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ABBREVIATION LIST

ATSDR	Agency for Toxic Substances and Disease Registry
BAQE	Bureau of Air Quality Evaluation
BFB	4-bromofluorobenzene
BTEX	benzene, toluene, ethylbenzene and xylenes
bwt	below the water table
cc	cubic centimeter
CHC	chlorinated hydrocarbon
CPSi	cancer potency slope, inhalation
CRM	certified reference material
CSM	conceptual site model
DDE	dichlorodiphenyldichloroethylene
DNAPL	dense non-aqueous phase liquid
DSRT	Division of Science Research and Technology (NJDEP)
EDSA	Electronic Data Submission Application
FID	flame ionization detector
FSPM	Field Sampling Procedures Manual
FTDS	field test data sheets (for Analytical Methods TO-15 and TO-17)
GC	gas chromatography
GC/MS	gas chromatography/mass spectrometry
GIS	Geological Information System
GWSL	Ground Water Screening Level
GWQS	Ground Water Quality Standards
HDNL	Health Department Notification Level
Hg	mercury
HQ	hazard quotient
HVAC	heating, ventilation and air conditioning
IA	indoor air
IASL	Indoor Air Screening Level

ID	inner diameter
IEC	immediate environmental concern
IRIS	Integrated Risk Information System
IRM	interim remedial measure
ITRC	Interstate Technology and Regulatory Council
J&E	Johnson and Ettinger model
Koc	organic carbon partition coefficient
LCS	laboratory control samples
LFPS	low-flow purging and sampling
LNAPL	light non-aqueous phase liquid
MDL	method detection limit
MIBK	4-methyl-2-pentanone
MW	monitor well
µg/m3	microgram per cubic meter
MTBE	methyl tertiary-butyl ether
NAPL	non-aqueous phase liquid
NELAP	National Environmental Laboratory Accreditation Program
N.J.A.C.	New Jersey Administrative Code
NJDHSS	New Jersey Department of Health and Senior Services
NJDEP	New Jersey Department of Environmental Protection
OD	outer diameter
OQA	Office of Quality Assurance (NJDEP)
OSHA	Occupational Safety and Health Administration
PA DEP	Pennsylvania Department of Environmental Protection
PA/SI	Preliminary Assessment and Site Investigation
ppbv	parts per billion by volume
PCE	tetrachloroethene (also called perchloroethene)
PDBS	passive diffusion bag samplers
PEL	permissible exposure limit
PID	photoionization detector
QA/QC	quality assurance/quality control

RAL	Rapid Action Level
RAW	Remedial Action Workplan
RBC	risk based concentration
RfC	reference concentration
RfD	reference dose
RfDi	reference dose, inhalation
RL	reporting limits
RRT	relative retention time
SCAN	continuous scanning mode
SDG	sample delivery group
SGSL	Soil Gas Screening Level
SIM	selective ion monitoring
SOP	Standard Operating Procedures
SRM	standard reference material
SSURGO	Soil Survey Geographic Database
SSV	safe sampling volume
TBA	tertiary butyl alcohol
TCE	trichloroethene
TRSR	Technical Requirements for Site Remediation (N.J.A.C. 7:26E)
URF	unit risk factor
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VI	vapor intrusion
VOC	volatile organic compound(s)

1.0 INTRODUCTION

Vapor intrusion (VI) has received increased attention and evolved rapidly over the last few years as a potential exposure pathway of concern in the investigation and remediation of contaminated sites. VI is defined as the migration of volatile chemicals from the subsurface into overlying buildings (USEPA 2002b). The presence of volatile organic compounds (VOC) in soil or ground water offers the potential for chemical vapors to migrate through subsurface soils and along preferential pathways (such as underground utility lines) potentially impacting the indoor air quality of affected buildings.

The accumulation of volatile vapors in impacted structures can result in more immediate health concerns associated with high levels of contaminants, as well as the potential for chronic (i.e., long term) health effects associated with lower levels of site related contaminants. This document addresses both chronic effects and more immediate health concerns.

The objective of the NJDEP document is to provide guidance in determining whether VI of site related contaminants is occurring and to highlight what actions are appropriate. This document replaces the New Jersey Department of Environmental Protection's Indoor Air Sampling Guide for Volatile Organic Compounds (NJDEP 1999).

1.1 Regulatory Basis for the Guidance

The regulatory basis for the evaluation of the VI pathway is rooted in various sections of the Department's Technical Requirements for Site Remediation (NJDEP 2003a), or TRSR. The TRSR (N.J.A.C. 7:26E-1.11) state that the first priority during remediation is to ensure that "contaminants in all media should be contained and/or stabilized to prevent contaminant exposure to receptors and to prevent further movement of contaminants through any pathway." N.J.A.C. 7:26E-1.13 sets forth narrative ground water remediation standards for contaminated sites which "Ensure no release of contaminants to the ground surface, structures or air in concentrations that pose a threat to human health."

Many of the other narrative ground water remediation standards in N.J.A.C. 7:26E-1.13 are also relevant to the VI pathway, including the policies and narrative criteria from the Ground Water Quality Standards (GWQS), in N.J.A.C. 7:9-1.2 and 1.7. These requirements incorporate human health and welfare concerns specified in the November 13, 1991 Basis and Background for the GWQS.

In addition to the above, the TRSR at N.J.A.C. 7:26E-3.5 stipulate that "the site investigation of building interiors shall be conducted when contaminants . . . outside the building have the potential to migrate into the building." The TRSR at N.J.A.C. 7:26E-4.1 also state that the purpose of a remedial investigation is to "identify the migration paths and actual or potential receptors of contaminants on or through air, soil, bedrock, sediment, ground water, surface water and structures at a contaminated site."

Furthermore, N.J.A.C. 7:26E-4.4(h)3viii specifies that the occurrence of ground water contamination above the applicable remediation standards must include evaluation of "any subsurface utilities, basements or other structures to determine whether vapor hazards as a result of the ground water contamination may exist for receptors associated with the utility or structure." The TRSR at N.J.A.C. 7:26E-6.3(d)7 also stipulate that the submission of a proposal for natural ground water remediation must demonstrate that "contaminant levels in ground water do not present a vapor risk to any receptors."

1.2 Intended Use of the Guidance

The NJDEP guidance is intended for use in the evaluation of the VI pathway at primarily VOC contaminated sites located within the state of New Jersey. While this document concentrates on VOC contaminated sites, the Department may investigate other volatile compounds for the VI pathway on a case by case basis. The potential for VI impacts shall be evaluated if volatile contaminated media are present at a site. In addition, this evaluation shall be considered for sites where active ground water and/or soil remediation systems are proposed or being undertaken that may affect soil vapor concentrations and the generation of potentially volatile/toxic degradation products with the potential to impact the air quality of nearby structures. These systems include, but are not limited to, air sparging, bioremediation, bioventing and chemical oxidation systems.

The intended use of this document is to assist interested parties in determining whether VI impacts may be present that require additional actions to mitigate or eliminate actual or potential human health impacts. This guidance addresses those procedures currently recommended by the New Jersey Department of Environmental Protection (NJDEP or the Department) in the evaluation of potential VI related impacts at a site. While this document is guidance, not regulation, evaluation and remediation for the VI pathway is required as part of the TRSR (as previously discussed). It is therefore recommended that the regulated community consult with the Department before implementing methodologies/procedures not included in this document.

1.3 Overview of the Guidance

This guidance incorporates a risk based, staged approach to evaluate the potential for VI at sites under review. The document has been developed after consideration of the latest, state of the science procedures/methodologies currently included in USEPA and other State guidance, as well as information available from conferences and training events, that address the VI pathway. While the Department has incorporated many of the latest recommended methodologies in the document, New Jersey specific characteristics, input parameters and policies have also been included, where applicable.

The Department's investigative strategy for the VI pathway consists of a series of stages designed to consistently and logically progress through the process of assessing the potential for VI. These stages are structured to be consistent with the organization of a typical investigation as required in the TRSR. Further detail on these stages can be found throughout this document. In addition, the Decision Flow Chart (Appendix A) should be consulted when assessing the VI pathway.

Chapter 2 provides a detailed introduction to concepts relevant to the VI pathway and guidance on developing a conceptual site model (CSM).

VI Pathway Investigative Strategy

Preliminary Assessment and Site Investigation

Stage 1	Assess potential for vapor intrusion
Stage 2	Rapid Action Determination
Stage 3	Evaluate existing data against screening levels

Remedial Investigation

Stage 4	Develop and implement VI Investigation Workplan
	4A. Delineate GW contamination
	4B. Investigate soil gas
	4C. Conduct sub-slab and indoor air sampling
Stage 5	Evaluate RI data using generic screening levels
Stage 6	Prepare and implement site-specific investigation
Stage 7	Evaluate data using generic or site-specific screening levels

Remediation and Monitoring

Stage 8	Determine appropriate remedial action
Stage 9	Implement remedial action
Stage 10	Establish a long-term monitoring program
Stage 11	Assess ability to terminate remedial action

Chapter 3 describes the general decision framework for the phased approach the Department has defined for the evaluation of a site. The Preliminary Assessment and Site Investigation phase presents a series of situations where prompt action is necessary in order to address potential impacts to public health. The Remedial Investigation phase deals with strategies for investigating and assessing the VI pathway. Site-specific screening options and procedures are included in this phase. Finally, the Remediation and Monitoring phase addresses remedial actions, monitoring and maintenance at the site.

The generic screening levels and their application are discussed in Chapter 4. Chapter 5 covers the site-specific screening options available for use in the evaluation of a site. Recommended investigative procedures for ground water, soil gas and/or indoor air are presented in Chapter 6. Chapter 7 discusses the evaluation of analytical data collected to address the pathway.

Consideration of background ambient air and indoor air quality in the evaluation of a site is discussed in Chapter 8. Chapter 9 includes current guidance on addressing sites contaminated with petroleum hydrocarbons. Remedial alternatives along with monitoring and institutional control requirements are covered in Chapter 10. Chapter 11 contains guidance on community outreach when evaluating potential VI impacted sites. The tables and appendices included in the guidance are listed in the Table of Contents and provide detailed information in support of the various topics included in the document.

1.4 Guidance Updates

As previously noted, evaluation of the VI pathway is a rapidly evolving field. With this knowledge, the Department will update the document as the state of the science advances. The Department intends to modify the screening level tables twice a year based on updates to the USEPA Region III Risk Based Concentration (RBC) Table used in the development of the screening levels. The Department will also modify the guidance as appropriate based on advances in the recommended methodologies, analytical procedures and associated analytical reporting limits.

The current document along with updates to the screening levels and other sections of the document are, or will be, presented on the Department's web site at www.state.nj.us/dep/srp/guidance/vaporintrusion/. It is recommended that interested parties refer to the NJDEP web site to ensure that they are using the most current information in the evaluation of a site.

