

IV. SOIL VAPOR SAMPLING

The following guidelines are for conducting soil vapor sampling in San Diego County. The references used to develop these guidelines are presented in **Appendix III**. Other vapor survey standards may be applicable for a particular application. For cases under DEH jurisdiction, a work plan must be submitted and approved prior to initiation of fieldwork in accordance with Section 6 of this document.

This section does not provide guidance on indoor air sampling. For such guidance, the reader is referred to published Standard Operating Procedures (SOPs) for indoor air sampling by EPA Region 1 and the State of Massachusetts (listed in Appendix III).

A. Introduction

Soil vapor surveys can be used for a number of purposes, including the following:

- **Initial Site Screening**, where the objective is to assess if volatile organic chemicals (VOCs) are present;
- **Site Assessment/Characterization**, where the objective is to assess the source, extent, and magnitude of impacted soil, groundwater and/or vapor;
- **Risk Assessments**, where the objective is to assess the risk to public health; safety and the environment;
- **Remediation and Post-Remediation Monitoring**, where the objective is to assess remediation progress or completion; and
- **Ongoing Monitoring** for risk assessment, remediation monitoring, landfill gas monitoring, and background methane monitoring.

These guidelines provide information on the following:

- Common methods of sample collection;
- Transient and other environmental factors that could affect the outcome of a vapor survey;
- Vapor survey design for a variety of sites, including petroleum-related sites, dry cleaners and industrial facility sites, methane testing sites; and
- Documentation, including work plans, field notes and reporting.

B. Overview of Soil Vapor Survey Methods

Three principal methods exist for collecting soil vapor data:

- Active
- Passive
- Flux Chambers

Each method offers advantages and disadvantages that are briefly described below. The design and protocols of a soil vapor survey program are dependent upon the objectives of the program, the types of contaminants anticipated to be present, and the site conditions. There are a variety of sampling methods and equipment designs for collecting soil vapor samples that can potentially yield different values.

Active: The active approach consists of the withdrawal of an aliquot of soil vapor from the subsurface, typically with a sampling probe, followed by analysis of the withdrawn vapor. Analysis is often performed on-site using a variety of analytical instruments. Alternatively, soil vapor samples can be stored in gas-tight containers and analyzed at an off-site laboratory. The active method is quantitative, and values are reported in concentration units (e.g., parts per million by volume [ppmv], micrograms per liter [$\mu\text{g/L}$] -vapor). This approach is the most common soil vapor collection method for a number of reasons, including ease of sample collection, opportunity for real-time data to direct further sampling, and the ability to acquire quantitative measurements.

Passive: The passive approach consists of the emplacement of an adsorbent into the subsurface and subsequent removal and analysis of the adsorbent. The adsorbent is typically placed in the upper end of an inverted container having an open bottom. Measured values cannot be reported as concentrations, only as total adsorbed mass (e.g., micrograms [μg]) or in some other form of relative units, because the amount of vapor that comes into contact with the adsorbent is unknown. Due to this limitation, passive surveys are useful for qualitative purposes only. Because one effect of the adsorbent is to concentrate the soil vapor, this approach offers advantages over the active approach in locations of low vadose zone permeability and sites with lower contaminant concentrations (less than $0.1 \mu\text{g/L}$ -vapor). However, contaminants must still have an appreciable vapor pressure to be detected by this method. The technique requires two visits to the field, one to deploy the adsorbents and a second trip to retrieve them, and does not allow for the acquisition of real-time data.

Flux Chambers: Flux chambers consist of an enclosed chamber that is placed on the surface for a specific period of time. Vapor concentrations are measured in the chamber after a period of time. This method is also quantitative and yields both concentration data in the chamber and flux data (mass/area-time). Flux chambers are

the least common soil vapor survey method, and are typically used only for risk-based applications when direct vapor fluxes out of the subsurface are desired.

C. Procedures Which Influence Reported Soil Vapor Data

Soil gases can travel long distances from the contamination source and can potentially be representative of the “general area of contamination.” However, soil gas surveys should be used cautiously. Due to chemical specific characteristics, geologic conditions, and atmospheric influences, soil gas surveys can provide misleading results. Reported soil vapor data can depend greatly upon the collection protocols that are used to generate the data. For this reason, it is important to understand the factors that may influence the reported data when collecting soil vapor data. This section presents a description of a number of various factors that influence the reported data for different methods.

