

APPENDIX C
EVALUATION OF THE VAPOR INTRUSION PATHWAY

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C.1 . STEP 1: EVALUATE WHETHER THE PATHWAY IS COMPLETE . C-2¶

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Attachment C-1: SOIL VAPOR GAS SAMPLING PROTOCOL . C-5¶

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Figure C-1 . Flowchart for Vapor Intrusio ... [1]

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... [3]

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<#>The locations of the point and area of rel ... [6]

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ATTACHMENT C-1¶

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*Slab Vapor Probes and Sampling Using EPA Method TO-15 to
Support Vapor Intrusion Investigations*

C.1 Introduction and Scope

The procedure used to quantitatively evaluate the vapor intrusion pathway is presented in this appendix. This protocol or other MDNR-approved guidance must be used. Figure C-1 shows the step-by-step approach to evaluate the vapor intrusion pathway. Each of the steps illustrated in the flowchart is described below. Specific equations used to calculate the soil vapor target levels are presented in Appendix B.

For consistency, MDNR prefers that soil vapor sampling be conducted using this protocol unless extenuating circumstances make application impractical.⁵

The objective of this step is to determine whether any of the following vapor intrusion-related pathways are complete:

- Vapor intrusion from sub-surface soils, and
- Vapor intrusion from groundwater.

Determining whether the vapor intrusion pathway is complete typically occurs during the development of the exposure model, (refer to Section 6.1) and is based on a combination of site-specific information and professional judgment.

This protocol does not specifically pertain to sub-slab vapor sampling (a means of collecting soil gas samples from beneath a building via the installation of monitoring points through the foundation of the building). If site conditions warrant collection of sub-slab vapor samples, MDNR recommends that procedures under development by the United States Environmental Protection Agency (“USEPA”) be used. USEPA’s current sub-slab sampling guidance is included as Attachment 1. Sub-slab sampling, whether in accordance with USEPA or other guidance or procedures, must be conducted under a MDNR-approved work plan.

This protocol is designed to facilitate a quantitative evaluation of soil gas. Passive soil gas monitoring is generally a qualitative activity used to guide the installation of permanent sampling points. As such, passive soil gas monitoring may not be used to quantitatively monitor soil gas or assess risks associated with vapor intrusion. Passive soil gas monitoring may be used preliminarily to assist in planning a quantitative soil gas sampling event.

⁵ MDNR anticipates the US EPA will issue new guidance regarding petroleum vapor intrusion in early 2013. The MDNR may subsequently revise this appendix after discussion with stakeholders, public notice and rulemaking.

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Soil Gas Sampling Protocol[¶]
January 1, 2013[¶]

Deleted: The Missouri Risk-Based Corrective Action (MRBCA) Process for Petroleum Storage Tanks (January 2004) guidance document (“Guidance”) requires evaluation of the indoor air inhalationvapor intrusion pathway at sites having petroleum contamination in soil, groundwater, or both. For sites where the indoor air inhalationvapor intrusion pathway is complete currently or in the future and soil or groundwater representative concentrations exceed Tier 1 or Tier 2 Site-Specific Target Levels (“SSTLs”) for the indoor air inhalationvapor intrusion pathway, the guidance allows the pathway to be further evaluated through soil gas sampling. Such sampling must be conducted in accordance with the provisions of this protocol or under other approved guidance. If sampling is conducted in accordance with this protocol, the work plan need not be submitted to and approved by the Missouri Department of Natural Resources (MDNR). However, if the work plan is based on guidance other than or in addition to this guidance, the work plan must be approved by MDNR prior to implementation.[¶]

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Deleted: The purpose of this document is to provide guidance for conducting soil gas sampling at petroleum storage tank sites. The routine evaluation of the indoor inhalationvapor intrusion pathway at contaminated sites is a relatively recent development. As a result, methods, procedures, and technology related to evaluating the pathway continue to evolve. While this guidance is, in part, prescriptive, MDNR does not intend for this guidance to be overly limiting with respect to the use of other appropriate methods, procedures, and equipment for measuring concentrations of chemicals of concern in soil gas. Even so, departures from this guidance must be present ... [8]

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A work plan is required for all soil gas sampling at MRBCA sites. The work plan must should be submitted to and approved by MDNR prior to the occurrence of the soil gas sampling event.[¶]

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Deleted: This protocol is not intended to prohibit those conducting evaluations under the MRBCA process from using means other than those specified herein to measure soil gas concentrations at a petroleum storage tank site. However, depart ... [9]

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C.2. Soil Gas Probe Installation

C.2.1 Installation Requirements.

- A. The Missouri Well Construction Rules at 10 CSR 23-1.010 through 10 CSR 23-6.060 govern the installation and abandonment of monitoring wells, the definition of which includes wells used for soil gas monitoring. Refer to these rules prior to installing soil gas sampling points in the field.

C.2.2 Sampling Depth.

- A. To the extent possible, soil gas sample depths should be chosen to minimize the effects of changes in barometric pressure, temperature, or breakthrough of ambient air from the surface, and to ensure that consistent and representative samples are collected. In determining appropriate sampling depths, strong consideration should be given to the lithology of the subsurface. Under no circumstances may soil gas samples be collected from a depth of less than 18 inches.
- B. Soil gas sampling depths must be consistent from sampling point to sampling point. Samples may be collected at multiple depths (see C.2.2.C below) but, in comparing data, be certain that all of the data used in the comparison was collected from a consistent depth; for instance, do not compare soil vapor data collected at 60 inches with data collected from 18 inches.
- C. Generally, soil gas samples must be collected at a minimum of two discrete depths at each sampling point. Where contamination in soil is very shallow or groundwater is very shallow (i.e., less than approximately 5 feet below the ground surface), one sample from a single depth might be sufficient.
- D. One of the two soil gas samples collected at each sampling point must be collected at a depth no greater than 3 feet below the foundation of the enclosed space or potential future enclosed space. The depth at which the second sample is collected will be dependent on site conditions, primarily the depth to contamination.
- E. For structures having basements, one or more soil gas samples must be collected adjacent to basement walls (i.e., no further than 5 feet from the

Deleted: <#>Installation of monitoring wells greater than 10 feet in depth and having a riser less than 2 inches in diameter or installed in a borehole less than 6 inches in diameter require a variance issued by MDNR's Geological Survey and Resources Assessment Division (GSRAD).¶

wall and, generally, at a depth approximately equal to the midpoint of the wall; this depth might need to vary depending on the characteristics of the structure). Unless soil or groundwater contamination is found below the building, soil gas sampling adjacent to the basement walls need only occur on the side or sides of the building where the contamination is found (e.g., if the soil or groundwater contamination is south of the building, soil gas sampling must, at a minimum, occur on the south side of the building). If soil or groundwater contamination is found below the elevation of the basement floor, soil gas samples must also be collected just below the elevation of the floor.

- F. For structures without basements, soil gas samples should be collected below the depth of the foundation, with the first sample collected at a depth of no more than 3 feet [below the bottom of the foundation](#).
- G. For hypothetical future buildings, if there is no other information available to select depth, soil vapor samples should be taken at target depths of approximately 3 feet and 10 feet below ground surface⁷. This method assures that data is available to assess vapor intrusion threats to both “slab-on-grade” buildings and those having basements. If groundwater is too shallow to allow sampling at one or both of these depths, samples should be collected immediately above the capillary fringe or the top of soil contamination. If soil contamination extends to the surface, sample at a depth approximately equal to the anticipated depth of the future structure’s foundation.
- H. In all cases, if groundwater is too shallow to allow soil gas sampling at the depths specified above, samples shall be collected immediately above the capillary fringe⁸. If soil contamination extends to the surface, sample at a depth just below the expected or actual foundation or floor of the structure.