2.0 CONCEPTUAL SITE MODEL

Assessing the potential for VI to indoor air should begin with visualizing a simplified version of the site or physical setting; this simplified idea, picture, or description is a conceptual site model (CSM). This chapter serves as a guide for developing a CSM and also as a detailed introduction to the VI pathway. Although not required, NJDEP strongly recommends early development of a written, illustrated CSM that can be used to plan, scope, and communicate the next steps in the investigation and any remedial actions, if needed. Starting an investigation in the absence of a CSM is likely to increase costs and decrease efficiency. The CSM should be updated and refined, as new data become available.

The basic components of a CSM are known or suspected contaminant sources, contaminant migration pathways, potential human receptors and the exposure routes by which these receptors may come in contact with contaminants on a site-specific basis. Figure 2-1 below is an illustration of a simple, preliminary CSM for the VI pathway.

General CSM for Vapor Intrusion

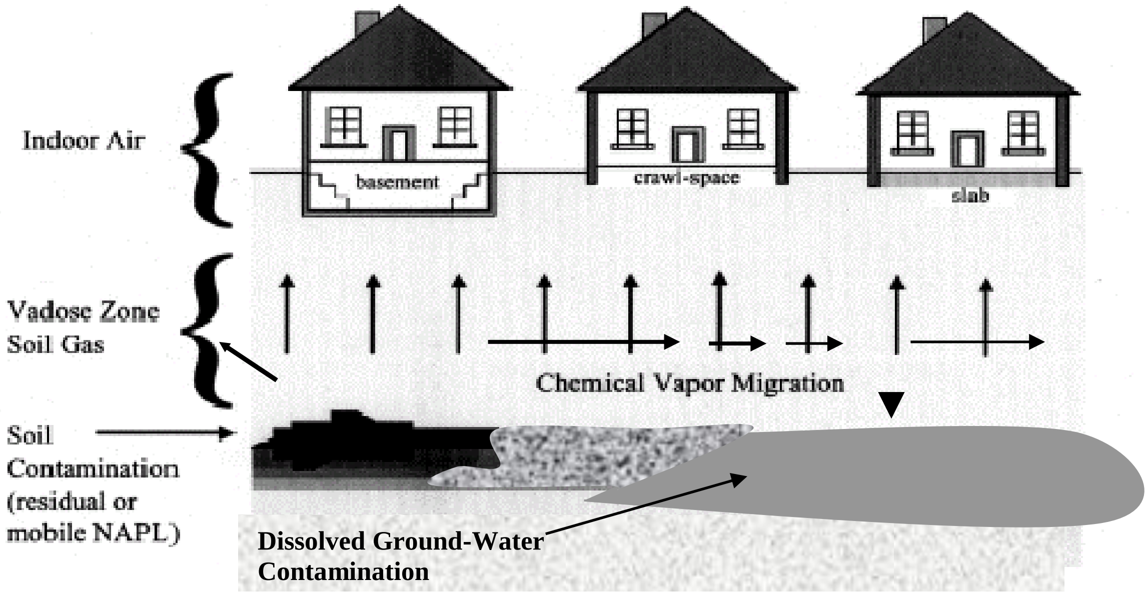


Figure 2-1. General Vapor Intrusion Conceptual Model
Source: USEPA 2002b

The CSM serves to identify currently complete or potentially complete pathways to receptors and the potential for future risks. There is always some degree of uncertainty in estimating current or future exposures, and the CSM should explicitly address uncertainty, often through consideration of "worst-case" and "best estimate" scenarios. If neither scenario poses any unacceptable risks or both scenarios pose unacceptable risks, it may not be necessary to reduce uncertainty through further investigation or analysis prior to implementing corrective measures or concluding the pathway poses no unacceptable risk. Otherwise, additional information may be needed to reduce uncertainty to a level where current and future risks can then be characterized and addressed, as needed. The CSM, therefore, can be an effective tool for investigation and risk management decisions, functioning to streamline those pathways that need to be addressed and those that do not.

Figures, maps, cross sections, diagrams/flow charts, tables and graphs can be used to summarize and illustrate the overall CSM, its various components, and the associated data. These visual aids are more effective tools than text descriptions alone for communicating complex information to interested parties. The narrative should clarify which CSM components are site-specific, measured or known, and which include assumptions or general information.

Investigators (i.e., person(s) responsible for evaluating the VI pathway) should start a CSM by incorporating all relevant site-specific data, historical information, and relevant general concepts/information. Relevant off site and regional information (e.g., aerial photographs, Geographic Information System data, historical and current tax maps, etc.) should also be incorporated.

As new data are collected, it is vital to compare them with the current CSM and modify the CSM as needed by incorporating the new information. The accuracy of the CSM can be evaluated by the degree to which new information is consistent with expectations based on the CSM prior to the data collection.

A CSM is not a mathematical model, but can be the basis for a mathematical model. This chapter focuses on the conceptual framework, which must be developed before any mathematical representation or modeling is attempted. The following subsections describe the components of the CSM in detail:

- Sources of VI
- Vapor Migration Mechanisms
- Receptors and
- Factors Affecting Vapor Migration.

2.1 **Sources of Vapor Intrusion**

Initial consideration in the preparation of a CSM should be centered on whether there is a vapor source with the potential to cause VI. In general, a vapor source of VI can be defined as the presence, or reasonably suspected presence, of a chemical of sufficient volatility and toxicity in the subsurface with sufficient mass and/or concentrations to pose a possible inhalation risk within current or future occupied overlying enclosures. This definition includes the presence of a volatile chemical or chemicals adsorbed to, or in the pore space/fractures of unsaturated soil or rock, or in the uppermost portions of the saturated zone. Such vapor sources can exist in the form of: free phase or residual NAPL above or near the top of the saturated zone; contaminated soil in the vadose zone; and shallow dissolved phase contamination in ground water. Another possible source of subsurface VI is the release of volatile compounds in the vapor phase from underground tanks or piping and certain types of aboveground facilities that use volatile compounds during operations. This particular source is commonly referred to as a “vapor cloud.” Sources of indoor air contamination not associated with VI (e.g., ambient air, building materials, consumer products) should also be considered when developing and evaluating a CSM.

2.2 **Vapor Migration Mechanisms**

When a chemical of sufficient volatility and toxicity is present in the subsurface, there are several transport mechanisms by which the chemicals can migrate. The CSM should identify the major and minor migration pathways and processes through which a receptor can be exposed at a particular site. The four main transport mechanisms that should be considered are described and illustrated below.

- Diffusion of vapors from sources in the unsaturated zone
- Diffusion of vapors from sources in shallow ground water
- Advective/convective transport of vapors
- Vapor migration through preferential pathways

2.2.1 Diffusion of vapors from sources in the unsaturated zone

Diffusion occurs as a result of a concentration gradient between the source and the surrounding area; it can result in the upward, lateral or downward migration of vapors through the vadose zone. The location of the source is an important factor influencing the direction of vapor migration. Identifying soil gas concentration gradients may help determine the location of unidentified vapor sources. Figure 2-2 illustrates lateral and downward vapor migration in the

Vapor Diffusion

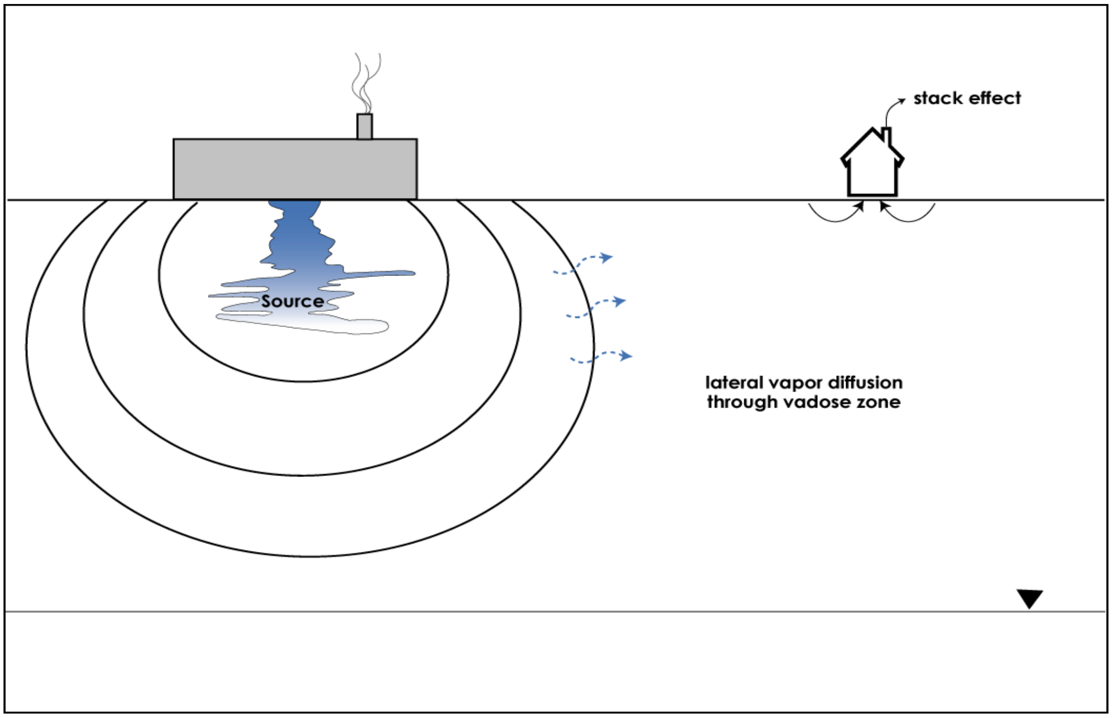


Figure 2-2. Vapor Diffusion from Release at Surface
Source: McAlary 2003

unsaturated zone from a release of contaminants near the surface The USEPA Draft Vapor Intrusion Guidance (USEPA 2002b) recommends 100 feet as an initial estimate for steady state travel distance based on diffusive vapor transport in the vadose zone**.** Variability in site characteristics, such as soil porosity, effective permeability, ground surface cover, ambient temperature and age of a release may increase or decrease the distance vapors migrate. A relatively impermeable surface cover above a vapor source for example, may increase the distance a vapor plume would travel laterally if it significantly impedes vapors from escaping to the atmosphere.

2.2.2 Diffusion of vapors from sources in shallow ground water

Diffusion occurs as a result of a concentration gradient between the source and the surrounding area; in this case, the source is shallow groundwater contamination and/or NAPL. This can result in the upward or lateral migration of vapors through the vadose zone. Figure 2-3 illustrates diffusion of vapors in the vadose zone from shallow ground water contamination. Depending on the hydraulic conductivity, hydraulic gradient, aquifer heterogeneity, time since chemicals were released and natural attenuation processes, the distribution of volatile chemicals in ground water may extend considerable distances.