1. Active Soil Vapor Surveys

Sample Spacing: The selection of sampling locations is strongly dependent upon the objectives of the program and the need for adequate coverage. Predetermined and widely spaced grid patterns are most commonly used for reconnaissance work, while closely spaced, irregularly situated locations are commonly used for covering specific source areas. Guidelines on sample spacing for various applications are summarized in Section 5 of this guidance.

Collection Depth: Collection depths should be chosen to maximize the chances of detecting contamination, yet minimize the effects due to vapor movement, changes in barometric pressure, and surface temperature, or breakthrough of atmospheric air from the surface (refer to Section 4 of this guidance for further discussion of these factors). To optimize the chances of detecting contamination and minimizing the potential pitfalls due to vapor movement, soil vapor samples should be collected as close to the suspected contamination source as practically possible. Guidelines on collection depth for various applications are summarized in Section 5.

Purge Volume: The sample collection equipment used for active soil vapor surveys has an internal volume that is filled with air or some other inert gas prior to insertion into the ground. This internal volume, often called the dead volume, must be completely purged and filled with soil vapor to ensure that a representative soil vapor sample is collected. Different opinions exist on the optimum amount of vapor to be purged. At a minimum, enough vapor should be withdrawn prior to sample collection to purge the probe and collection system of all ambient air or purge gas (1 purge volume). Some believe that similar to a groundwater monitor well; a minimum of three system volumes should be purged. Most experienced soil vapor personnel purge a minimum of one and a maximum of five system volumes before collecting a

sample. Since soil vapor data are often interpreted in a relative fashion, it is important that the purge volume is consistent for all samples collected from the same site.

While it is important to collect enough vapor to purge the system, collecting too much vapor can also have drawbacks. The larger the quantity of soil vapor withdrawn, the greater the uncertainty in the location of the collected sample, and in turn, the greater the potential that atmospheric air might have been drawn down the outside of the probe body. In addition, large purge volumes can create vacuum conditions that cause contaminant partitioning from the soil into the gas phase, which is not representative of in situ soil vapor conditions. Thus, sampling equipment with small internal dead volumes offers advantages over systems with larger dead volumes because the former systems require significantly less vapor to be withdrawn when purging the system.

Excessive Vacuums Applied During Collection: Soil vapor samples collected under high vacuum conditions or under a continuous vacuum may contain contaminants that have partitioned from the sorbed and dissolved phase into soil gas created by the collection process, rather than contaminants present in the undisturbed soil vapor. For collection systems employing vacuum pumps, the vacuum applied to the probe should be kept to a minimum necessary to collect the sample and measured and recorded.

Probe Seals: For collection systems with large purge volumes or designed to collect large sample volumes, it is often necessary to seal the probe at the surface. Seals may also be necessary for small volume systems if the soils are extremely porous and the sampling depth is close to the surface (less than 3 feet). Most common sealing techniques are to pack the upper contact of the probe and the soil with grout or to use an inflatable seal. Seal integrity can be easily tested by allowing a tracer gas (e.g., propane or butane) to flow around the probe at the contact with the ground surface and to analyze a collected soil vapor sample for the tracer gas.

Probe Decontamination: All external parts should be wiped clean and washed as necessary to remove any soil or contaminant films. The internal vapor pathway should be purged with a minimum of five volumes of air or an inert gas, or replaced, or washed if contamination or water is present in the probe. Probes fitted with internal tubing offer advantages because the internal tubing can simply be replaced.

Systems with Vacuum Pumps: Soil vapor samples from collection systems employing vacuum pumps should be collected on the intake side of the pump to prevent potential contamination from the pump. Further, because the pressure on the intake side of the pump is below atmospheric, soil vapor samples must be

collected with appropriate collection devices, such as gas-tight syringes and valves, to ensure that the samples are not diluted by outside air.