C.2.3 Lateral Spacing of Soil Gas Sampling Points

⁷ [When sampling to evaluate the potential for vapor intrusion into future buildings, unless physical site constraints or an activity and use limitation prevents where and what type of building may be constructed on the property, the sampler must assume a building with a basement and a building without a basement could be built anywhere on the site, including within all areas of contamination, and collect samples accordingly.](#)

⁸ [In some cases where groundwater is very shallow, the capillary fringe might extend to or very near the ground surface. In such cases, soil vapor sampling may not be possible.](#)

- A. Soil gas sampling is intended to assess vapor intrusion threats from soil and groundwater to existing ~~and~~ hypothetical future buildings. Therefore, sampling points should be laterally spaced to adequately represent soil gas concentrations proximate to such structures, taking into consideration the location of contamination relative to the structures. The actual number of soil gas sampling points necessary for a given site will depend on the size and number of buildings, the location of the buildings relative to soil and groundwater contamination, and, for the evaluation of hypothetical future structures, the extent or size of the contamination plume. The following provisions should be considered as general guidelines rather than specific requirements. The locations and spacing of soil gas sampling points will ultimately be dependent on site-specific characteristics.
- B. Generally, soil gas sampling points should be located along each side of each existing building that is proximate to soil or groundwater contamination. In addition, for existing buildings, samples should be collected above the area of highest contamination. However, if contamination is located to one side of an existing structure, the collection of samples only from that side of the structure might be adequate. If any wall of the structure exceeds 50 feet in length, a minimum of two sampling points is required along that wall.
- C. To assess vapor intrusion threats to future structures, sampling points must be installed in the area having the highest contaminant concentrations on the site. Generally, four sampling points should be utilized to evaluate future structures. However, if the size of the plume exceeds 2,500 square feet, more than four sampling points will be required, with the total number dependent on the overall size of the plume. In general, sampling points should be spaced no greater than 50 feet apart and preferentially placed within the anticipated footprint of the future structure, if known.

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C.2.4 Probe Construction Materials.

- A. Sample probes consist of a probe tip through which the soil gas sample is collected, and probe tubing that extends from the probe tip to the ground surface.
- B. Sample probe tubing should be of a small diameter (1/8 to 1/4 inch). Diameter selection should consider site soil types. In general, smaller tubing diameters can result in higher sample vacuum conditions, which can

make sample collection more difficult. Tubing must be inert and non-adsorptive. Polyethylene and other flexible tubing tend to adsorb COCs and skew results and should not be used.

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- C. The sample probe should be constructed of materials that will not react or interact with target compounds. Suggested materials are nylon, ~~copper~~, ~~Teflon~~, poly vinyl chloride (PVC), ~~and~~ stainless steel. If copper ~~or stainless steel~~ is used, the ~~material~~ must first be adequately cleaned to remove oil residue that might be present from the manufacturing process.

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- D. The probe tip should be covered with fine screen or connected to a short (< 2 feet) section of perforated pipe, glass frit, tubing, or screen mesh.

C.2.5 Probe Installation.

- A. MDNR recommends that permanent probes, wells, or other soil gas sampling devices be installed to allow for the assessment of seasonal variability (a minimum of two soil gas sampling events are required at any site at which soil gas sampling is conducted, as discussed at C.3.2 below). However, data may also be collected from temporary sampling points, such as through the probe rods of a direct push drill machine.

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- B. Boreholes may be installed using direct push or hollow-stem auger drilling equipment or hand-driven using a rotary hammer or a hand auger. Note, however, that direct push probes might not be suitable for all soil conditions, as smearing of the sidewalls can occur in fine-grained soils. Such smearing could preclude passage of vapor from the soil into the borehole.

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- C. Before any drilling activities, utility clearance for the installation area should be obtained. In addition, utilities proximate to the contamination must be identified and assessed as possible soil gas conduits. Utilities near or above contamination must be screened using a PID or FID (as appropriate) and the results recorded.

- D. The borehole is advanced to the target sampling depth. If samples will be collected at multiple depths within the same borehole, the borehole is initially advanced to the deepest sampling point and the deepest sampling point installed first.

- E. The probe tip is placed midway between the top and bottom of the sampling interval within a sand pack extending 6 inches above and below the sampling interval. The grain size of the sand pack should be appropriately sized (for example, no smaller than the adjacent formation) and installed to minimize disruption of airflow to the sampling tip.
- F. At least 1 foot of dry granular bentonite should be placed on top of the sand pack to preclude the infiltration of hydrated bentonite grout into the sand pack. Refer to Figure 1 for an illustration of this sealing method.
- G. The borehole should be grouted to the surface (or, for nested samplers, the bottom of the next sampling interval) with hydrated bentonite. Adequately sealing soil gas sampling probes is very important to minimize the exchange of atmospheric air with the soil gas and to maximize the representativeness of the sample. The surface seal should be a minimum of 2.5 feet thick. If conditions warrant shallow sampling depths, great care should be taken in installing the surface seal to limit atmospheric infiltration.
- H. If multiple sampling points are installed within a single borehole, the borehole must be grouted between sampling points. One foot of dry granular bentonite must be placed between the filter pack and the grout at each sampling location within the borehole, as illustrated by Figure 1.
- I. Tubing must be properly marked at the surface to identify the probe location and depth. Particularly when multiple probes are installed within a single borehole, tubing must be labeled immediately upon installing each separate probe.
- J. To minimize any separation between the soils and the outside of the probe, avoid lateral movement of probes once they have been installed.
- K. Examples of a single depth soil gas probe and a multi-depth or “nested” soil gas probe are shown in Figure 1. Figure 1 is only an example: soil gas sampling points need not necessarily be constructed in strict accordance with the figure.
- L. Documentation of subsurface soil stratigraphy via borehole logging and other methods can be very important in evaluating soil gas data. While delineation of contamination should be largely complete at any site undergoing soil gas sampling, MDNR recommends that soils be logged,

field screened, and sampled for COC analysis during probe installation for the purpose of providing further information regarding the distribution of contamination. Soil stratigraphy data can be very important in determining soil gas fate and transport.

C.2.6 Surface Completion.

- A. Unless soil gas probes are properly abandoned the same day they are installed, probes must be properly secured, capped, and completed to prevent infiltration of water or ambient air into the subsurface and to prevent accidental damage or vandalism. For surface completions, the following components may be installed, as necessary:
 - i. Gas-tight valve or fitting for capping the vapor point;
 - ii. Fitting for connection to above ground sampling equipment;
 - iii. Protective flush mounted or above ground well vaults, and/or
 - iv. Guard posts.

C.2.7 Probe Abandonment

- A. All monitoring wells, including those used for soil gas monitoring, must be abandoned in accordance with Missouri Well Construction Rule 10 CSR 23-4.080, "Plugging of Monitoring Wells." This rule states, in part, that monitoring wells less than 10 feet in depth must be plugged with grout or by returning uncontaminated native material into the hole it was taken from.
- B. 10 CSR 23-4.080 also states, in part, that temporary monitoring wells (i.e., closed within 30 days) greater than 10 feet in depth must be plugged by removing any temporary pipe and filling the well from total depth to 10 feet from the surface with approved grout, with the remainder of the well filled with uncontaminated native material or grout. The plugging of all monitoring wells greater than 10 feet in depth must be reported to MDNR on a registration report form supplied by GSRAD.
- C. A monitoring well that is abandoned in accordance with 10 CSR 23-1.010 must be plugged immediately.

C.3 Sampling Frequency

C.3.1 Factors affecting soil gas values.

A. Certain atmospheric and seasonal factors that are not within human control can affect soil gas values. For instance, temperature, barometric pressure, and precipitation can affect soil gas values as these factors fluctuate over time. Because these factors will fluctuate, actions must be taken to ensure soil gas data collected at a site is representative of a variety of atmospheric conditions. MDNR has determined that the best way to account for these factors is to require multiple soil gas sampling events over time.

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C.3.2 Sampling frequency.

A. At a minimum, two soil gas sampling events must occur, with no less than three months between events. In cases where measured soil gas values vary significantly from the first to the second event, additional sampling may be required. In most cases, the maximum number of sampling events will be four, with events spaced evenly over a period of one year. Samples must be collected from the same location and depth during each sampling event.

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C.3.3 Duplication of sampling events.

A. Under this guidance, soil gas samples may be collected from either permanent or temporary sampling points. Clearly, sampling may be easily duplicated if permanent sampling points are installed. However, if temporary points are used (i.e., those closed within at most 30 days), actions must be taken to ensure that subsequent samples are collected from the same location and depth as the initial samples. To do so, MDNR requires that the location and depth of temporary sampling points be accurately and durably recorded. Sampling points should be marked in the field to ensure that they can be subsequently found. MDNR recommends that the location of each sampling point be recorded using Global Positioning System (GPS) coordinates. GPS coordinates should be accurate to ± 5 feet. The methods used to record the temporary sampling locations and depths and a copy of the actual written record of such information must be included in the soil gas sampling report submitted to MDNR.