Within a set volumetric space where contaminated ground water is the only source of vapors in the subsurface, the total mass of volatiles off-gassing from ground water and diffusing through the vadose zone (vertical mass flux) cannot exceed the total mass of volatiles moving through that space laterally in ground water. For aquifers with slower ground water velocity, the lateral mass flux in shallow ground water leaving the source area may be the limiting factor in VI impacts.

Diffusion of Vapors From Ground Water

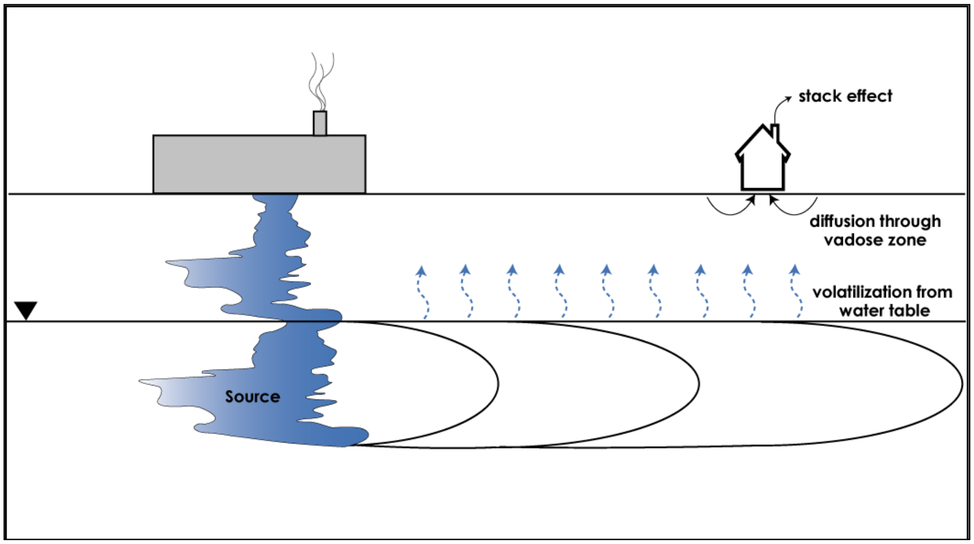


Figure 2-3. Vapors Diffusing toward Buildings from Shallow Ground Water

Source: McAlary 2003

2.2.3 Advective/convective transport of vapors

The horizontal and vertical movement of vapors located near a building foundation is often affected within an area referred to as the “zone of influence” (see Figure 2-4). Chemicals entering this zone are drawn into the building via soil gas advection and convection resulting from building interiors that exhibit a negative pressure relative to the outdoors and the surrounding soil. The reasons for this pressure differential include: 1) factors relating to operation of HVAC system including inadequate combustion or makeup air and unbalanced air supply and exhaust systems; 2) the use of fireplaces and other combustion sources, which results in venting of exhaust gases to the exterior; 3) the use of exhaust fans in bathrooms and kitchens; 4) higher temperatures indoors relative to outdoors during the heating season or as a result of solar radiation on rooftops; and 5) pressure exerted on the wall of a building caused by wind movement over the building (Bernoulli’s principle). The combination of these actions/conditions results in a net convective flow of soil gas from the subsurface through the building foundation to the building interior. As would be expected from the above list, indoor air volatile concentrations are generally higher during the heating season in homes affected by VI.

Advective/Convective Transport of Vapors

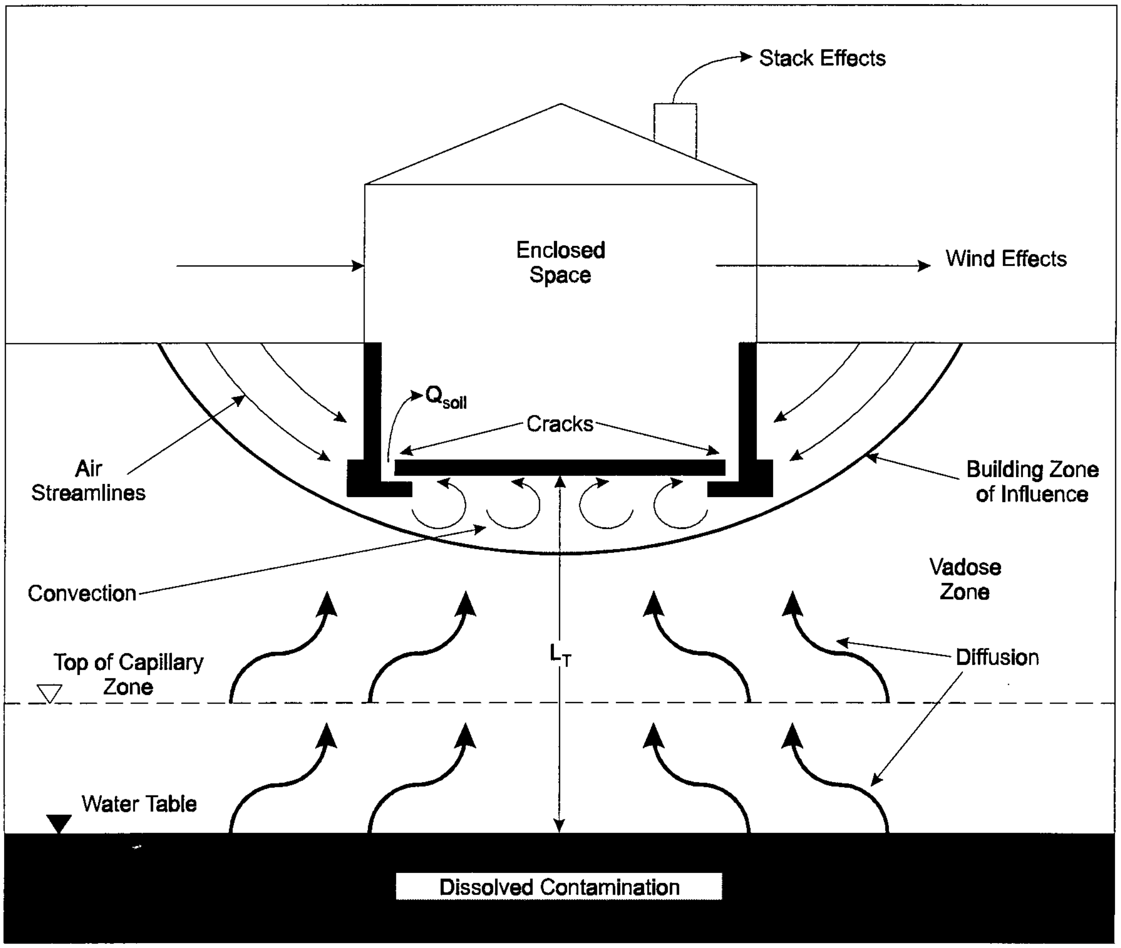


Figure 2-4. Advective and Convective Transport Near Buildings

Source: USEPA 2004d

Figure 2-4 illustrates the transport of vapors near a typical residence or building with a basement. The rate of contaminant entry through the foundation and the air exchange rate of the building will determine the concentration of the contaminants in the home resulting from VI. A similar pattern of soil gas movement can occur around buildings without a basement or around those without any concrete foundation slab. The term Q_{soil} in Figure 2-4 represents the rate of soil gas entry into the building. In many cases, granular fill materials are placed beneath concrete slabs or adjacent to building footings, which may be much more permeable to air flow than surrounding soils. Air flow will occur through the path of least resistance, so the streamlines for air flow may be different than those depicted on Figure 2-4.

Advective/convective transport of vapors can occur in other scenarios. It has been observed that certain commercial and business operations may result in volatile organic vapors entering the unsaturated zone solely as a vapor possibly due to density differences between these vapors and the atmosphere (USEPA 2002b; Hartman 1998). These operations could include tetrachloroethene (PCE) dry cleaning units, vapor degreasers in machine shops, spray booths in inking or painting facilities using chlorinated solvent based inks or paints, and USTs/underground piping. Highly permeable deposits and very high vapor concentrations are necessary for there to be significant density dependent transport below ground, therefore this scenario is likely to be relatively rare. Contaminated soil vapor may also occasionally result from pressurized buildings forcing contaminated indoor air out through openings in the foundation and into nearby soil. The affected area or zone of influence would likely be relatively small, but could affect sub-slab or other soil gas samples collected below buildings or structures such as those described above.

Another possible advective vapor transport mechanism, called “barometric pumping,” is caused by cyclic changes in atmospheric pressure. These changes create a “piston like” force on soil gas, possibly causing a cyclic up and down flow of contaminant vapors in the affected interval. The magnitude of a barometric pressure cycle is typically a small percentage of atmospheric pressure and its effect decreases with depth. The soil texture, soil air permeability, and moisture content affect the depth to which the pressure change may affect vapor transport. Soil gas compression and expansion in response to barometric pressure fluctuations may alternately enhance or inhibit VI.

In areas subject to tidal fluctuation in the water table, or rapid increases in the water table elevation due to stormwater runoff, such increases in water table elevation may enhance advective transport.

2.2.4 Vapor migration through preferential pathways

In preparation of each CSM, investigators may look for the presence and locations of natural and man made pathways in the subsurface with high gas permeability through which vapors can rapidly migrate. The term preferential exposure pathway has been defined, in part, as:

> "…a natural (e.g., shallow rock or vertically fractured soil) or manmade (e.g., buried utilities) feature that creates a sufficiently direct pathway from a source to a receptor to make the use of the default model [the Johnson and Ettinger model] for predicting indoor air concentrations unacceptable. Shallow utilities buried at a depth that is insignificant with respect to the column of soil between the slab and the source do not automatically constitute a preferential pathway, nor should this definition include surface paving outside the building or the presence of crushed stone beneath the slab as normally placed for slab foundation material." (PA DEP 2004)

Naturally occurring fractures and macropores may facilitate vertical or horizontal vapor migration while anthropogenic features such as utility conduits would likely facilitate horizontal vapor migration due to their shallow depth (USEPA 2002b). Buildings that are, or may become, inhabited should be evaluated if they are associated with a preferential pathway that is within some reasonable distance of a source area (based on professional judgment).

Investigators should also evaluate the potential for VI in situations where a preferential pathway leading to a structure runs near to, or through, a source area. For sources containing aerobically degradable contaminants, however, it is unlikely that sufficient vapors will reach the structure to result in a VI problem unless the pathway and structure are both very close to the vapor source. Biodegradation of benzene, toluene, ethylbenzene, and xylene (BTEX) vapors in the vadose zone has been shown to be a very efficient process as long as sufficient oxygen is available (DeVaull, et.al. 1997). Thus, if a preferential pathway is not close to a source area, biodegradable vapors would likely degrade before reaching the pathway and/or within the pathway before reaching the structure.