Sample Containers and Storage of Samples: While on-site analysis is advantageous to ensure sample integrity, soil vapor samples can be collected and analyzed off-site. To minimize potential effects on the sample integrity, it is recommended that:

- Maximum storage time does not exceed 48 hours after collection.
- Do not chill samples during storage as is common with soil and water samples.
- If stored samples are to be subjected to changes in ambient pressure (e.g., shipping by air), gas-tight vials or canisters are recommended. Tedlar bags are not allowed.
- For fuel related compounds (TPHv, BTEX) and biogenic gases (CH₄, CO₂, and O₂): Allowable containers include Tedlar bags, gas tight vials (glass or stainless steel), and Summa Canisters.
- For halogenated compounds (e.g., TCE, TCA, PCE): Allowable containers must be gas tight, but also dark to eliminate potential effects due to photo destruction. Tedlar bags have been shown to not be a reliable storage container.

Collection of Soil Vapor Samples with Summa Canisters: Because Summa Canisters generally are large volume containers (3 to 6 liters) under high vacuum, extra care should be exercised during sample collection to ensure that air from the surface is not being inadvertently sampled or that desorption of contaminants from the soil does not take place. The possibility of breakthrough from the surface increases, the closer the samples are collected to the surface (less than 5 feet below grade) or when using Summas to sample from surface flux chambers. To minimize the potential of surface breakthrough, seals around the probe rod at the surface should exist. To minimize the potential desorption of contaminants from the soil, Summa Canisters should be filled at a rate less than half a liter per minute.

2. Passive Soil Vapor Surveys

Sample Spacing: The selection of sampling locations for passive sampling is based upon the same considerations as active soil vapor methods: program objectives and the need for adequate coverage. Predetermined and widely spaced grid patterns are most commonly used for reconnaissance work, while closely spaced, irregularly

situated locations are commonly used for covering specific source areas. Guidelines on sample spacing for various applications are summarized in Section 5.

Collection Depth: Passive surveys are nearly always conducted by burying the collector close to the surface (6 inches to 3 feet). This protocol was developed not for technical reasons, but for convenience in deploying and retrieving the collector. Ideally, similar to active surveys, collectors should be deployed as close to the suspected contamination source as practically possible to minimize the effects of vapor movement. In addition, collectors buried within five feet of the surface will be very susceptible to air infiltration due to changes in barometric pressure and surface temperature. If the outside air is contaminated, for example at an active gasoline station or inside of an active dry-cleaning operation, the passive collectors could conceivably adsorb more contamination from infiltration of the surface air than from subsurface contamination. In this situation, it is advisable to bury the collector to deeper depths (greater than 5 feet).

Exposure Period: As with collection depth, the exposure period for passive collectors is generally selected more for convenience factors than for technical reasons. The key assumption that is invoked when interpreting passive soil vapor data is that each collector is exposed to the same quantity of soil vapor. Thus, passive collectors are typically deployed for the same period of time on a site or the data is normalized based upon the exposure time. Typical exposure times are a few days to two weeks.

In practice, the exposure period for a passive collector should depend upon the concentration of the contaminant of interest and desired detection levels. In areas of suspected high concentration, collectors can be left in the ground for shorter periods (1 to 5 days). In areas of suspected low concentrations, collectors are often left in the ground for two or more weeks. For areas of unknown concentration, the optimum approach is to determine the deployment time by burying a number of collectors in the same location and measuring them over a period of time.

Method Blanks: Since the passive soil vapor method does not enable real-time data, analysis of blanks is extremely important to verify that detected contamination was not from another source, such as the passive collector itself or handling and storage during transport from the site to the laboratory. The only way to evaluate this possibility is to include a method blank and trip blank as part of the sample batch. A method blank consists of an unused collector picked at random from the collector batch. A trip blank is an unused collector that is kept sealed, and accompanies the other collectors to and from the site and to the laboratory for analysis.

3. Surface Flux Chamber Surveys

Sample Spacing: The primary motive of flux chamber surveys is to measure the upward flux of vapor out of the ground or into a room for risk-based purposes. A minimum of three chambers should be deployed in the room or on the ground surface to provide representation of the area of interest and to demonstrate reproducibility. Chambers should preferably be located in areas where surface features suggest possible conduits to the subsurface (e.g., cracks, drains, electrical conduits, etc.). At least one chamber should be deployed in the area of maximum subsurface contaminant concentration if identified from a previous subsurface investigation.