C.4 Soil Gas Probe Equilibration and Purging

C.4.1 Monitoring Point Equilibration.

A. During probe installation, subsurface conditions are unavoidably disturbed. The subsurface soil gas profile should be allowed to equilibrate following this disturbance. The following equilibration times are recommended:

- For probes installed using the direct push method, soil gas sampling should not be conducted for at least 30 minutes following probe installation. MDNR recommends waiting several hours.
- For probes installed with hollow stem auger drilling methods, soil gas sampling should not be conducted for at least 48 hours following probe installation.

B. Prior to sampling, soil gas sampling probes should be purged to ensure that stagnant or ambient air is removed from the sampling system and to assure samples collected are representative of subsurface conditions. The following purge procedure is recommended:

- Calculate the volume of the sampling system by summing the volume of the probe screened interval (including filter pack void space, accounting for porosity of sand pack), the volume of tubing from the probe tip to the ground surface, and the volume of above ground tubing connecting the soil probe to the sample collection device.
- Purge the monitoring point until at least three volumes of the full sampling system have been evacuated. Purging should be conducted at flow rates and vacuum conditions similar to those for sample collection (described below).
- If the soil matrix is such that purging as recommended above is not possible due to low or no flow conditions (i.e., gas will not flow or flow is severely restricted), the probe should be advanced deeper to look for zones of higher permeability. If the deeper probe does not encounter a higher permeability zone and low or no flow conditions persist, the probe should be abandoned and a new probe advanced elsewhere on the site.
- If low or no flow conditions are found across the site and soil gas sampling is therefore not possible, an alternative method of soil gas sampling, such as sub-slab sampling, may be proposed. Because sub-slab gas samples are generally extracted from the porous granular material underlying a slab, sub-slab sampling may be a practical

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method of soil gas sampling when subsurface sampling is not. As discussed at C.1 above, if site conditions warrant sub-slab sampling, the sampling should be conducted in accordance with current EPA sub-slab sampling guidance.

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C.5 Soil Gas Sample Collection Procedures

C.5.1 Sample Containers.

- A. Samples may be collected in Tedlar bags or gas-tight syringes if samples are analyzed on-site in a mobile laboratory. Syringes may not be used if samples are analyzed off-site at a fixed laboratory. For samples to be analyzed off-site at a fixed laboratory, Summa canisters or Tedlar bags or equivalent containers may be used. MDNR recommends working with the laboratory that will analyze the samples in choosing appropriate sample containers. MDNR prefers that small volume – 1 L or 500 mL – Summa canisters be used. Certain situations might warrant the use of a larger Summa canister but, in general, the small volume canisters should be used.
- B. The analytical laboratory or other supplier of sample containers must certify that all sample containers supplied by them are free of contaminants at concentrations exceeding contaminant detection levels.

C.5.2 Sampling Flow Rate.

- A. An initial sampling rate of 200 milliliters per minute (mL/min) or less is recommended.
- B. A regulated flow meter should be placed between the probe and the sample container to control and measure the flow rate.
- C. The sampling rate may be modified based on specific field conditions, including the vacuum observed. Data for samples collected at a flow rate exceeding the recommended rate of 200 mL/min shall be flagged in the report submitted to MDNR. MDNR will not necessarily reject flagged data. Flagging is intended to facilitate a more thorough review of the data.

C.5.3 Vacuum Conditions.

- A. To measure sample collection vacuum, a vacuum gauge must be placed between the probe and the sample container. MDNR recommends a sampling vacuum of less than 100 inches of water. Note, however, that when using a Summa canister, the vacuum gauge reading is dominated by

the vacuum in the canister and does not reflect the vacuum at the probe tip. Therefore, with a canister, the vacuum gauge reading becomes meaningless as does the 100 inches of water requirement at C.5.3.C below.

- B. To achieve the target sampling vacuum, the sampling flow rate should be adjusted using the flow regulator.
- C. If the sampling vacuum exceeds 100 inches of water, and a reduction in the sampling flow rate does not reduce the vacuum, continue to attempt to collect the sample, recording flow rate and vacuum conditions. Data for samples collected under a vacuum of greater than 100 inches of water must be flagged. MDNR will not necessarily reject or consider such data suspect; flagging simply facilitates a more thorough review of the data.
- D. If the sample container cannot be filled within an expected time frame, such time being dependent on the size and type of the sample container and sampling equipment (e.g., tube diameter), discontinue sampling and document vacuum observations. Generally, data from samples collected under such conditions will not be valid.

C.5.4 Field Conditions.

- A. Generally, soil gas sampling should not be conducted within 48 hours of a significant precipitation event (for example, 0.5 inch or greater of rain) or comparable on-site watering. However, whether sampling is conducted is dependent on the depth to which soil is wetted relative to the planned depth of sample collection. The depth to which the soil is wetted is dependent, at least in part, on the ground cover, the type of soil, and the soil moisture content prior to the precipitation event. Sampling should not occur if soils are wetted at a depth equal to or greater than the planned sampling depth.

C.5.5 Sample Collection.

- A. Aboveground sampling equipment consists of connector tubing, regulated flow meter, pressure gauge, and purging equipment. An example sampling train is shown in Figure 2.
- B. Connect aboveground sampling equipment to probe at the surface. Check all sampling system connections and fittings for tightness and obvious deterioration.

- C. Quick connect fittings and nylon tubing should be used to ensure vacuum tightness of the system and that chemicals in the air stream are not reacting with or adsorbing to the tubing. Compression fittings should be avoided for all connections except at the Summa canister (if used).
- D. Purge at least three volumes of air from the sampling system as described at C.4.1.B above. After purging is complete, close the valve to the purge line and/or disconnect purge apparatus, as appropriate.
- E. Connect the sample container to the sampling line, using quick-connect, airtight fittings.
- F. Follow the leak test procedures described in Section C.6, below.
- G. Open valve and collect sample into sample container, following the sample flow rate and vacuum guidelines discussed above. During sampling, measure and record sample flow rate and vacuum every two to five minutes.
- H. Disconnect sample container and immediately label the container with sample identification information.
- I. If Summa canisters are used, measure the final pressure of the canister using a pressure gauge. Record the final canister pressure.
- J. Store sample containers out of direct sunlight, and do not chill.

C.5.6 Quality Control Samples.

- A. The collection of at least one field duplicate per sampling event or one per twenty samples, whichever is greater, is required.
- B. Duplicate samples shall be collected in separate sample containers, using the same procedures and at the same location and depth as the original sample.
- C. Preferably, duplicate samples should be collected simultaneous to collection of the primary sample using a sampling tee. Alternatively, the duplicate may be collected immediately after the collection of the primary sample.
- D. At least one equipment blank must be collected per sampling event or per 25 samples, whichever is greater.

C.5.7 Recordkeeping.

The following information should be recorded in a field notebook or on sampling forms (Figure 3 shows an example field form) and reported to MDNR as necessary to document the procedures utilized at a specific site to collect soil gas data.

- A. MDNR recommends using a relatively simple conceptual site model related to the vapor intrusion pathway. Such a model can be very useful before, during, and after a soil gas sampling investigation. The conceptual site model should, at a minimum, include information on the location of utility corridors and other potential preferential pathways for soil gas migration, depth to groundwater, distances between sources and receptors (include both current and potential future structures), and soil type and soil stratigraphy.
- B. Sample identification information, including the locations and depths at which the samples were collected, sample identifiers, date, and time.
- C. Field personnel involved in sample collection.
- D. Weather conditions (e.g., temperature, wind speed, barometric pressure, precipitation, etc.).
- E. Sampling methods, devices, and equipment used.
- F. Purge volumes prior to sample collection. Relate the purge volumes to the volume of the sampling equipment, including the tubing connecting the sampling interval to the surface.
- G. Volume of soil gas extracted (i.e., volume of each sample).
- H. Vacuum of canisters before and after samples collected.
- I. If observable, the apparent moisture content of the sampling zone (e.g., dry, moist, saturated). An alternative to a qualitative measurement of soil moisture is to collect a soil sample from the soil gas sampling interval for laboratory measurement of soil moisture. If a soil sample is collected for this purpose, include a copy of the laboratory data sheet.
- J. Shipment information, including chain of custody protocols and records.

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C.6 Leak Testing

C.6.1 Requirements.