2.3 Receptors

The Technical Requirements for Site Remediation (NJDEP 2003a) define a receptor as "any human or other ecological component which is or may be affected by a contaminant from a contaminated site." The primary VI receptors are the human occupants of enclosed spaces overlying subsurface volatile contamination. Exposure to volatiles can result in health problems in individuals occupying a building subject to VI. Enclosed spaces or buildings, for the purpose of this guidance, are defined as any structure currently or potentially impacted by subsurface volatile contaminants. To account for possible change in future use, VI is of potential concern in buildings/enclosed spaces whether or not they are currently occupied. Buildings with significant air exchange rates (e.g., commercial garages/spaces with large doors/openings) or significantly limited use (e.g., small utility sheds) will be evaluated on a site-specific basis.

Human exposure typically can take place under a residential (unrestricted use) or nonresidential (restricted use) exposure scenario. Residential settings include single family homes, townhouses, and apartment buildings. Receptors under a residential exposure scenario consist of both adults and children who are expected to spend a greater period of time in a residential setting than those individuals in a nonresidential setting. As discussed in Chapter 4, it is the Department's policy that day care centers and schools are evaluated as a residential use due to the potentially sensitive nature of the exposed population (children).

Nonresidential settings include office buildings and commercial or industrial complexes. Nonresidential receptors consist of adult workers in the above buildings or complexes. Nonresidential settings with sensitive populations (e.g., working pregnant women) will be handled on a site-specific basis. Occupational settings that fall under the purview of OSHA may be handled differently than those not subject to OSHA regulations when indoor air concentrations from normal operating practices can not be ruled out.

2.4 Factors Affecting Vapor Migration

Vapor and liquid transport processes and their interactions with various geologic and physical site settings (building construction and design) under given meteorological conditions have unique effects on the VI pathway. Variations in building design, construction, use, and maintenance, site-specific stratigraphy, sub-slab composition and temporal variation in atmospheric pressure, temperature, precipitation, infiltration, soil moisture, water table elevation, and other factors, combine to create a complex and dynamic system. General aspects of several of these processes and site settings/conditions are described and illustrated below. These factors are not listed in a prioritized manner and not all factors are relevant at every site:

- Biodegradation (of volatile contaminants as they migrate in the vadose zone)
- Site Stratigraphy
- Soil Moisture and Ground Water Recharge
- Fluctuations in Water Table Elevation
- Ventilation Systems in Commercial/Industrial Buildings.

2.4.1 Biodegradation

Many volatile contaminants, especially nonchlorinated hydrocarbons, can be degraded by indigenous soil microbes in the presence of oxygen. Oxygen is ubiquitous in the atmosphere, at a concentration of about 21%, which constitutes an essentially limitless supply. Oxygen is transported to the subsurface by barometric pumping, and by diffusion if there is a concentration gradient, which will develop at sites where oxygen is being consumed in the subsurface at appreciable rates. In some cases, oxygen is consumed at rates faster than it migrates downward, so degradation rates vary significantly from site to site (Roggemans et al. 2001).

2.4.2 Site Stratigraphy

Figure 2-5 illustrates a hypothetical example of how determining site stratigraphy can be crucial to discovering actual or potential vapor migration pathways. Figure 2-5 depicts a geologic layer of low permeability that is both dipping toward a nearby building and creating a perched water table. Perched, saturated zones are often very localized and only intermittently present. As shown in Figure 2-5, a local perched zone may also occur where there is a leak in a water supply or sewer line. The direction of dip shown in Figure 2-5 is causing contaminated ground water in the perched zone to move in the opposite direction from the regional water table. This situation creates the potential for VI in a location that would not be expected, based solely on determination of the regional ground water flow direction. Conversely, a low permeability layer in the unsaturated zone can impose significant impedance to upward migration of vapors from an underlying source (e.g., ground water), and prevent unacceptable VI in areas where it might otherwise occur. The second scenario is probably more common but, in either case, some understanding of the stratigraphy is necessary to develop an appropriate CSM.

Performing investigative work to evaluate natural and manmade stratigraphy (e.g., boring logs, surface geophysics) could also reveal features such as a highly permeable gravel layer or a dry, fractured clay layer. Both types of layers could result in increased vapor migration rates, and/or distances, possibly as far as a few hundred feet from a source area (McAlary 2003; USEPA 2002b). Not including such stratigraphic features in a CSM could negatively affect the selection of appropriate sampling methods, or locations.

Perched Water Transport

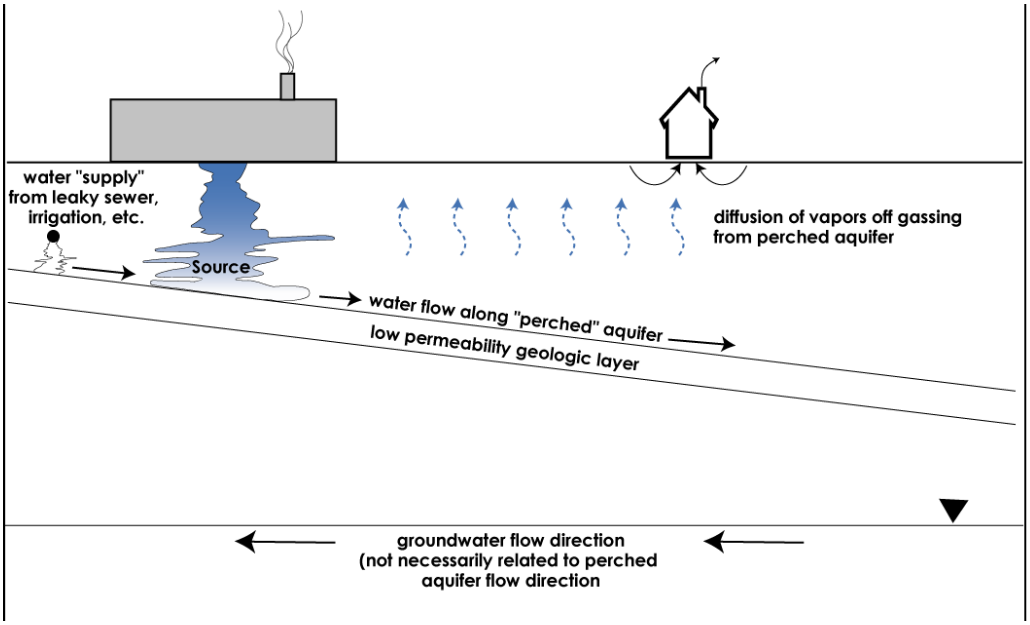


Figure 2-5. Low Permeability Layer Affecting Vapor Migration

Source: McAlary 2003

2.4.3 Soil Moisture and Ground Water Recharge

The rate of vapor diffusion is about 10,000 times that of diffusion of dissolved contaminants through water. Thus, high soil moisture levels in the vadose zone can dramatically reduce the effective rate of vapor migration through soil. The possible impact of high soil moisture should be considered in the development of the VI investigation workplan. More specific information on how these changes could affect investigative approaches is discussed in Chapters 4 and 6.

In many areas of New Jersey, aquifer recharge is likely to play a significant role in vapor migration. In the Coastal Plain Physiographic Province, and wherever the surficial saturated layer occurs in unconsolidated sediments and deposits with a ground water flow regime that is relatively homogeneous and isotropic, infiltrating precipitation and irrigation can often influence the vertical migration of a ground water contaminant plume. As such, it is important to assess the actual or potential degree of site-specific infiltration. Factors such as the relative amount of precipitation in a given period of time, type of surface cover, extent of lawn watering, and soil permeability should be evaluated.

As ground water moves away from the source area, infiltrating water that reaches the water table will lie on top of the contaminated ground water and, gradually, a lens of clean ground water may form above a contaminant plume (Figure 2-6). The probability of this occurrence, and the thickness of the lens, would increase as the plume moves further away from the source, especially in areas where precipitation can rapidly infiltrate and/or a downward hydraulic gradient exists due to other factors.

An NJDEP Site Remediation Program May 2001 newsletter article, entitled “Diving Plumes that Migrate to Depths Below the Water Table,” (Griesemer 2001**)** is available at www.state.nj.us/dep/srp/news/2001/0105_04.htm. The article describes this phenomenon and various causes for a “diving plume.”

Clean Water Lens Impeding Diffusion to Vadose Zone

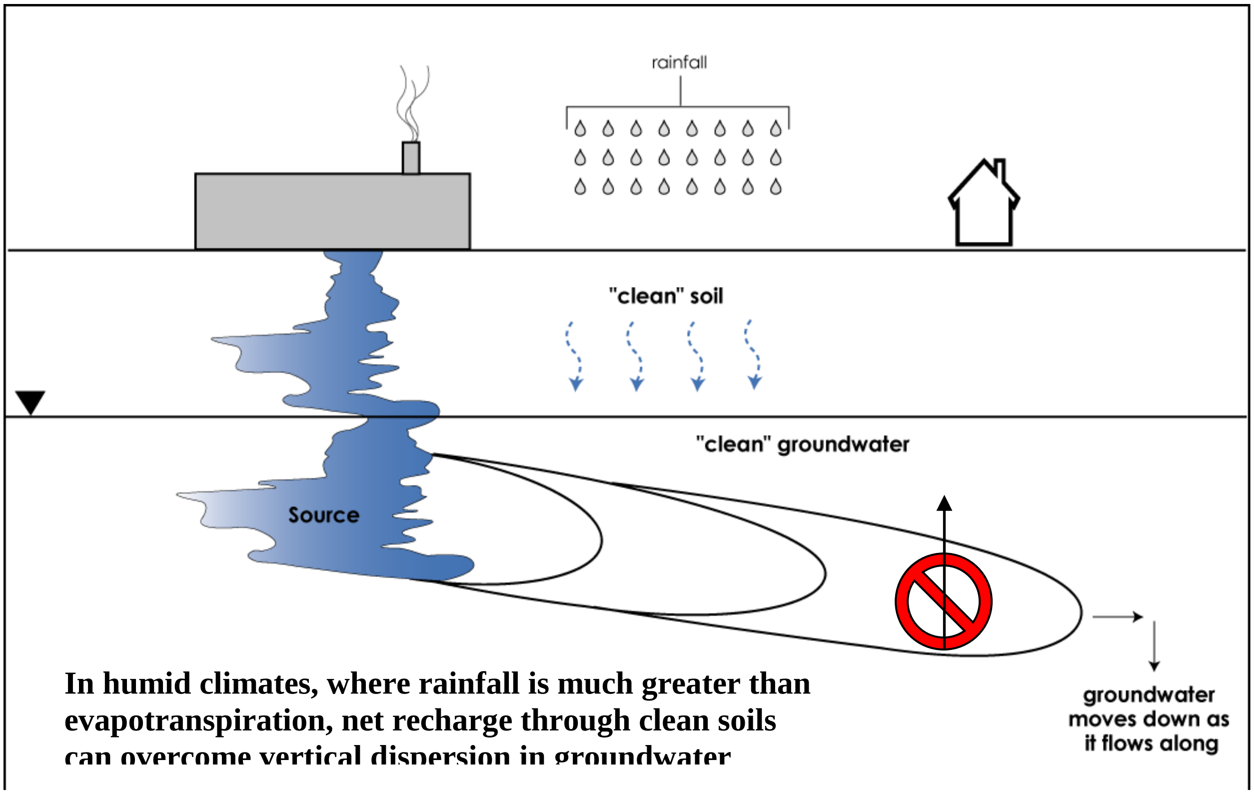


Figure 2-6. Clean water Lens Impeding Diffusion to Vadose Zone

Source: McAlary 2003

Because the rate of diffusion of contaminants through the overlying clean ground water is so slow, the overlying ground water can greatly impede or prevent volatiles in deeper ground water from reaching the unsaturated zone, thus possibly preventing a vapor intrusion situation (Fitzpatrick and Fitzgerald 2002; McAlary et al. 2004).