Insertion Depth or Seals: Valid measurements require that the bottom of the chamber be sealed from exchange with atmospheric air. On soil surfaces, chambers are either inserted into the ground to a depth of one or more inches or the chamber flange covered with native soil or sealant. On finished surfaces such as floors, an airtight seal must be made between the chamber bottom and the surface, typically using a gasket or sealant.

Covers: Reflective coverings are sometimes necessary in outside locations to protect against temperature extremes that could create advective flow. Opaque coverings are required to minimize the potential of photo destruction of compounds.

Exposure Period: Chambers should be deployed for a minimum of eight hours, with the exposure period during normal occupancy conditions. Longer exposure times, on the order of 24 hours, are preferred since they give a time-integrated result that is more representative of the actual flux into a surface enclosure.

Number of Samples per Exposure Period: Collection and analysis of multiple samples from a chamber at regular intervals over the deployment period (e.g., every 4 hours) is advised since it allows estimates of precision, enables spurious measurements to be eliminated, and any variability in the measured fluxes to be detected.

Sample Containers and Storage of Samples: Refer to the same section under active soil vapor surveys (Section 3a) for a description of applicable containers and storage considerations.

D. Transient and Other Environmental Effects

1. Temperature

Temperature can have an effect on soil vapor concentrations, since both the vapor pressure and water solubility of compounds is temperature dependent. However, temperature variations decrease with depth in the soil column, and in southern California, will be typically less than 1°C at depths greater than 3 feet below ground surface (bgs). This level of temperature variation will not create a measurable effect.

Seasonal temperature variations are also minimal in southern California, and except for special environments, such as the desert, are unlikely to create a significant effect on soil vapor concentrations in the vadose zone.

2. Barometric Pressure

Changes in barometric pressure can lead to a pressure gradient between the soil vapor and atmosphere creating a flow of soil vapors out of the vadose zone during barometric lows and into the vadose zone during barometric highs. The potential effects decrease with increasing sampling depth. Barometric pressure should be recorded for samples collected at depths shallower than five feet bgs for risk-based applications.

3. Earth Tides

Earth tides (movement of soil vapor due to variations of the earth's geometric shape due to gravitational pull) have been promoted as a factor on soil vapor movement. However in reality, fluctuations in water levels during periods of maximum gravitational pull (new and full moons) are less than 0.1 foot. Hence, earth tides do not have a significant effect on soil vapor movement and concentration.

4. Precipitation (Rainfall)

Infiltration from rainfall can potentially impact soil vapor concentrations by displacing the soil vapor, dissolving volatile organic compounds, and by creating a "cap" above the soil vapor. In practice, infiltration from large storms only penetrates into the soil on the order of inches. Hence soil vapor samples collected at depths greater than three feet bgs are unlikely to be significantly affected. Soil vapor samples collected closer to the surface (less than 3 feet) may be affected and it is recommended that measurement of percent moisture of the soil is performed if shallow sampling is performed during or shortly after significant rainfall (greater than 1 inch).

E. Soil Vapor Survey Design For Specific Types of Sites

This section gives specific guidelines for common types of sites.

1. Petroleum Related Sites, Including Underground Storage Tanks

a. Chemical Specific/Analytical Considerations

Because petroleum products, such as gasoline and diesel, are complex mixtures containing a wide variety of different hydrocarbons, the appropriate analytical measurements depend upon the product type as follows:

- Volatile Hydrocarbons (TPH by CA-LUFT or 8015 modified): Suitable for gasoline range hydrocarbons (sufficient vapor pressure to enable detection), including mineral spirits, Stoddard solvent, aviation fuels, and some blends of jet fuels. This method is not suitable for nonvolatile petroleum hydrocarbons such as oils and most polyaromatic hydrocarbons (PAHs). Semi-volatile hydrocarbons (diesel, kerosene) may be detected if they are relatively fresh.
- Aromatics (BTEX): Methods 8021 or 8260.
- MTBE and Oxygenates: Either method 8021 or 8260, although method 8260 is advantageous to eliminate false positives due to co-elution with other hydrocarbons.
- Methane, Carbon Dioxide, Oxygen: For methane, the typical method is gas chromatography method with a flame detector, such as 8015 modified. For carbon dioxide and oxygen, the typical method is gas chromatography method with a thermal conductivity detector, such as ASTM Method 1945-96.
- PAHs: Due to low vapor pressures, these compounds cannot be detected by active soil gas methods (except for naphthalene) and only the lightest ones can be detected by passive soil gas methods.

b. Site Assessment/Characterization Applications

Certain components of a UST system are more likely to fail than others. For example, the tops of USTs where bungholes or man ways are present, seams in the UST, seams, patches and elbows in the piping runs, and dispensers are typical sources of leaks. In addition, the base of the tank pit and associated piping can often be source zones due to the pooling of leaked substances. The sampling program should be designed to cover the most likely sources.

Soil Vapor Method: The active soil vapor method is most typically employed. The passive soil vapor method can also be used, especially in locations with limited access and at sites where relatively low concentrations of VOCs are expected.

Sample Location and Spacing: The sampling locations and grid spacing should be sufficiently small to encounter areas of former USTs, piping, dispensers, etc. and any areas of gross contamination. When historical data regarding the layout of a UST system are unavailable, a useful strategy is to collect samples in a grid pattern. For a typical service station, a grid spacing of about 50 feet is reasonable. For more detailed site assessment/ characterization, a sample spacing of 10 to 20 feet is reasonable in the source area.

Collection Depth: Soil vapor samples are typically collected from 5 to 15 feet bgs to assess surface and UST releases. The chosen depth will be dependent upon the suspected source and what is being assessed: soil and/or groundwater. To assess the vertical extent of contamination, collect samples every 5 feet to 10 feet depending upon the depth to groundwater at the location of highest concentration.

c. Health Risk Assessment Program Design

Soil Vapor Method: The active method is most commonly used. Passive soil vapor methods are not applicable since they are nonquantitative. Permanent probes/implants offer the advantage of assessing transient effects that could affect contaminant vapor flux rates. Surface flux chambers may also be used.

Sample Location and Spacing: Enough samples should be collected to allow a representative estimate of the average flux to the base of the existing or future structure. At a minimum, samples should be collected at the location of highest vadose zone contamination, near or under the structure, and at each corner of the structure (inside if possible, immediately outside if not).

Collection Depth: For active soil vapor programs, samples should initially be collected from 5 feet bgs unless there is reason to suspect shallower contamination. If the calculated risk exceeds allowable levels, a vertical profile of the soil vapor at shallower depths may be appropriate. Samples from shallower depths are more subject to infiltration of surface air and variability due to transient effects. If soil vapor data from depths less than 5 feet bgs are collected, additional sampling events may be appropriate to ensure representative values.

Sample Frequency: Typically, a single sampling event should be sufficient to assess this risk pathway. In some situations additional sampling events may be appropriate, e.g., where the calculated risk from the first sampling event is close to acceptable levels or for shallow sampling depths.

d. Post-Remediation Assessment and Contaminant Monitoring

Sample spacing and collection depth will be dependent upon the objective of the monitoring and upon the size of the remediation area. For risk assessment and remediation monitoring, use the respective protocols described previously, but using semi-permanent probes/implants that are sampled multiple times over the course of the project.

e. Special Considerations for Fuel Sites

Vapor Leak: Gasoline vapor in equilibrium with fresh free-phased product, such as in USTs, contains approximately 8,000 µg/L-vapor of benzene and greater than 1,000 µg/L-vapor of toluene and xylene. Reformulated gasoline vapor can contain MTBE or ethanol at concentrations greater than 100,000 µg/L-vapor. Subsurface vapor leaks are possible from USTs and piping associated with them (vent pipes, pipe joints, vapor recovery lines, and tank bungs). Such leaks can create situations with no corresponding detectable soil contamination. Soil vapor located near or at the leak will contain relative concentrations of these compounds similar to the vapor in the UST. Soil vapor located further from the source may contain only some of these compounds due to differences in their physical properties.