- A. Leakage during soil gas sampling may dilute samples with ambient air and produce results that underestimate actual site concentrations or contaminate the sample with external contaminants. Therefore, MDNR is requiring that a leak test be conducted each time a soil gas sample is collected to determine whether leakage has occurred. Leak testing may be conducted with or without a shroud.
- B. For each sample, use a hand pump to vacuum test the sampling equipment after assembly.
- C. A leak check, or tracer, compound such as isopropanol is recommended to determine if leaks are present. Other compounds such as helium, pentane, isobutane, propane, and butane, may be used as leak check compounds. MDNR may approve the use of other leak check compounds on a request-specific basis. Select a leak check compound that is not known or suspected to be site-related or otherwise associated with the site or nearby properties.
- D. Immediately before sampling, place the leak check compound at each location where ambient air could enter the sampling system or where cross contamination may occur. For liquid compounds (for example, isopropanol), wet a paper towel with the leak check compound and place the towel over each location where ambient air could enter the sampling system. These areas include: the base of the soil probe at ground surface, the connection from the soil gas probe to the sampling line, and any connections within the sampling line. Gaseous leak check compounds require a device to hold the vapor near the test location, such as a shroud at the surface. The type of device and leak check compound to be used must be specified in the soil gas sampling work plan.
- E. The leak check compound must be included in the list of analytes looked for during laboratory analysis of each sample.

C.6.2 Detection of leak check compound.

- A. If greater than 100 ug/L of the leak check compound is detected in a sample, the following actions must be taken:
- Review the analytical results that show a detection of the leak check compound.

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- If a review of the data indicates that the analytical data is accurate, evaluate the cause of the leak through system testing.
- Based on the concentration of the leak check compound detected, evaluate the impacts of the leak on sample collection and sample integrity. Document the findings and the evaluation in the soil gas investigation report submitted to MDNR.
- In certain cases, MDNR will reject data in which a leak check compound has been detected at a concentration in excess of 100 ug/L unless it can be demonstrated that the data remains valid.

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C.7 Laboratory Analysis

C.7.1 Off-site and On-site Analysis.

- A. Samples may be analyzed either off-site in a fixed laboratory or on-site in a mobile laboratory. On-site analyses can provide for a more timely indication of problems with sample system leaks or short-circuiting, thus allowing corrections to be made and resampling to occur while drilling and sampling equipment remains on the site. Whether samples are analyzed on or off-site, the probes from which the samples are collected should either be installed as permanent sampling points or their location clearly and durably marked so that sampling can be duplicated during subsequent gas sampling events. Procedures for on-site sampling and analysis must be clearly documented in the work plan submitted to MDNR and approved by MDNR prior to implementation.

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C.7.2 Analyses Required.

- A. Contaminants of concern (COCs): For petroleum product spills, COCs include benzene, toluene, xylenes, ethylbenzene, MTBE, TPH-GRO, and naphthalene.
- B. Leak test compound. The leak test compound used must be included in the analyses except when the leak testing method used involves real-time monitoring for the leak check compound. Real-time monitoring must be proposed in a work plan submitted to and approved by MDNR.
- C. The entity performing the work may also analyze vapor samples for oxygen, carbon dioxide, nitrogen, methane, and other indicators of the biodegradation of hydrocarbon vapors, though these analyses are not

required. Of these, MDNR recommends analyzing for oxygen and carbon dioxide, at least. If samples for oxygen analysis are collected, the oxygen sample should be collected after the COC sample, as oxygen sampling requires the use of an oxygen meter and pump.

C.7.3 Analytical Methods.

- A. Fixed laboratory analysis: Gas chromatograph by EPA Method TO-14A, TO-15, or an equivalent air analysis method. Summa canisters are required for these analytical methods. SW-846 Methods 8260B and 8021 may be used if detection limits below applicable target levels can be achieved.
- B. On-site laboratory analysis: Gas chromatography using SW-846 Methods 8260B or 8021. Method detection limits must be below applicable target levels. Other methods may be used only with prior approval of MDNR.
- C. Selected laboratory analyses must meet detection limits that support site objectives (i.e., detection limits must be lower than applicable target levels).
- D. Regardless of whether the analyses are conducted at an off-site, fixed laboratory or an on-site mobile laboratory, the laboratory must provide adequate and complete Quality Assurance and Quality Control (QA/QC) data for each analysis. QA/QC data should be developed in accordance with the provisions of the analytical method used or as stipulated in SW-846.

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Deleted: The soil gas sampling work plan submitted to MDNR for review and approval must specify the analytical methods to be used.

C.8 Documentation of Soil Gas Sampling Event.

C.8.1 Soil gas investigation report.

- A. A soil gas investigation report that includes a discussion of field operations, any deviations from this protocol, data inconsistencies, soil gas sampling results, calculation of representative soil gas COC concentrations, other significant procedural and analytical details, and conclusions and recommendations must be prepared and submitted to MDNR. The report may be included as part of a risk assessment report.
- B. At a minimum, the soil gas investigation report must contain the following:

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- A site plan map, a map identifying soil gas probe locations, and a map showing soil and groundwater contamination relative to the locations of the soil gas probes and any current and known future structures.
- A site map on which soil gas concentration data has been plotted. The map must be at the same scale as the maps discussed above.
- A narrative description of probe installation and sampling procedures, including leak check testing.
- Analytical data summary tables.
- Laboratory data sheets.
- A table showing applicable target levels and if target levels are calculated at Tier 2, appropriate documentation showing how the site-specific target levels were calculated.
- A narrative discussion of analytical results, including a comparison of soil gas sampling results to soil vapor target levels.
- If data was collected to demonstrate whether and to what degree COC vapors are biodegrading, all relevant supporting data plus a narrative interpretation of the data must be included⁹.
- Legible copies of field forms, logs, and associated notes pertinent to probe installation and soil gas sampling.
- As-built diagrams of probes or wells showing overall construction and the depth at which samples were collected.
- QA/QC data.
- Conclusions and recommendations.

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⁹ An investigation of biodegradation must include soil gas samples collected at multiple depths from the same sampling location. In addition to sampling for COCs at each depth, samples shall also be collected for analysis of oxygen and carbon dioxide concentrations.