2.4.4 Fluctuations in Water Table Elevation

Even where a clean water lens has been created as described above, changes in the elevation of the static water level may affect whether VI occurs. A significant drop in water table elevation (e.g., during a prolonged drought) can expose an area of contaminated ground water previously separated from the vadose zone by a clean water lens resulting in a potential VI situation.

Falling Water Table

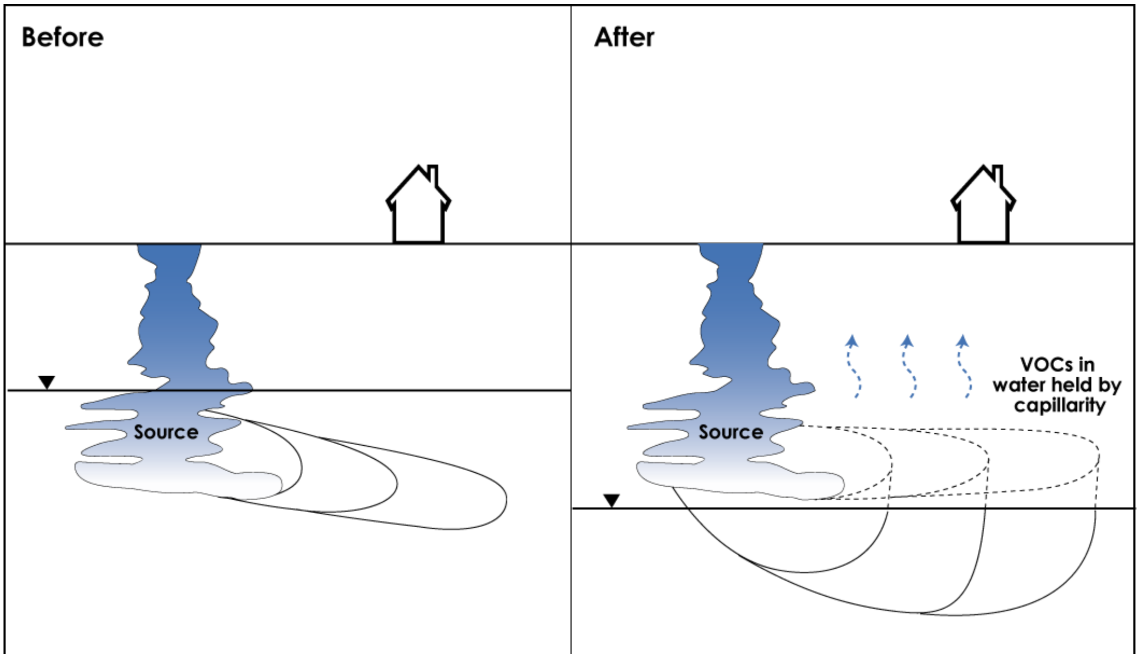


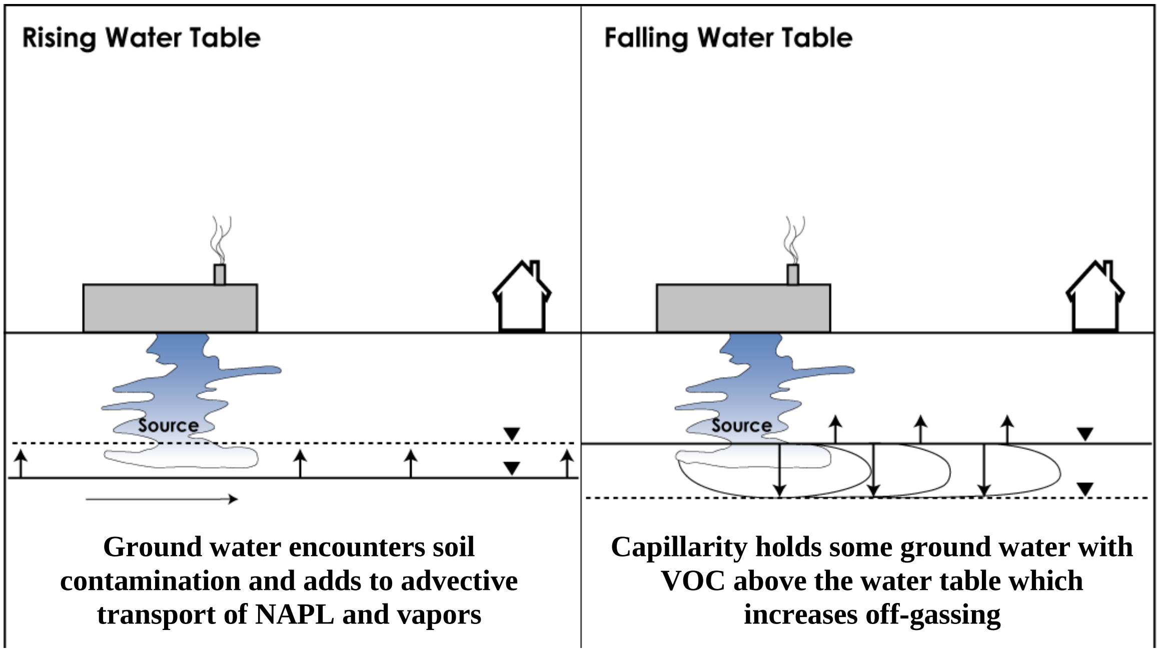
Figure 2-7. Falling Water Table Exposes Dissolved Plume to Vadose Zone

Source: McAlary 2003

If seasonal water table fluctuations are small relative to the thickness of the clean water lens, then off gassing will be impeded. Where the lens is thin (2 to 3 feet) even normal water level changes may result in the vertical movement of volatiles as depicted in Figure 2-7. This situation increases the contaminated surface area where diffusion into the unsaturated zone can occur. Some of those vapors may migrate far enough to cause VI into buildings and some can move into and above the depth interval where the clean water lens previously existed and subsequently partition back into the dissolved phase, contaminating capillary water and fresh recharge water (Mendoza and McAlary 1990). Water table fluctuations may result in short term variation in volatilization to the vadose zone over a few weeks to months. This variation could affect indoor air concentrations where the pathway is already complete or change whether VI occurs. These phenomena can have important implications for appropriate ground water sampling procedures and for when soil vapor sampling is important.

Figure 2-8 illustrates a situation where NAPL reaches the capillary fringe and/or soil is contaminated with residual NAPL in the zone surrounding the capillary fringe. Fluctuations in the water table could smear the product vertically and greatly enhance the phase transfer “vertical mixing” between vapor and dissolved contamination discussed in the previous paragraph. As the plume moves in the downgradient direction, these processes would result in much higher volatile concentrations near the water table than in deeper intervals not within the zone of fluctuation. Vapors would be likely to migrate much further in this scenario than one where NAPL and high levels of contaminants do not reach the moist transition zone just above the capillary fringe. This phenomenon has been called an interface zone ground water plume, with the interface zone being defined "to include the upper ground water zone in close proximity to the water table, the fully saturated capillary fringe and the transition zone to residual water saturation" (Rivett 1995).

Water Table Fluctuations



Rising Water Table

Ground water encounters soil contamination and adds to advective transport of NAPL and vapors

Falling Water Table

Capillarity holds some ground water with VOC above the water table which increases off-gassing

Figure 2-8. Fluctuations in Water Table Create Interface Zone Vapor Plume

Source: McAlary 2003

2.4.5 Ventilation Systems in Commercial/Industrial Buildings

Commercial and industrial buildings often are designed with higher air exchange rates than residential structures, which may reduce the potential for VI. However, heating, ventilating and air conditioning (HVAC) systems in these buildings may intentionally, or inadvertently, result in either building depressurization or positive indoor air pressure relative to outdoors. Also, a mix of these two situations may occur depending on location within the building. Different floors of multistory buildings may exhibit different pressure readings (e.g., negative pressure on lower floors and positive pressure on upper floors). Therefore, prediction of potential soil gas entry rates into these buildings would generally require site-specific assessment.

The actual case example depicted in Figure 2-9 shows a subsurface vadose zone source of VOC immediately adjacent to an industrial building. VI was not occurring at this site and no significant trichloroethene (TCE) vapors were detected in soil gas immediately below the building. Contaminated ground water was moving away from, not under the building. As indicated in Figure 2-9, the HVAC system pumps air into the building, most likely causing it to be positively pressurized (McAlary 2004). Therefore, advective/convective transport of TCE vapors toward the building due to a stack effect around the building was apparently not occurring. Another likely reason that no significant TCE was detected in the soil gas under the