Potential Impact of Vapor Contamination on Groundwater: Leaking gasoline vapors from a UST are a likely contaminant pathway to groundwater for both MTBE and ethanol, due to their high concentrations in the tank vapor and extremely low Henry's constants. In contrast, leaking gasoline vapors are an unlikely contaminant pathway to groundwater for the aromatics due to their lower concentrations in the tank vapor and moderate Henry's constants. The potential importance of this contaminant pathway increases with decreasing groundwater depth and is particularly acute in locations where the water table is near or above the UST, and where the vadose zone is dry. Sampling programs assessing this contaminant pathway should focus on the collection of soil vapor samples vertically through the vadose zone at regular intervals down to groundwater. The concentration profile down to groundwater and concentration at the groundwater interface may enable an estimate of the importance of this pathway.

2. Dry Cleaners and Industrial Facilities With Non-Petroleum VOCs

At industrial facilities, a variety of contaminants, conditions, and potential sources can exist. Many industrial sites contain above ground solvent sources, such as degreasers,

clarifiers, storage tanks, ink presses, spray booths, which can leak into the vadose zone. Subsurface sources can include leakage from drains, sumps, pipelines, and manufacturing lines. Consequently, a soil vapor survey at an industrial facility should be performed only after a thorough site reconnaissance has been performed to establish the potential sources and types of contamination. At dry cleaner sites, soil vapor contamination commonly exists under the washer unit, and soil contamination with corresponding soil vapor contamination commonly exists near liquid release sources such as sumps, drains, storage areas, and other disposal areas.

a. Chemical-Specific/Analytical Considerations

Chemicals associated with industrial facilities vary depending upon the type of facility, but typically include chlorinated solvents and degreasers, such as methylene chloride, trichloroethane (TCA), trichloroethylene (TCE) perchlorethylene (PCE), acetone, and methyl ethyl ketone. Not all compounds at a facility may be detectable by soil vapor methods depending upon their vapor pressures. At dry cleaner sites, the primary compound is perchlorethylene (PCE) and its breakdown products: vinyl chloride, dichloroethylene (cis and trans 1,2 DCE), and trichloroethylene (TCE). For quantitative programs, the two most common analytical methods employed are 8021 and 8260. Regardless of the actual analytical method used, the detection limits, calibration procedures, and other QA/QC criteria should meet the requirements in the soil vapor analysis section of this manual.

b. Site Assessment/Characterization Applications

Soil Vapor Method: The active soil vapor method is most typically employed. The passive soil vapor method can also be used, especially in locations with limited access.

Sample Location, Spacing, and Depth: A soil vapor survey performed as part of a site assessment and characterization would ideally be performed in a phased approach, starting with a wide spacing between sampling points (50 to 100 feet) to obtain an overall assessment of the site (and off-site if necessary) then focusing the sampling in areas of higher contamination to better define its limits (10 to 25 feet). Vapor samples should be collected from all potential source areas. Initial sampling depths should be determined by the type of release anticipated:

- Surface and near surface releases: 3 to 5 feet bgs.
- Deep releases (e.g., tanks, pipelines): at bottom of tank or pipeline.
- To assess the vertical extent of contamination, collect samples every 5 to 10 feet depending upon the depth to groundwater at the location of highest concentration.

c. Health Risk Assessment

The collection method, sample location, sample spacing, and collection depth criteria are the same as described for fuel sites, with the following exception. For health risk assessments at adjoining rooms/businesses to a dry cleaner in a strip mall, active soil gas samples should also be collected within one foot of the base of the slab to test for the presence of higher soil vapor concentrations caused by preferential transport at the bottom of the slab. Procedures used to collect samples at this shallow depth should ensure that no ambient air is collected, e.g., seals around the probe barrel. If soil vapor data from depths less than five feet bgs are collected, additional sampling events may be appropriate to ensure representative values.