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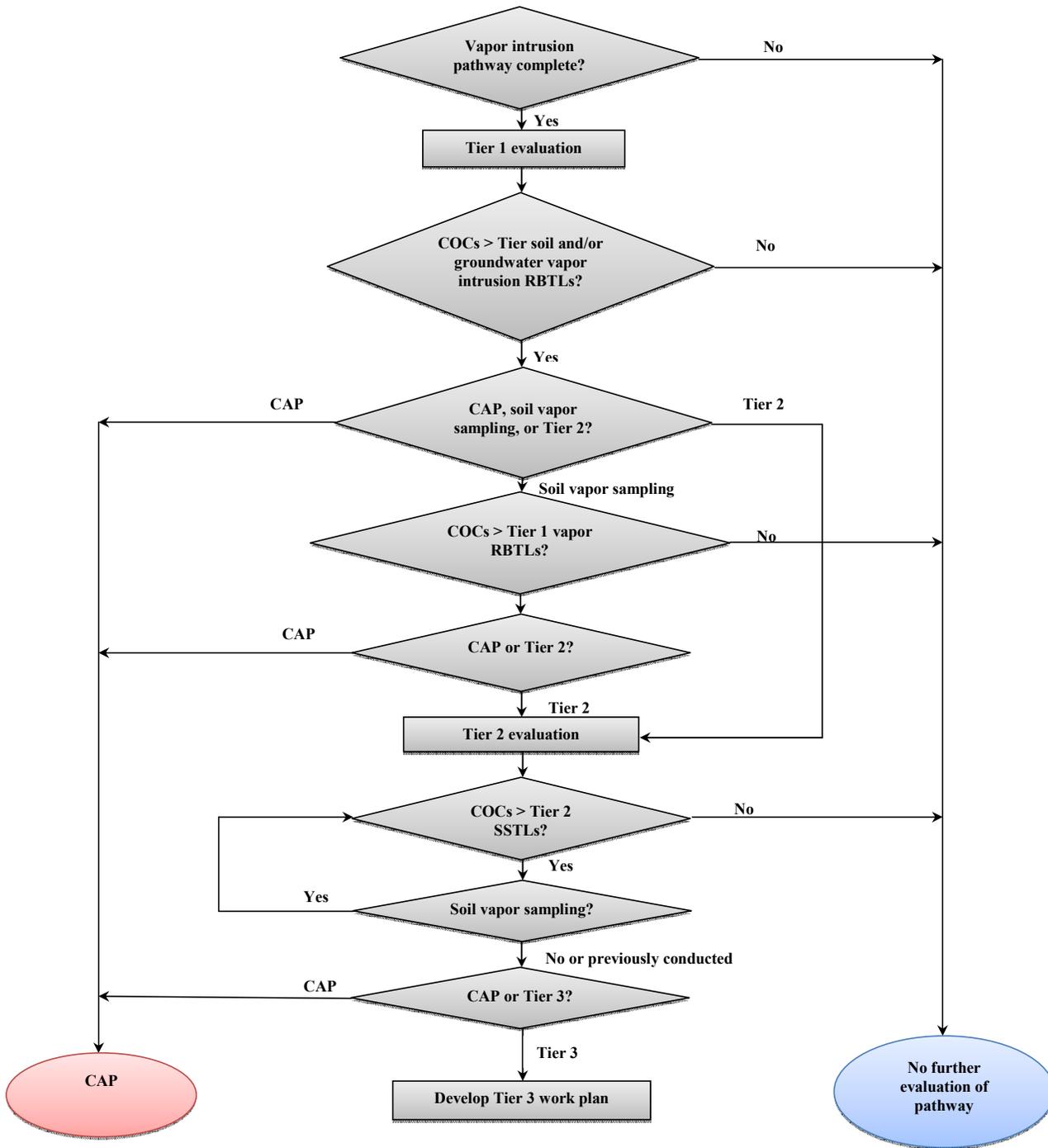
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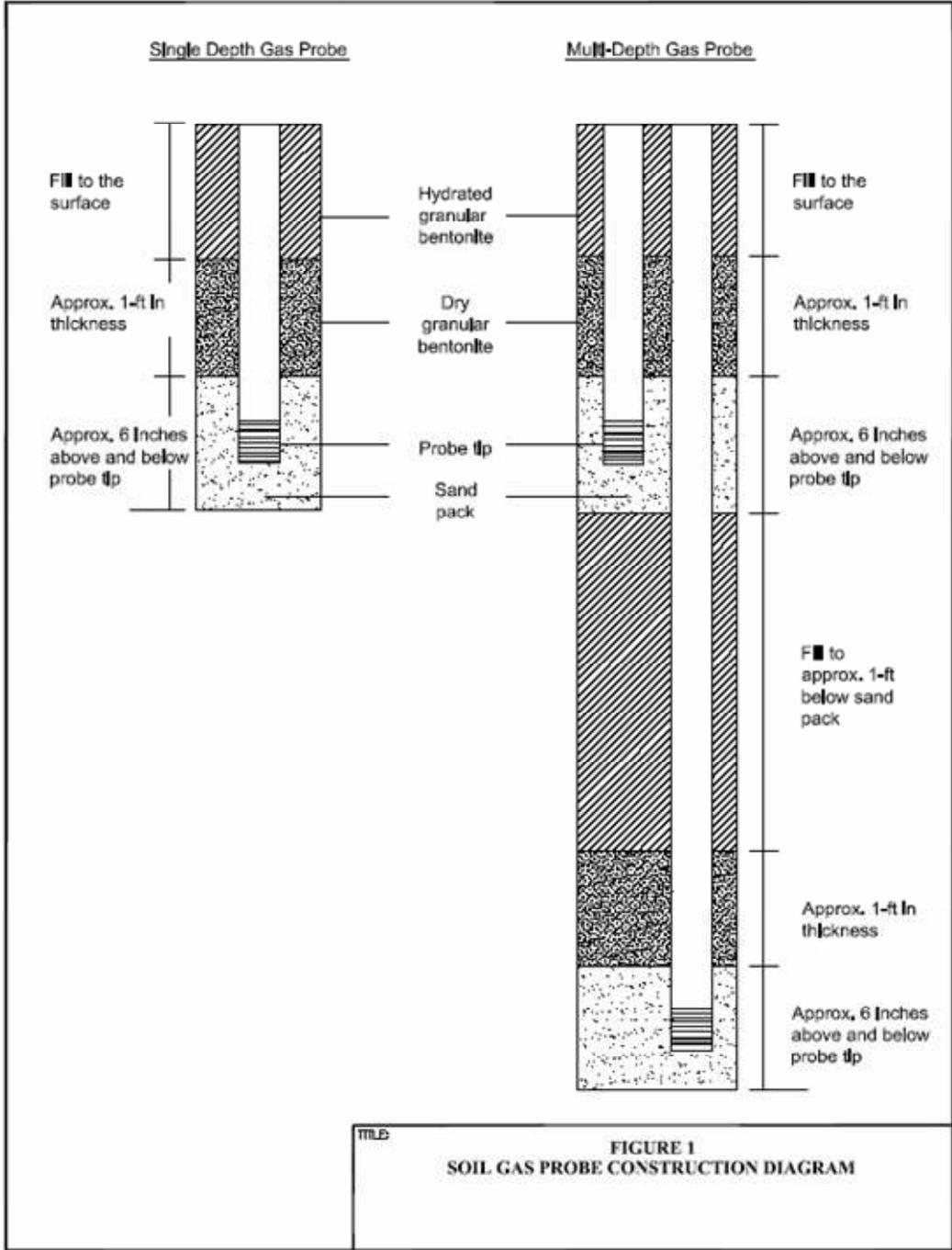
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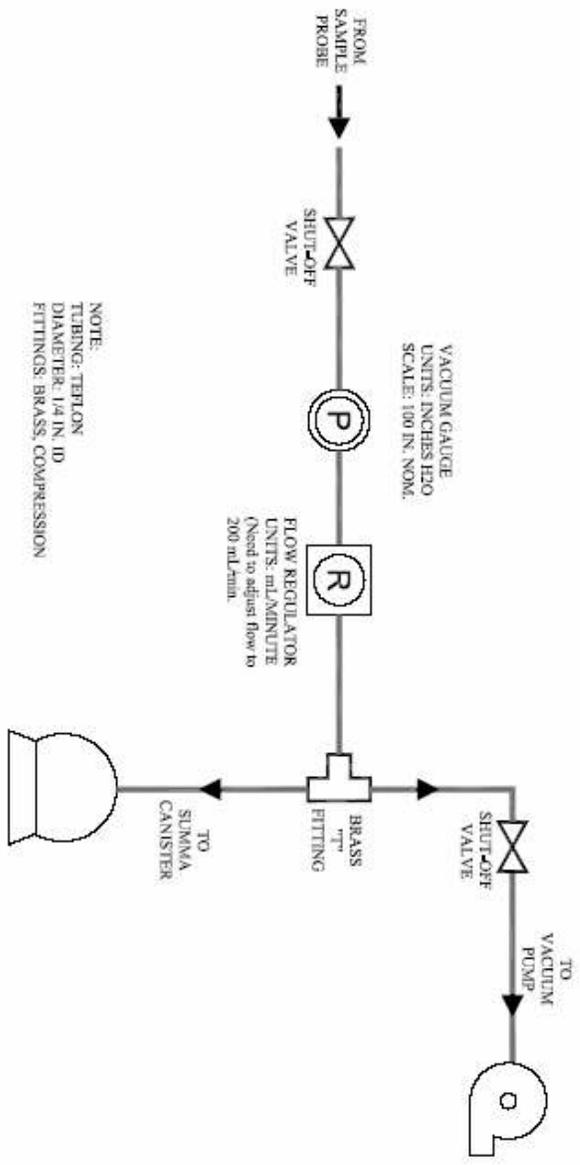
FIGURES



CAP: Corrective Action Plan
 RBTL: Risk-Based Target Level
 SSTL: Site-Specific Target Level

Figure C-1. Flowchart for Vapor Intrusion





NOTE:
TUBING: TEFLON
DIAMETER: 1/4 IN. ID
FITTINGS: BRASS, COMPRESSION

FIGURE 2
EXAMPLE SOIL GAS SAMPLING PLAN

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ATTACHMENT

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Standard Operating Procedure (SOP) for Installation of
Sub-Slab Vapor Probes and Sampling Using
EPA Method TO-15 to Support Vapor Intrusion
Investigations

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Background

Vapor intrusion is defined as vapor phase migration of volatile organic and/or inorganic compounds into occupied buildings from underlying contaminated ground water and/or soil. Until recently, this transport pathway was not routinely considered in RCRA, CERCLA, or UST investigations. Therefore the number of buildings or homes where vapor intrusion has occurred or is occurring is undefined. However, considering the vast number of current and former industrial, commercial, and waste processing facilities in the United States capable of causing volatile organic or inorganic ground-water or soil contamination, contaminant exposure via vapor intrusion could pose a significant risk to the public. Also, consideration of this transport pathway may necessitate review of remedial decisions at RCRA and CERCLA sites as well as implementation of risk-reduction technologies at Brownsfield sites where future development and subsequent potential exposure may occur. EPA's Office of Solid Waste and Emergency Response (OSWER) recently (2002) developed guidance to facilitate assessment of vapor intrusion at sites regulated by RCRA and CERCLA where halogenated organic compounds constitute the bulk of risk to human health. EPA's Office of Underground Storage Tanks (OUST) is considering modifying this guidance to include underground storage tank sites where petroleum compounds primarily determine risk and biodegradation in subsurface media may be a dominant fate process.