Industrial HVAC

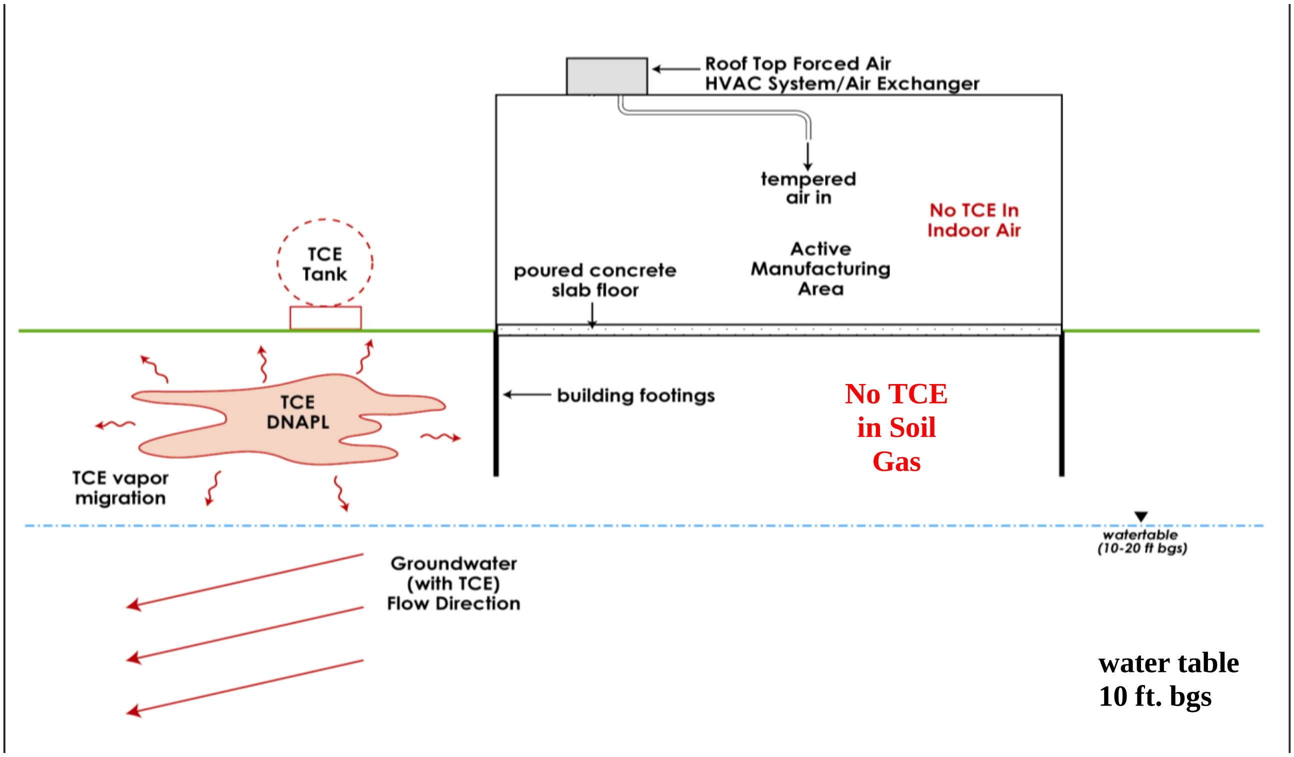


Figure 2-9. Industrial HVAC Preventing Vapor Intrusion

Source: McAlary 2003

building is that the building footings were installed through most of the vadose zone thickness, inhibiting lateral diffusion of TCE through the vadose zone to the area directly under the building. It may be the combined affect of both the HVAC system and the building's foundation construction that prevented VI in this case.

Other case examples also indicate that commercial and industrial HVAC systems can create a positive air pressure within a building (Berry-Spark et al. 2004), instead of the assumed negative pressure indicated in Figure 2-4. All relevant building characteristics should be investigated and included in the CSM. For commercial buildings, facility engineers can often provide considerable detail on HVAC design and operations.

3.0 DECISION FRAMEWORK

The Decision Flow Chart (Appendix A) is designed to assist the investigator in assessing the appropriate steps when evaluating the VI pathway. The chart was formulated to address most typical situations where suspected indoor air impacts may have occurred due to sources outside the building (e.g., soil or ground water contamination) or known spills inside the building. As always, please consult the NJDEP case manager or technical support personnel for any circumstances that are unique or present complex problems not fitting the paradigm.

The Department has utilized a phased approach to the investigation of the VI pathway. This framework follows the basic provisions of the USEPA's Draft Vapor Intrusion Guidance (2002b) and incorporates both generic and site-specific procedures. Refer to Section 1.3 for further discussion on the phased approach.

The Preliminary Assessment and Site Investigation phase encompasses those circumstances where rapid action may be required. The Remedial Investigation phase employs generic screening levels that can be compared to analytical data from indoor air, sub-slab or near slab soil gas, and ground water samples to resolve whether there is the potential for this pathway to be complete. At this time, generic screening levels for soil sample results have not been developed. Site-specific parameters or alternative sampling approaches can be employed as part of the remedial investigation. The Remediation and Monitoring phase addresses remedial actions and monitoring requirements.

3.1 Preliminary Assessment and Site Investigation

Preliminary Assessment and Site Investigation (PA/SI) consists of three stages - a general assessment of the VI pathway (Stage 1), a determination whether rapid action is warranted at the site (Stage 2), and a comparison of available data to the generic screening levels.

In order for the VI pathway to be complete, there must be a source (principally volatile organic compounds), a potential pathway involving an impacted matrix (e.g., groundwater, soil, and/or soil gas), and an impacted receptor (current or future) proximal to the source or pathway. Stage 1 involves confirming that one or more contaminants of concern represent a potential risk due to VI. In general, the compounds listed in Table 1 are the principal VI contaminants (although other compounds may be added to the list in the future).

Stage 2 defines a series of situations where VI is likely to require rapid action. This action may be limited to the prompt implementation of a VI investigation. Alternately, the decision may be made that an interim (or emergency) remedial measure is required. These conditions include:

- Known spill in a structure (e.g., heating oil tanks);
- Physiological effects reported by occupants (with a known or suspected source nearby);
- Wet basement or sump with contaminated ground water nearby;
- Odors reported in a structure (with a known or suspected source nearby);
- Free product (as defined in N.J.A.C. 7:26E) at the water table under or immediately adjacent to a structure; and,
- Other short-term safety concerns.

Consistent with the USEPA (2002b), short term safety concerns are “known, or are reasonably suspected to exist, including: a) measured or likely explosive or acutely toxic concentrations of vapors in a building or connected utility conduits, sumps, or other subsurface drains directly connected to the building and b) measured or likely vapor concentrations that may be flammable/combustible, corrosive, or chemically reactive.” For the purposes of Stage 2, odors refer to “chemical” or “solvent” or “gasoline” complaints by occupants.

Professional judgment should be applied to these qualitative criteria when a determination is made to implement a rapid action. The condition in question should be related to an event or observation in or immediately adjacent to the structure in question. As with all indoor air sampling events, the investigator should properly assess the relative impact from background sources on the overall indoor air quality.

The Department has prepared Rapid Action Levels (RAL) in Table 2 that represent trigger levels for the initiation of prompt action at occupied buildings to further investigate the VI pathway and/or minimize impacts to building occupants through the implementation of an interim remedial measure (IRM). The VI investigation can proceed following the mitigation of the RAL exceedance. If a building is currently unoccupied, the rapid pace associated with the RAL is unnecessary. The investigation and/or remedial action can proceed at the normal speed of implementation.

In addition, Health Department Notification Levels (HDNL), developed in consultation with NJDHSS, are also listed in Table 2. These values, when exceeded in occupied buildings, indicate the need for the Department to inform the local and/or state health departments about the site and the associated vapor intrusion related indoor air concentrations for further evaluation and possible emergency actions. On a case by case basis, the health department may also be notified when elevated indoor air levels below the HDNL are present in an occupied school, day care center, health care facility, or other structure with sensitive receptors.

Stage 3 employs generic screening levels to determine whether the VI pathway warrants further investigation and/or remediation based on existing data. The Department has developed these screening values for ground water, indoor air and sub-slab or near slab soil gas. (Refer to Appendix G for further discussion on the development of these screening levels.)

Ground water data should be compared to NJDEP Ground Water Screening Levels (GWSL) in Table 1. When indoor air samples are collected, the results should be compared to the NJDEP Indoor Air Screening Levels (IASL) in Table 1. The NJDEP Soil Gas Screening Levels (SGSL) in Table 1 should be compared to the sub-slab and/or near slab soil gas results. Soil gas data collected from exterior soil gas locations (as distinct from sub-slab or near slab) are generally not appropriate for comparison to the SGSL. Refer to Section 6.3 (Exterior and Near Slab Soil Gas Sampling Procedures) for further discussion on the applicability of exterior soil gas results.

Consistent with USEPA policy, the Department recommends a VI investigation where structures are within 100 feet horizontally or vertically of shallow ground water contamination in excess of the GWSL. Under a future use scenario, additional investigation may be necessary for undeveloped parcels using the same criterion. If the depth to the shallowest ground water exceeds 100 feet, a VI investigation is not required unless vertical preferential pathways exist and the CSM indicates there is a significant VI risk. Section 6.2.1 includes further guidance regarding this issue.

The 100-foot distance criterion for investigating the VI pathway does not consider the aerobic biodegradation of petroleum hydrocarbons, particularly the BTEX compounds. Depending on the site conditions, the criterion is likely to be too conservative for petroleum hydrocarbons. Therefore, the Department will utilize a 30-foot distance criterion (both horizontal and vertical) for petroleum related ground water contamination. (Refer to Chapter 9 for a clarification on petroleum hydrocarbons, or PHCs.) The 30-foot PHC distance criterion is based, in part, on the Pennsylvania VI guidance (2004).

If free product is present, the 100-foot distance criterion should be used, irrespective of the chemical composition of the free product.

3.2 Remedial Investigation

The Remedial Investigation (RI) Phase involves the evaluation of the VI pathway.

If the current results reveal exceedances of the generic screening levels (or insufficient data exists), a VI investigation workplan shall be prepared and implemented (Stage 4). Alternately, the option of implementing a remedial action as a proactive approach may be considered.

The Department recommends ground water (in most circumstances) as the first medium to be investigated for the VI pathway (Stage 4A). Unlike other states (e.g., California), the ground water table across most of New Jersey is relatively shallow and ground water data is readily available in the vicinity of the receptors. Thus, a ground water investigation is the appropriate first stage for most VI investigation workplans. Section 6.2, Ground Water Investigation and Sampling Procedures, should be consulted to ensure that the ground water data are both representative and valid. In some instances, the Department may require sub-slab and indoor air sampling concurrent with ongoing ground water and exterior soil gas investigations. Depending on the site-specific CSM, the investigator may elect to conduct soil gas and/or indoor air sampling prior to initiating a ground water investigation.

In cases where soil contamination represents a potential source of VI, the use of ground water data and the GWSL alone are NOT appropriate. The investigator should employ soil gas and/or indoor air samples to assess whether soil contamination is a source of VI.

Assuming the potential vapor source is not in the unsaturated zone (soil), no further investigation of the VI pathway is required if appropriate ground water data are less than the NJDEP GWSL (and free or residual product is not present at the water table). However, if the ground water data exceed the screening levels, further investigation will be necessary.

The next stage of the VI investigation is the collection of soil gas samples (Stage 4B). Near slab (or sub-slab) soil gas sampling allows the investigator to quantify contaminant levels in soil gas immediately under or outside the foundation of the building. Section 6.3, Exterior or Near Slab Soil Gas Sampling Procedures, provides the particular requirements for collecting near slab soil gas samples. The procedures for collecting sub-slab soil gas samples are found in Section 6.4. For assessing undeveloped parcels, exterior soil gas sampling can be employed using a grid approach. The soil gas results from sub-slab, near slab, and exterior samples (where appropriate) can be compared to the NJDEP SGSL. Exceedances of the SGSL will require further evaluation of the VI pathway through the collection of indoor air data. Alternatively, the investigator may elect to implement a remedial action to address the VI pathway.

