB119D-SO-15-101516	10/15/2016	15		**1640**	**26.4**
SB-119D	SB119D-SO-19-101516	10/15/2016	19		**406**	**28.2**
SB-119D	SB119D-SO-32-101516	10/15/2016	32		**160 J**	**16.4**

Notes:

Bold result indicates that the chemical was detected at the value reported.

bgs = below ground surface

J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

mg/kg = milligram per kilogram

Table 3-7. Groundwater Sampling Results

Phase 1 Sitewide Soil Vapor Investigation Report

221 Sunset Drive, Camdenton, Missouri

Location ID:			**MW-102**	**MW-106**	
Sample ID:			**MW102-GW-7.7-12.7-100416**	**MW106-GW-5.7-12.7-100416**	**MW106-GW-5.7-12.7-D-100416**
Date:			**10/4/2016**	**10/4/2016**	**10/4/2016**
Well Screen Interval (ft bgs):		**VISL**	**7.7 - 12.7**	**5.7 - 12.7**	**5.7 - 12.7**
Chemical					
1,1,1-Trichloroethane	µg/L	7400	0.1 U	0.1 U	0.1 U
1,1-Dichloroethane	µg/L	7.6	0.1 U	**0.032 J**	**0.032 J**
1,1-Dichloroethene	µg/L	200	0.1 U	**0.5**	**0.46**
cis-1,2-Dichloroethene	µg/L	NA	**0.082 J**	**240**	**260**
Methylene Chloride	µg/L	760	1 U	1 U	1 U
Tetrachloroethene	µg/L	15	0.1 U	0.1 U	0.1 U
trans-1,2-Dichloroethene	µg/L	NA	0.1 U	**1**	**1**
Trichloroethene	µg/L	1.2	**0.12**	**32**	**34**
Vinyl Chloride	µg/L	0.15	0.1 U	**0.49**	**0.5**
Field Parameters					
pH		-	7.14	6.37	-
Conductivity	µS/cm	-	0.584	2.144	-
Temperature	deg C	-	21.64	22.38	-
Oxidation-reduction potential	mV	-	10.6	37.2	-
Dissolved oxygen	mg/L	-	1.73	3.24	-
Turbidity	NTU	-	0.80	8.22	-

Notes:

µg/L = micrograms per liter

Bold result indicates that the chemical was detected at the value reported.

Bold and underlined results indicate that the chemical exceeds the Vapor Intrusion Screening Level.

VISL (Vapor Intrusion Screening Level) = VISLs calculated using the VISL Calculator Version 3.5.1 (May 2016 RSLs); based on a residential scenario, a groundwater temperature = 25 deg C, target risk = 1E-6, and target hazard quotient = 1. Although EPA updated RSLs in June 2017, there were no changes to the RSLs for the site-related VOCs. Therefore, the VISLs presented on this table reflect EPA's most recent RSLs.

J = The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

U = The analyte was analyzed for but was not detected above the reported sample quantitation limit.

bgs = below ground surface

µS/cm = microSiemens per centimeter

deg C = degrees Celsius

mV = millivolts

mg/L = milligrams per liter

NTU = Nephelometric Turbidity Units