The OSWER guidance recommends indoor air and sub-slab gas sampling in potentially affected buildings at sites containing elevated levels of soil-gas and ground-water contamination. To support the guidance and improve site-characterization and data interpretation methods to assess vapor intrusion, EPA's Office of Research and Development is developing a protocol for sub-slab gas sampling. When used in conjunction with indoor air, outdoor air, and soil gas and/or ground-water sampling, sub-slab gas sampling can be used to differentiate indoor and outdoor sources of volatile organic and/or inorganic compounds from compounds emanating from contaminated subsurface media. This information can then be used to assess the need for sub-slab depressurization or other risk-reduction technologies to reduce present or potential future indoor air contamination due to vapor intrusion.

Sub-Slab Vapor Probe Construction and Installation

1. Prior to drilling holes in a foundation or slab, contact local utility companies to identify and mark utilities coming into the building from the outside (e.g., gas, water, sewer, refrigerant, and electrical lines). Consult with a local electrician and plumber to identify the location of utilities inside the building.
2. Prior to fabrication of sub-slab vapor probes, drill a pilot hole to assess the thickness of a slab. As illustrated in **Figure 1**, use a rotary hammer drill to create a "shallow" (e.g., 2.5 cm or 1 in) "outer" hole (e.g., 2.2 cm or 7/8 in diameter) that partially penetrates the slab. Use a small portable vacuum cleaner to remove cuttings from the hole if penetration has not occurred. Removal of cuttings in this manner in a competent slab will not compromise sampling because of lack of pneumatic communication between sub-slab material and the source of vacuum.
3. Then use the rotary hammer drill to create a smaller diameter "inner" hole (e.g., 0.8 cm or 5/16 in) through the remainder of the slab and some depth (e.g., 7 to 8 cm or 3 in) into sub-slab material. **Figure 2** illustrates the appearance of "inner" and "outer" holes. Drilling into sub-slab material will create an open cavity which will prevent obstruction of

probes during sampling by small pieces of gravel.

4. The basic design of a sub-slab vapor probe is illustrated in **Figure 3**. Once the thickness of the slab is known, tubing should be cut to ensure that probes "float" in the slab to avoid obstruction of the probe with sub-slab material. Construct sub-slab vapor probes from small diameter (e.g., 0.64 cm or 1/4 in OD x 0.46 cm or 0.18 in ID) chromatography grade 316 stainless steel tubing and stainless-steel compression to thread fittings (e.g., 0.64 cm or 1/4 in OD x 0.32 cm or 1/8 in NPT Swagelok female thread connectors) as illustrated in **Figure 4**. Use of stainless-steel materials to ensure that construction materials are not a source of VOCs.
5. Set sub-slab vapor probes in holes. As illustrated in **Figure 5**, the top of the probes should be completed flush with the slab and have recessed stainless steel or brass plugs so as not interfere with day-to-day use of buildings. Mix a quick-drying portland cement which expands upon drying (to ensure a tight seal) with water to form a slurry and inject or push into the annular space between the probe and outside of the "outer" hole. Allow cement to cure for at least 24 hours prior to sampling.
6. Install at least 3 sub-slab vapor probes in each residence. As illustrated in **Figure 6**, create a schematic identifying the location of each sub-slab probe.

Sub-Slab Sampling

1. Connect dedicated a stainless-steel fitting and tubing (e.g., 1/8 in NPT to 1/4 in tube Swagelok fitting and 30 cm or 1 ft of 1/4 in I.D. Teflon tubing to a sub-slab vapor probe as illustrated in **Figure 7**. Use of dedicated fitting and tubing will avoid cross-contamination issues.
2. Connect the Teflon tubing to 1/4" ID Masterflex (e.g., 1.4 in ID high performance Tygon LFL) tubing and a peristaltic pump and 1-L Tedlar bag as illustrated in **Figure 8**. Use of a peristaltic pump will ensure that sampled air does not circulate through a pump causing potential cross contamination and leakage.
3. Purge vapor probe by filling two dedicated 1-L Tedlar bags. The internal volume of sub-slab probes is insignificant ($< 5 \text{ cm}^3$). A purge volume of 2 L was chosen based on the assumption of a 0.64 cm (1/4") air space beneath a slab and an affected sample diameter of 0.61 m (2 ft).
4. Use a portable landfill gas meter to analyze for O_2 , CO_2 and CH_4 in Tedlar bags as illustrated in **Figure 9**.
5. Collect sub-slab vapor samples in evacuated 10% or 100% certified 1-L Summa polished canisters and dedicated particulate filters as illustrated in **Figure 10**. Check vacuum in canisters prior to sampling. Sampling will cease when canister pressure reaches atmospheric pressure. Submit canisters to a commercial laboratory for analysis by EPA Method TO-15.
6. Collect at least one duplicate sub-slab sample per building using dedicated stainless-steel tubing as illustrated in **Figure 11**.



Figure 1. Drilling through a slab



Figure 2. "inner and "outer

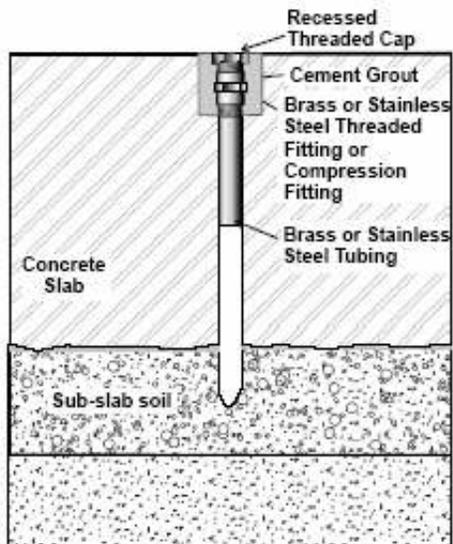


Figure 3. General schematic of sub-slab vapor probe

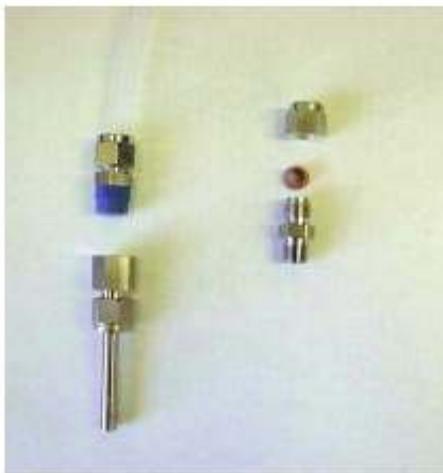


Figure 4. Stainless steel sub-slab vapor probe components



Figure 7. Compression fitting to probe



Figure 8. Purge prior to sampling



Figure 9. Analysis of O₂, CO₂, and CH₄



Figure 10. Sampling in 1-L evacuated canister for TO-15 analysis



Figure 11. Collection of duplicate sample

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Figure C-1 Flowchart for Vapor Intrusion

Figure C-2 Location of Nested Soil Vapor Probes

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The procedure used to quantitatively evaluate the vapor intrusion pathway is presented in this appendix. Figure C-1 shows the step-by-step approach to evaluate the vapor intrusion pathway. Each of the steps illustrated in the flowchart is described below.