Recognizing the difficulties associated with background contamination (among several issues), indoor air sampling is typically the last step during a remedial investigation of the VI pathway (Stage 4C) that provides the most direct evidence regarding the air quality within a building. All other data (ground water, soil, sub-slab or near slab soil gas) simply reflect the potential for adverse impact on indoor air quality based on modeling or attenuation factors, and not the actual results. Thus, the Department recommends the collection of indoor air samples at this stage of the investigation. Refer to Section 6.6 for more information on indoor air sampling procedures. All indoor air samples (including crawl space air samples) should be compared to NJDEP IASL. After consideration of background contamination and confirming the results, exceedances of the IASL may require remedial action to mitigate the vapor intrusion (Stage 8).

One of the decision points in the generic screening process is to determine whether the data are valid and representative. This is an all-inclusive phrase designed to address a variety of issues dealing with the usability of the data. The provisions of this step include:

- Was the sampling plan designed to investigate the VI pathway (including seasonal variability for indoor air samples), approved by NJDEP, and accurately followed by the investigator?
- Were the samples properly collected - consistent with the NJDEP Field Sampling Procedures Manual (2005) and this document?
- Is the investigator confident that the sampling equipment was not moved or otherwise tampered with (some sampling events are left in place for extended periods without supervision)?
- Were the samples validated (QA/QC) and determined to be acceptable?
- Was consideration given to potential background contamination?
- Were any other issues that might impact on the data's usability addressed appropriately?

Each of the above provisions should be answered affirmatively in order to proceed along the flow path. Any negative responses simply identify deficiencies in the data acquisition that require the collection of additional data. Unless the data are determined to be valid and representative (as discussed above), no conclusions can be made regarding the VI pathway.

3.3 Site-Specific Screening Options

At any point after Stage 3, the investigator can elect to utilize site-specific screening options as part of the VI investigation. While the generic GWSL are based on the presence of sandy soils, the Department has developed GWSL for Alternate Soil Textures (presented in Table 3 of the document) based on loamy sand, sandy loam, and loam soil that result in less conservative screening levels. Laboratory soil grain size analysis, as described in Section 5.2, is required to justify the use of the GWSL for Alternate Soil Textures at a site.

Additional site-specific screening options that are available to the investigator (Stages 6 and 7) include (but are not limited to):

a) Utilization of alternative soil gas sampling procedures (flux chambers, continuous monitoring, vertical depth profiling);
b) Assessment of biodegradation for petroleum hydrocarbons (oxygen levels in subsurface soils, depth to ground water table);
c) Development of alternate attenuation factors (with sub-slab or near slab soil gas);
d) Modifications to the J&E Model (depth to vapor source and overlying unsaturated zone soil type);
e) Use of recent chemical toxicity, risk assessment methodology or exposure parameter changes not yet reflected in the NJDEP guidance, in the generation of applicable IASL; and,
f) Implementation of other appropriate site-specific screening options.

As discussed in Chapter 5 of the guidance, site-specific adjustments to the J&E model (including specific building parameters) may be submitted to the Department for review and approval. An institutional control on the property and regular monitoring (see Chapter 10) to protect against changes in future use/building construction may be required.

Approval of any site-specific screening option should be obtained from NJDEP in advance of its implementation as part of a VI investigative workplan. The workplan should incorporate provisions to verify the effectiveness of the site-specific screening option to adequately assess the VI pathway. In most cases this will involve the collection of additional field data. For example, the investigator may want to utilize site-specific depth to vapor source and/or overlying unsaturated zone soil type as part of the J&E modeling effort. The workplan should include a full characterization of these parameters in the area of the inhabited building(s) being investigated (or undeveloped areas where future construction is possible).

In another case, multiple buildings may exist over a ground water plume. The investigator may propose to assess the VI risk using RI procedures for a representative number of “worst-case” buildings and apply the results to the entire site (or expand the investigation if necessary based on these results). The workplan should document the characteristic nature of the buildings selected based on ground water concentrations, locations on the site, soil type, building construction, and other factors NJDEP may deem appropriate. (Refer to Chapter 5 for further discussion on the Site-Specific Screening Procedures.)

3.4 Remediation and Monitoring

Once the VI investigation is complete, a selection of the appropriate remedial action shall be made. Consistent with N.J.A.C. 7:26E-5, a Remedial Action Selection Report (RASR) shall be prepared (Stage 8). Chapter 10, Remedial Actions, should be consulted for guidance on the applicable remedial alternatives.

An institutional control may be established within the limits of the ground water exceedance to address future use of the overlying land. Depending on the degree of exceedance and other site specific factors, current (and potentially future) inhabited buildings or environmental media may be monitored to assess any VI risk. Building construction can incorporate remedial designs to eliminate address the VI pathway. Engineering controls may be appropriate based on the results of the remedial investigation, current/future land use and site conditions.

A Remedial Action Workplan (RAW) shall be prepared upon the Department’s approval of the RASR (Stage 9). The RAW must include discussions on long term monitoring and maintenance of the proposed remedial action (Stage 10).

Finally, the decision to terminate the proposed remediation upon remediation of the VI pathway (Stage 11) can be addressed in the RA Progress Report.

4.0 GENERIC VAPOR INTRUSION SCREENING LEVELS

4.1 Introduction

The Department has developed Ground Water Screening Levels (GWSL), Indoor Air Screening Levels (IASL) and Soil Gas Screening Levels (SGSL) to assist in the evaluation of potential VI impacts at sites under review. The applicable screening levels are listed in Table 1. The development of the screening levels is described in detail in Appendix G. As discussed in Chapter 3, exceedances of the screening levels indicate that VI is of potential concern and that further evaluation and/or potential remediation of the pathway is necessary.

The toxicity factors used in the development of the Department's screening levels are based on the USEPA *Region III Risk Based Concentration (RBC)* Table. USEPA Region III revises the RBC table twice a year (April and October) based on new toxicity factor information and any changes in the exposure parameters or calculation procedures. The Department will modify the affected screening level values and associated tables based on updates to the RBC table shortly after the information becomes available. The Department will also update the methodology used to develop the screening levels and the analytical reporting limits values as the state of the science advances.

Updates to the screening levels will be presented on the Department's web site at http://www.state.nj.us/dep/srp/guidance/vaporintrusion/. Modifications to the tables, since the last version, will be marked with a double asterisk (**) adjacent to the name of the affected chemical. It is recommended that users refer to the Department web site directly rather than rely on printed versions of the tables to ensure that the most current information is used.

4.2 Ground Water Screening Levels

The Department has developed screening levels for ground water in order to protect against unacceptable inhalation exposures to volatiles due to the migration of chemicals from contaminated ground water to indoor air. The GWSL are shown in Table 1. The Department used the Johnson and Ettinger (J&E) Model with New Jersey specific parameters, when appropriate, in the development of the screening levels.

4.2.1 Application of the Ground Water Screening Levels

The USEPA states in its Draft Vapor Intrusion Guidance that the J&E model should not be used when the distance between the water table and the building foundation is less than five feet (USEPA, 2002b). Reasons for this include 1) the potential for seasonal fluctuations in the water table to bring ground water in direct contact with the building foundation, and 2) the potential for fill material, rather than native soil, to be present immediately under building foundations, and 3) the potential for the soil capillary zone to extend up the building foundation. The difficulty with the five-foot requirement is that New Jersey has many areas in the state with shallow ground water and the five-foot requirement would result in many locations being eliminated from consideration when using the ground water screening criteria. Since the screening level is relatively insensitive to the groundwater depth (see Appendix G), the Department has adopted slightly more liberal criteria for use of screening numbers calculated using the J&E model.

The Department’s ground water screening criteria may be used where the ground water is as close as two feet below the building foundation when 1) the seasonal high water table does not reach the building foundation, 2) the water table does not extend into fill material directly under the building foundation, and 3) the top of the capillary zone does not reach the building foundation. Regarding Item 3, the capillary zone does not normally extend through fill material under buildings, which is typically coarse in nature. For situations where no fill material is present under a building’s foundation, the top of the capillary zone may be estimated using Table 4-1. The capillary zone heights were calculated with the J&E model.

Table 4-1

Capillary Zone Heights for Select Soil Textures

Soil Texture	*Capillary Zone Height (cm)*	*Capillary Zone Height (feet)*
Sand	17	0.6
Loamy Sand	19	0.6
Sandy Loam	25	0.8
Sandy Clay Loam	26	0.9
Sandy clay	30	1.0
Loam	38	1.2
Clay Loam	47	1.5
Silty Loam	68	2.2
Clay	82	2.7
Silty Clay Loam	134	4.4
Silt	163	5.3
Silty clay	192	6.3

As indicated in Table 4-1, the capillary zone is greater than two feet in height for some soils with silt and clay content. Therefore, the water table must be greater than two feet below the building foundation in those situations. Site specific field determinations may be made in these circumstances for soil texture.

Provided the above conditions are met, the Department's GWSL are judged to be adequately conservative for use at sites where unsaturated soil is present below the building foundation.

GWSL should not be applied where a building foundation is in direct contact with competent, massive bedrock containing discrete fractured zones if vertical fractures are very likely to act as preferential pathways for vapors (i.e., directly connecting contaminated ground water with building foundations). The GWSL may be used for soils that contain gravel, assuming they exhibit relatively homogeneous, isotropic conditions. The GWSL can also be applied (with Department approval) where the water table is in bedrock and nearby site specific data indicate there is unsaturated soil, fill, or geologic material below a building foundation through which subsurface air flow would approximate, or approach, porous media conditions. In many areas bedrock in the vadose zone and at the water table is so highly weathered and/or densely fractured that these conditions will be met even if deeper, more competent bedrock creates very heterogeneous flow conditions.

4.2.2 Degradation of BTEX Chemicals

It has been reported that oxygen levels above 4% are adequate for substantial degradation of BTEX chemicals to occur within a short distance in the vadose zone (DeVaull et al. 1997). For this reason, it has been suggested that an additional attenuation factor should be applied to the screening values in order to account for degradation of these chemicals. Suggested values for this degradation dilution factor are 3-10 (USEPA 2002b), 1-100 (Hers et al. 2004), 100-1000 (Fitzpatrick and Fitzgerald 2002) and 500-35,000 (Ririe et al. 2002). Thus far, the database is small regarding hydrocarbon attenuation factors. However, it appears that the additional attenuation factor is at least 10^{-1} (Hers 2004). For this reason, the GWSL listed in Table 1 for benzene, toluene, ethylbenzene and xylene are set at ten times the value calculated using the J&E model.

4.3 Indoor Air Screening Levels

Residential and nonresidential IASL to be used in the evaluation of indoor air analytical results are presented in Table 1 and are discussed below. The IASL are based on the *USEPA Region III Ambient Air Risk Based Concentrations (RBC)* Table. The NJDEP screening levels represent the higher of the health-based (RBC) indoor air values and the USEPA Method TO-15 analytical reporting limits (as defined in Appendix G). Screening levels indicating the need for more prompt action at a site are presented in Table 2. The basis of the screening levels is discussed in Appendix G.