d. Post-Remediation Assessment and Contaminant Monitoring

Sample spacing and collection depth will be dependent upon the objective of the monitoring and upon the size of the remediation area. For risk assessment and remediation monitoring, use the respective protocols described previously, but using semi-permanent probes/implants that are sampled multiple times over the course of the project.

e. Special Considerations for Solvent Sites

Vapor Clouds: Due to their high vapor pressures and high vapor densities, vapors may emanate from containers or pipes holding gaseous or liquid chlorinated compounds, collect on the floor, penetrate through the slab, and create a zone of contaminated vapor in the vadose zone. Such leaks can create soil vapor contamination with no corresponding detectable soil contamination. Such vapor clouds are commonly found under the washer unit at dry cleaners, under vapor degreasers, and in other above ground confined spaces containing solvents.

Potential Impact of Vapor Contamination on Groundwater: Due to their relatively low Henry's constants, the potential for vapors leaking from the surface to significantly impact groundwater is low, except in cases of very high soil vapor concentrations (typically greater than 100 µg/L-vapor at the groundwater interface) or in the presence of contaminated soil. Sampling programs assessing this contaminant pathway should focus on the collection of soil vapor samples vertically through the vadose zone down to groundwater. The concentration profile down to groundwater and concentration at the groundwater interface will enable an estimate of the importance of this contaminant pathway.

3. Methane Testing

a. Chemical Specific/Analytical Considerations

Methane is a colorless, odorless gas existing naturally in atmospheric air at a concentration of approximately 2 to 3 ppmv. It is commonly formed in the subsurface from the anaerobic breakdown of organic matter and can reach concentrations in the soil gas exceeding 50% in areas with abundant sources of organic carbon. Sources for methane generation include landfills, swamps and bogs, petroleum (oil and gas) reservoirs, farmlands, and areas contaminated by organic matter sources (sewage, petroleum spills, etc.). Methane may also originate from nonbiogenic, thermal origins, such as from volcanic sources. Because petroleum reservoirs are rare in San Diego County, the most likely sources of high methane on a site will be from the degradation of organic matter or from a leak from an existing methane, natural gas line. In areas of known volcanic rocks or thermal activity (e.g., Jacumba), thermogenic sources of methane may contribute. If natural gas lines exist on a site, the local gas company (SDGE) will send personnel to test for leaks.

Analysis Methods: Methane is most commonly measured with either a flame ionization detector (FID) or thermal conductivity detector (TCD). FIDs are approximately 10,000 times more sensitive than a TCD and can detect methane in the low parts per million range. TCDs typically measure methane at concentrations exceeding 1 part per thousand (greater than 1,000 ppmv). Both portable and laboratory-grade instruments exist with these detectors. For applications where quantitative results are desired, the analytical methodology employed is typically gas chromatography (GC). A variety of gas chromatographic methods using the FID and TCD have been developed by the petroleum industry and may be used. EPA Method 8015 modified for methane may also be used. Regardless of the actual analytical method used, the detection limits, calibration procedures, and other QA/QC criteria should meet the requirements in the soil vapor analysis section of this manual.

Soil Vapor Method: Active soil vapor surveys and flux chamber surveys are applicable to methane investigations. Passive soil vapor surveys are not used for methane investigations since methane is not quantitatively absorbed on the passive collector.

b. Site Assessment/Characterization

Sample Spacing: The selection of sampling points is strongly dependent upon the need for adequate coverage and budget. General grid patterns with 50 to 100 feet centers are typical for reconnaissance work, while closer spaced, irregularly situated locations (10 to 50 feet) are commonly used for covering potential source areas.

Collection depth: A nominal collection depth of five feet bgs is generally considered to maximize the chances of detecting contamination yet minimizing the effects due to changes in barometric pressure, temperature, or breakthrough from the surface. Methane is generated under anaerobic conditions, which typically exist at greater depths in the vadose zone. For source determination, samples should be collected at various depths at the same location to determine the depth of the methane source.

c. Health Risk Assessment (Upward Vapor Migration)

Potential Risk: The principal health and safety risk posed by methane is the risk of explosion due to concentration buildup in confined spaces such as underground public utility structures (sewage lines, utility trenches and vaults) or above ground structures. The lower explosive limit (LEL) for methane is 5% (50,000 ppmv). Currently (as of January 2002), the San Diego County Department of Planning and Land Use Building Department is concerned if concentrations exceeding 10% of the LEL (5,000 ppmv) are detected in the shallow soil gas near existing or propose aboveground structures. Refer to County Code of Regulatory Ordinance, Title 8, Division 6, Section 86301.