C.1 STEP 1: EVALUATE WHETHER THE PATHWAY IS COMPLETE

The objective of this step is to determine whether any of the following vapor intrusion-related pathways are complete:

- Vapor intrusion from sub-surface soils, and
- Vapor intrusion from groundwater.

Determining whether the vapor intrusion pathway is complete typically occurs during the

of site-specific information and professional judgment. A few conditions under which the pathway would not be complete include:

All chemicals of concern (COCs) at the site are non-volatile. Chemicals with a dimensionless Henry's Law constant of 1×10^{-4} or less and a molecular weight greater than 200 are generally considered non-volatile (US EPA, 1996). If volatile chemicals are not present at a site, the vapor intrusion pathway for both current and future conditions would be incomplete.

For current conditions, if soil and groundwater within a horizontal distance of 25 feet of a structure are not affected by volatile COCs, the pathway would be considered incomplete.

Such a condition would be expected to occur where the release occurred away from existing buildings in a hydraulically down gradient direction and groundwater below the building was not otherwise affected.

For future conditions, anticipated site-specific land use and development must be considered in determining whether a building might be built on-site. The vapor intrusion pathway would be incomplete if such conditions prevent or prohibit the construction of a building on-site. An example of such a condition would be a spill over a pipeline right-of-way.

If all affected and potentially affected existing and planned future buildings include a vapor barrier that prevents the intrusion of vapors into a building or a passive or active venting system that prevents the buildup of vapors into a building, the vapor intrusion pathway shall be considered incomplete. Note, however, that the use of barriers or venting systems will be approved by MDNR only in combination with an appropriate activity and use limitation (AUL) that will ensure the long term operation and maintenance of the barrier or system.

C.2STEP 2: PERFORM A TIER 1 RISK ASSESSMENT

If the vapor intrusion pathway is or will be complete under current or reasonably anticipated future conditions, the evaluator tank owner or operator must perform a Tier 1 risk assessment. A Tier 1 risk assessment requires that the representative soil or groundwater concentrations be compared with the relevant Tier 1 risk-based target levels (RBTLs). The RBTLs for various receptors are tabulated in Tables 7-1 through 7-6.

If COCs in soil and/or groundwater exceed the vapor intrusion RBTLs, the tank owner or operator may choose to 1) adopt the Tier RBTLs as the cleanup levels and develop a Corrective Action Plan (CAP) to meet the RBTLs, 2) conduct a Tier 2 risk assessment, or 3) conduct soil vapor sampling in

If soil vapor sampling occurs prior to conducting a Tier 2 assessment, the tank owner or operator will develop representative soil vapor COC concentrations for comparison to the soil vapor RBTLs in Tables 7-1 (for residential land use) and/or 7-2 (for non-residential land use). The soil vapor sampling activities, development of representative soil vapor COC concentrations, and the comparison of the representative concentrations to the soil vapor RBTLs must be included in the Tier 1 risk assessment.

If soil vapor sampling is conducted and is representative of the entirety of the plume¹, the measured soil vapor COC concentrations take precedence over COC concentrations in soil and groundwater and the latter are no longer relevant to the vapor intrusion pathway.

C.3STEP 3: DETERMINE THE NEXT STEP: TIER 2 RISK ASSESSMENT OR CORRECTIVE ACTION PLAN

Based on the comparison in Step 2, one of the following two alternatives is possible:

Tier 1, Alternative 1: Representative soil, and groundwater, and soil vapor² COC concentrations³ are below Tier 1 vapor intrusion RBTLs, in which case no further evaluation of the vapor intrusion pathway is necessary.

Tier 1, Alternative 2: Representative soil, and groundwater, and/or soil vapor concentrations exceed the Tier 1 RBTLs, in which case one of the following two options must be selected (this assumes soil vapor sampling has occurred):

Tier 1, Option 1: Adopt Tier 1 RBTLs as the cleanup levels and develop a Corrective Action Plan (CAP) to achieve these levels; or

¹ If the soil vapor samples are representative of all current and future vapor intrusion pathways (i.e., existing and future enclosed structures), the measured soil vapor concentrations supersede measured concentrations of COCs in soil and groundwater relative to the vapor intrusion pathway. Therefore, if measured soil vapor COC concentrations are below applicable RBTLs (or SSTLs) but concentrations of COCs in soil and/or groundwater exceed applicable vapor intrusion RBTLs (or SSTLs), the measured soil vapor concentrations take precedence and the soil and groundwater concentrations are no longer applicable for the vapor intrusion pathway.

² The tank owner or operator will use the representative soil vapor COC concentrations developed at Tier 1 for comparison to the Tier 2 SSTLs, unless additional soil vapor sampling has been conducted, in which case the additional data must be included in developing new representative soil vapor COC concentrations.

³ See footnote 2 above; COC concentrations in soil vapor supplant COC concentrations in soil vapor relative to the vapor intrusion pathway; therefore, when soil vapor sampling occurs, COC concentrations only in soil vapor need to be below the RBTLs in result in no further evaluation of the vapor intrusion pathway to apply. In other words, the tank owner or operator must either meet soil and groundwater RBTLs

Tier 1, Option 2: Perform a Tier 2 risk assessment (Step 4).

C.4STEP 4: DEVELOP TIER 2 SOIL AND GROUNDWATER SSTLs

Using the procedures described in Section 8.2, Tier 2 Site-Specific Target Levels (SSTLs) for soil, and groundwater, and soil vapor (as appropriate) must be developed for each volatile COC and complete route of exposure. The SSTLs should be compared with representative soil, groundwater, and or soil vapor COC concentrations, and the path forward determined as discussed in Step 5.

C.5STEP 5: DETERMINE THE NEXT STEP: NO FURTHER ACTION OR SOIL VAPOR MEASUREMENT, CLEANUP TO TIER 2 SSTLs, OR TIER 3 RISK ASSESSMENT

Tier 2, Alternative 1: If the representative soil, groundwater, and soil vapor COC concentrations do not exceed the Tier 2 SSTLs⁴, no further evaluation of the vapor intrusion pathway is required.

Tier 2, Alternative 2: If the representative soil, groundwater, and soil vapor COC concentrations exceed the Tier 2 SSTLs, one of the following two actions must be taken:

Tier 2, Option 1: Adopt the Tier 2 SSTLs as the cleanup standards and develop a CAP to meet the SSTLs; or

Tier 2, Option 2: Conduct a Tier 3 risk assessment.

Soil and groundwater SSTLs developed in Step 4 should be compared with appropriate the site-specific representative concentrations to determine the next step. Based on the comparison, one of the following two alternatives is possible:

Tier 2, Alternative 1: Representative soil and groundwater concentrations do not exceed the Tier 2 soil or groundwater SSTLs. In this case, provided MDNR determines that the data used in the evaluation was adequate and appropriate, no further evaluation of the indoor inhalation pathway will be necessary.

Tier 2, Alternative 2: The soil or groundwater representative concentrations exceed the SSTLs, in which case one of the following two options is available.

Please note that, nationwide, considerable developments are currently underway in the development of soil vapor measurements. The entity performing the work is requested to familiarize themselves with the current-state-of the practice and not rely solely on the guidance provided below:

Tier 2, Option 1: Adopt the Tier 2 soil and groundwater SSTLs as the cleanup levels and develop a RMP to meet the cleanup levels.

Tier 2, Option 2: Develop and implement (upon MDNR approval) a work-plan to conduct a comprehensive soil vapor survey (Step 6).

C.6 SOIL VAPOR TARGET LEVEL DEVELOPMENT AND SOIL VAPOR MEASUREMENTS

Develop a work plan to perform a soil vapor survey as per the brief guidelines provided in Section C.7 *Soil Gas Sampling Protocol* found at the end of this appendix or other appropriate, equivalent guidance. If the work plan is to be based on guidance other than that found herein, the work plan must be submitted to MDNR along with either a copy of the guidance on which the work plan is based or, at least, a clear, detailed reference as to the guidance used. Where other than the guidance herein is used, the work plan shall not be implemented until approved by MDNR.

The work plan should be implemented in a timely manner upon receiving approval from MDNR. Upon completion of the last round of field measurements, representative soil vapor concentrations (developed as explained in Appendix E) shall be compared with calculated Tier 2 soil vapor. The specific equations used to calculate the soil vapor target levels are presented in Appendix B.

Tier 2 Soil Vapor, Alternative 1: If representative concentrations developed based on the measured soil vapor measured concentrations do not exceed the calculated Tier 2 soil vapor target levels, no further evaluation of the pathway is necessary. This assumes that sufficient soil vapor data is available, the data is representative of site conditions over time, and the groundwater plume is stable or shrinking.

Tier 2 Soil Vapor, Alternative 2: If the representative concentrations developed based on measured soil vapor measured concentrations exceed the calculated Tier 2 soil vapor target concentrations, one of three two options is available:

Tier 2 Soil Vapor, Option 1: Develop a RMP work plan to conduct remedial actions to meet the soil vapor target levels. Upon completion of the RMP, confirmatory soil vapor measurements shall be required.

Tier 2 Soil Vapor, Option 2: Develop a work plan to perform a Tier 3 risk assessment. A Tier 3 risk assessment may include several options.

These include re-analysis of soil vapor data using an alternative model or performing indoor air sampling.

With approval of MDNR, certain aspects of the *Soil Gas Sampling Protocol* herein may be modified based on other guidance. However, the protocol was developed to ensure that the resulting soil vapor data are representative, reliable, and relevant to the exposure pathways being evaluated. Therefore, soil vapor sampling conducted in accordance with the provisions of the protocol may occur without MDNR's formal approval of the work plan, though we recommend that sampling occur only after the work plan has gained MDNR approval. Soil vapor sampling conducted under a work plan developed based on guidance other than that herein should not occur until after the work plan has been approved by MDNR.

Specific technical provisions related to soil vapor sampling are addressed in the *Soil Gas Sampling Protocol*. If conditions at a site are unusual such that these provisions cannot be fully met, the work plan should be amended accordingly based on other guidance or professional judgment. In such case, the amended work plan must be submitted to MDNR and sampling should not be conducted until MDNR has approved the work plan.

The work plan should be implemented in a timely manner upon receiving approval from MDNR, if required. Upon completion of the last round of field measurements, representative soil vapor concentrations (developed as explained in Appendix E) shall be compared with either the Tier 1 soil vapor RBTLs or the calculated Tier 2 soil vapor SSTLs, as appropriate. The specific equations used to calculate the soil vapor target levels are presented in Appendix B.

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The intent of measuring COC concentrations in soil gas is to obtain spatially and temporally representative values that can be used to estimate receptor risk. Soil vapor concentrations at a site are affected by a number of factors, including (i) atmospheric conditions (temperature, pressure, moisture content etc.), (ii) soil stratigraphy, (iii) heterogeneity of soil, (iv) location of source, (v) age of the spill, and (vi) biodegradability characteristics of the soil-chemical "system."

To the extent that these factors cause spatial and temporal variations, soil vapor concentrations can be highly variable. Thus the MDNR does not consider a single soil vapor sampling event to be adequate for the characterization of COC vapors. Measurements must be made over time to represent the range of possible site conditions. Thus MDNR will require that a minimum of two sampling events be conducted at different times of the year (e.g., winter and summer). At sites where seasonal water table fluctuations are significant (> 5ft.), measurements must be made both when the water table is high and low.

The

must develop a work plan to satisfy the above objectives, submit the work plan to MDNR, and implement the fieldwork only upon written receipt of MDNR's approval of the work-plan. The work-plan shall include, but not necessarily be limited to, the following:

- The location where samples will be collected,
- The depth where samples will be collected,
- The number of samples to be collected,
- The frequency of sampling,
- Soil gas measurement techniques and laboratory analysis procedures, and
- QA/QC procedures.

Each of these is discussed below.

C.7.1 Location Where Samples will be Collected

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shall consider the following when siting soil gas borings:

- The locations of the point and area of release,
- The location of the highest concentrations of volatile COCs in ground water,
- The location(s) of existing on-site building(s),
- The location(s) of potential future on-site building(s),
- The location(s) of existing off-site buildings, and
- The location(s) of potential future off-site building(s).

Samples should be collected around the footprint of all existing or potential future buildings potentially affected by the release. In all cases, at least one soil vapor boring/implant shall be located in the source area or areas (i.e., the area of most impacted soil and the area above the most impacted groundwater). Sampling at off-site locations will only be required if COCs have migrated, or are likely to migrate, off-site in soil or groundwater. Except in the smear zone, soil is typically not impacted off-site.

The entity performing the work shall very clearly indicate the proposed locations of soil vapor borings/implants on a site map and explain the rationale for each location.

C.7.2 Sampling Depth

The depth at which samples will be collected depends on the depth to soil contamination and the depth to groundwater (the latter only if vapors emanate from groundwater). The

contamination (soil or groundwater) is very shallow (e.g., < 3 ft), a minimum of two soil gas samples at varying depths shall be collected. In all cases, one sample should be collected no more than 3 feet below the foundation of the enclosed space or potential future enclosed space. For structures having basements, soil gas samples should be collected below and adjacent to the basement wall. Possible locations of sampling points are shown in Figure C-2. If COCs exist under an existing building, the collection of samples below the building might be necessary, in which case boring through the foundation slab or drilling horizontal borings might be necessary to access soil below the slab.

C.7.3 Number of Samples to be Collected

As in the case of site characterization, the number of soil gas samples to be collected will depend on site-specific conditions. For existing buildings with soil or groundwater contamination below them, four borings, one on each side of the building, are required. Additionally, locating one or more borings within the source area might be necessary. As mentioned in C.7.2, samples should be collected at multiple depths within each boring.

C.7.4 Soil Gas Measurement Technique and Analysis

As mentioned above, soil vapor data must be collected on multiple occasions. Hence, soil implants used for soil vapor sampling should be sturdy and their location clearly identifiable so that they can be reliably used over an extended period of time. Soil implants may be installed using either direct push technology or (2" diameter) hollow stem augers. Care should be taken to install the implants in a manner that minimizes soil disturbance.

Soil vapor samples should be collected in a tedlar bag or an evacuated Summa canister and analyzed for the volatiles of concern. The decision whether to use a tedlar bag or a Summa canister should be based on the detection limits associated with the sampling and corresponding analytical methods. The method that results in detection limits equal to or less than the target levels must be used.

Prior to collecting the sample, the implants and tubing should be thoroughly purged to ensure that the sample sent for analysis is truly representative of the formation being sampled. For petroleum product spills, COCs include benzene, toluene, xylenes, ethylbenzene, MTBE, and naphthalene. The entity performing the work may also analyze the vapor samples for oxygen, carbon dioxide, nitrogen, methane and other indicators of the biodegradation of hydrocarbon vapors, though these analyses are not required. Measurements of these compounds may be used to demonstrate the occurrence of natural attenuation.

In addition to the above, soil samples should be collected as close to the vapor sampling implants as practical. Ideally, soil samples should be collected during installation of the

implants. Soil samples shall be analyzed for soil geotechnical properties (refer to subsection 5.6 of this document) and the volatile COCs. If groundwater is the anticipated source of vapors, a groundwater sample shall be collected below the point where soil vapor samples are collected.

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ATTACHMENT C-1

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Missouri Department of Natural Resources

**MISSOURI RISK-BASED CORRECTIVE ACTION (MRBCA)
FOR PETROLEUM STORAGE TANKS**

SOIL GAS SAMPLING PROTOCOL

January 2013

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The purpose of this document is to provide guidance for conducting soil gas sampling at petroleum storage tank sites. The routine evaluation of the indoor inhalation vapor intrusion pathway at contaminated sites is a relatively recent development. As a result, methods, procedures, and technology related to evaluating the pathway continue to evolve. While this guidance is, in part, prescriptive, MDNR does not intend for this guidance to be overly limiting with respect to the use of other appropriate methods, procedures, and equipment for measuring concentrations of chemicals of concern in soil gas. Even so, departures from this guidance must be presented in a work plan submitted to MDNR and utilized only with MDNR approval.

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Chibnall, Tim

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This protocol is not intended to prohibit those conducting evaluations under the MRBCA process from using means other than those specified herein to measure soil gas concentrations at a petroleum storage tank site. However, departures from this guidance must be specifically detailed in a written work plan submitted to MDNR and may be implemented at a regulated petroleum storage tank site only with the written approval of MDNR. For consistency, MDNR prefers that soil gas sampling be conducted in accordance with this protocol unless extenuating circumstances make application of this protocol impractical.