Sample Location and Spacing: Enough samples should be collected to allow a representative estimate of the average flux into the existing or future structure. For commercial sites, a minimum of four locations, one on each corner of the footprint, should be initially collected. For larger proposed residential developments, one location per lot is sufficient initially. Additional locations on the footprint or lot are advised if elevated levels (greater than 1,000 ppmv) are found. Refer to the previously referenced ordinance for any specific requirements on sites under the County Department of Planning and Land Use Building Department jurisdiction.

Collection depth: For active soil vapor programs, samples should initially be collected from five feet bgs. If significant levels (greater than 1,000 ppmv) are found at this depth, collection of a sample closer to the surface (1 foot to 2 feet) at the same location is advised to document if elevated levels approach the surface. It is also advisable to do vertical profile sampling at greater depths if significant levels are detected to determine if there is a potential methane source zone below the proposed structure.

d. Post-Development Assessment and Contaminant Monitoring

For contaminated sites, monitoring of the methane levels immediately below existing or proposed aboveground structures is advised. Refer to the existing County ordinance for specific requirements.

F. Documentation

1. Work Plan

If the lead agency is currently providing oversight and/or will be involved in some review capacity and potential (regulatory) site closure, an appropriate work plan should be prepared and submitted to the lead agency for review prior to implementation of the proposed soil vapor survey. Revisions to the work plan may be requested prior to approval.

The work plan should provide sufficient details, description of site conditions, and identify project objectives so that the lead agency can fully evaluate the proposed work. The work plan should reference the applicable section(s) of the SAM Manual or other guidance documents, rather than restating existing technical guidelines. The work plan should contain the main sections, and address specific issues, pertaining to:

- Health and safety
- Purpose and scope of work planned
- Background information (site history, existing analytical data, etc.)
- Current site conditions, depicting surface features and known buried structures
- Description of proposed work (i.e., sampling strategy and protocol, including sampling technique and analytical methodology)
- Schedule of proposed work

The type of equipment to be used and/or the contractor planned for the work should be identified. The needed information in the work plan should be presented in a succinct and accurate manner to facilitate the review process, using existing tabular data and clear illustrations as deemed necessary. Existing analytical data should also be presented in tabular form and/or graphically on maps.

2. Field Data

Data acquisition and good field notes are important to document site-specific conditions observed and encountered during the actual vapor sampling and related field work. Such information can/should be used to prepare the written report and other work products (i.e., data tables, maps, etc., as described in Section 5c. below). Accurate and clear field notes, maintained on special forms and work sheets, could be used to further assess site conditions and the findings of the vapor survey. The site-specific types of information that should be acquired in the field and documented include, but should not be limited to:

- Sampling locations (detailed map at an appropriate scale to illustrate the data points)
- Sampling methods and devices, including QA/QC procedures
- Field equipment calibration, detection limits, quantification, and unusual conditions
- Sample identification/designation
- Date and time of sample collection
- Identification of sampling personnel
- Sampling depth (including obstructions encountered), or sampling height
- Known or encountered stratigraphic/lithologic conditions, as applicable
- Apparent soil moisture conditions encountered, as applicable
- Weather conditions
- Sample purge volumes
- Volume of vapor sample extracted
- Analytical method(s)
- Chain-of-custody records

It is recognized that some of the information may be documented/maintained by the contractor (field technician) actually conducting the vapor sampling, if an outside company is used. The fieldwork should be supervised by an appropriately trained and experienced professional.

3. Report Preparation

The components of the summary report should include the items listed in Section 4, VI of this manual. Some of the items may not be applicable to the particular (site-specific) vapor survey to be performed. For example, information may not be available or understood regarding the lithologic/stratigraphic conditions beneath the concrete slab while conducting a building ventilation survey to assess potential volatile compounds within the enclosed space.