4.3.1 Application of the Indoor Air Screening Levels

The applicable IASL, after consideration of the analytical reporting limits, are presented in Table 1. The values are presented in both ug/m^3 and ppbv units. When site data are compared with the screening levels, the user should ensure that the concentrations and the screening levels are both in the same units (ppbv or ug/m^3).

Consistent with the proposed Soil Standards regulations, the Department requires the use of the residential IASL in the evaluation of residential properties, schools and day care centers. There may also be situations where other site-specific exposures occur that will be evaluated on a case specific basis.

The nonresidential IASL are applicable to industrial/commercial facilities where the adult is the receptor of concern. The Department's current policy requires that the nonresidential IASL are applicable to commercial/industrial sites when a discharge to the environment has occurred and the facility is not currently handling or using the subsurface contaminants of concern associated with the discharge. The evaluation of VI at facilities currently using the same chemicals present in the discharge impacted media (e.g., ground water) should include consideration of both the nonresidential screening levels and the applicability of the OSHA PEL to the subject building. As discussed in Chapter 10, the option to use the nonresidential IASL and/or the OSHA PEL is contingent upon obtaining an institutional control at the affected structure(s) to address potential future changes in site use. Nonresidential settings with sensitive populations (such as pregnant workers) will be handled on a site-specific basis.

While the Department does not subtract background air concentrations from the analytical results, site-specific background sources may be considered when interpreting indoor air data. Background contaminant levels, particularly ambient air results, may supercede the Table 1 values when higher since the Department does not require remediation to levels below background concentrations. Background determinations are made on a site-specific basis in consultation with the Department and as part of the overall multiple lines of evidence approach (see Chapter 8).

4.3.2 Alternate Indoor Air Screening Levels

As discussed in Chapter 5, Alternate IASL may be developed for a site as a site-specific evaluation based on chemical toxicity factor changes on IRIS or the USEPA Region III RBC Table that have not yet been reflected in the most recent NJDEP Vapor Intrusion Guidance document. Alternate IASL may also be developed based on recent changes in the risk assessment methodologies or exposure parameters that have not yet been included in the Department's Vapor Intrusion Guidance. As noted in Section 4.1, the Department will incorporate toxicity changes from the USEPA Region III RBC Table used to develop the screening levels shortly after the updated information becomes available.

4.3.3 Rapid Action and Health Department Notification Levels

The Department has developed indoor air concentrations to determine when prompt actions are indicated to address the potential for adverse VI related impacts. Table 2 presents Rapid Action Levels (RAL) to be used when evaluating site related indoor air analytical data. The table includes RAL values for thirteen chemicals that the Department has found to be the primary contaminants that drive remedial actions at VI impacted sites.

The RAL values represent trigger levels for the initiation of a rapid action at occupied buildings to further investigate the VI pathway and/or minimize impacts to building occupants through an interim remedial measure. Since, as described below, the RAL values are based on a residential exposure scenario, nonresidential facilities that do not include residential uses (e.g., apartments), schools and/or day care centers, may be evaluated on a site-specific basis. The RAL values are not applicable to nonresidential facilities currently handling the VI contaminant(s) of concern that are subject to OSHA requirements for that chemical. Potential change in future use, however, must be considered in the evaluation of these sites.

By policy, the Department has based the RAL values on a factor of 100 times the cancer health-based residential IASL or a factor of 2 times the noncancer health-based residential IASL (presented in Table G-4). The Department has based the RAL value for trichloroethene (TCE) on the Health Department Notification Level (discussed below) for TCE due to the current controversy concerning the appropriate toxicity factor for the chemical.

Health Department Notification Levels (HDNL), developed in consultation with the New Jersey Department of Health and Senior Services (NJDHSS), are also listed in Table 2. These values, when exceeded in occupied buildings, represent levels that trigger the Department’s referral of a site to the local health department and/or NJDHSS. The local health department and/or NJDHSS would use this information to make a decision in consultation with the NJDEP regarding the need for any emergency actions, such as the evacuation of an occupied building. On a case by case basis, the health departments may also be notified when elevated indoor air levels below the HDNL are present in an occupied school, day care center, health care facility, or other structure with sensitive receptors.

The HDNL are based on one-half of the Agency for Toxic Substances Disease Registry (ATSDR) acute duration Minimum Risk Level (MRL) or 1,000 times the cancer health based residential indoor air value in Table G-4, whichever is lower. The intermediate duration MRL is used in the absence of an acute MRL.

Should the driver chemical at a site be a volatile contaminant that does not currently have a RAL or HDNL value, the Department's Environmental Toxicology and Risk Assessment (ETRA) unit may be contacted at 609-633-1348 to identify an applicable action level.

4.4 Soil Gas Screening Levels

SGSL developed by the Department for the evaluation of the VI pathway are presented in Table 1. The SGSL are used in the evaluation of representative and appropriate (see Chapter 6) sub-slab soil gas and/or near slab soil gas analytical results. Exceedence of the SGSL indicates the potential for VI that necessitates further evaluation of the pathway as outlined in Chapters 3 and 7.

As discussed in Appendix G, the SGSL are based on the higher of the health-based soil gas screening values and the soil gas analytical reporting limits presented in Table G-6. The health-based soil gas screening values were calculated by dividing the unrounded health-based indoor air values by an attenuation factor (α) of 0.02.

The attenuation factor and health-based soil gas screening values will be updated as the state of the science advances and as new information becomes available from USEPA. Site-specific attenuation factors and SGSL may be developed as a part of the remedial investigation (see Chapter 5).

5.0 SITE-SPECIFIC SCREENING PROCEDURES

This chapter discusses site-specific screening options available for the evaluation of the VI pathway. The use of a site-specific option to address the pathway will, in general, require the collection of more detailed site information. Departmental approval of the alternative approach should be obtained by the investigator prior to its implementation in the evaluation of a site. As discussed in Chapter 3, use of an alternative methodology must also include provisions in the associated VI investigative workplan to verify the effectiveness of the site-specific screening approach with actual field data. It should be noted that use of the options described below in Sections 5.1 and 5.2 is subject to the same limitations applied to the generic screening criteria (see Section 4.2.1).

5.1 Default Screening Numbers for Alternate Soil Textures

Using the J&E model, the Department has developed GWSL for Alternate Soil Textures, which are shown in Table 3. The levels were developed using the same "default" values and assumptions used in the generic GWSL except for those based on soil texture. Table 3 includes screening levels for loamy sand, sandy loam and loam soil textures. Values for vadose zone soil bulk density, total porosity, and water filled porosity are built into the J&E spreadsheet and set according to the selected soil texture. Laboratory soil grain size analysis of soil samples (Section 5.2.3) is required for acceptable use of the Table 3 screening levels as well as for other site-specific screening options discussed below. Acceptable use of the Table 3 screening levels requires that at least 75% of the soil vertical profile be as fine as the selected soil texture. If this criterion is not met, the coarsest soil texture must be used.

5.2 Site-Specific Use of the J&E Model for Calculation of VI GWSL

Site-specific modeling of VI may be accomplished using the J&E model. However, the allowed uses of the model for site-specific analysis are limited. While the input parameters of the J&E model are adjustable for site-specific conditions, some of them have no effect on the calculated screening level, many of them have only a moderate effect, and many parameters are not amenable to site-specific measurement. Therefore, only a few parameters are practical for site-specific adjustment as summarized in Section 5.2.7. The potential for each class of input parameters to be adjusted is discussed in detail in Sections 5.2.1 through 5.2.6. Instructions for using the J&E spreadsheets have been published (USEPA 2004d). Only Version 3.1 (or later versions), available from the USEPA Office of Solid Waste and Emergency Response, may be utilized (www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.html).

5.2.1 Chemical Properties

The chemical properties (organic carbon partition coefficient, Henry's law constant, diffusivity in air, diffusivity in water, water solubility, boiling point, critical temperature and enthalpy of vaporization) are fixed constants and not subject to change. While variable numerical values for these constants have been reported in the literature, the Department has decided to rely on the same data sources used in the USEPA Draft Vapor Intrusion Guidance (USEPA 2002b) and in the USEPA Soil Screening Guidance document (USEPA 1996a). See Appendix G for more information. Chemical properties will be updated as needed in future revisions of this document.

5.2.2 Toxicological and Exposure Parameters

USEPA Region III based unit risk factors (URF) and reference concentrations (RfC) have been used in the development of the screening levels presented in this document. While the Department will update the screening levels based on toxicity factor changes in the latest USEPA Region III Risk Based Concentration (RBC) Table, site-specific evaluations may be submitted that incorporate new IRIS or Region III based toxicity factors that have not yet been incorporated into the screening levels. The target risk level of 10^{-6} and the target hazard quotient of 1 may not be adjusted.

While the generic GWSL are based on a residential exposure scenario (as discussed in Appendix G), site-specific GWSL under a nonresidential (worker) exposure scenario may be developed for a site. The following USEPA exposure assumptions may be used for a nonresidential (worker) scenario:

- Exposure duration - 25 years. (Averaging time for noncarcinogens must be changed to 365 days x 25 years)
- Exposure frequency - 250 days/year
- Child adjustment factor (discussed in Appendix G) - may be eliminated under the worker scenario. This adjustment allows use of the J&E model output without multiplying the screening level by a factor of 0.74 (or 0.26 for vinyl chloride) that accounts for childhood exposure.
- The USEPA recommended averaging time for carcinogens may not be changed and is fixed at 70 years.

The exposure parameters used in the J&E model may be modified as a site-specific option based on recent changes in the risk assessment methodologies or exposure parameters that have not yet been included in this document.

Note that the option of using the above nonresidential exposure parameter values, or any other values other than the generic residential screening values (excluding toxicity factor and risk assessment methodology updates), will require an institutional control necessary to protect for future change in the use of the property.

5.2.3 Soil Texture

This parameter has a large effect on the calculated screening level and may be changed from the most conservative texture, sand, if adequate site-specific information is obtained. The use of soil textures finer than loam is allowed only if it can be demonstrated that these soils are not fractured. Alternately, a sand soil texture may be used when modeling these fine soil textures. Sand may also be used for soils that contain gravel, assuming they exhibit porous media conditions.

The Department's acceptance of an alternate soil texture shall be based on soil texture analysis. To establish soil texture, collect soil cores using a Shelby Tube, direct push sampler, or split spoon. One representative boring within 10 feet of the structure will be sufficient for most single family homes with additional borings necessary for larger structures. The soil cores/samples should be collected continuously (every two or four feet depending on the length of the sampling device) from the base of the foundation depth to the surface of the static water level. A grain size analysis is then completed on the cores/samples. A variety of methods exist to determine grain size of a given soil sample. The Department will consider any of the following techniques acceptable: sieve analysis for the sand and gravel portions of a given sample with pipette or hydrometer measurements of the silt and clay fractions, rapid sediment analyzers, or electro-resistance multichannel particle size analyzers.

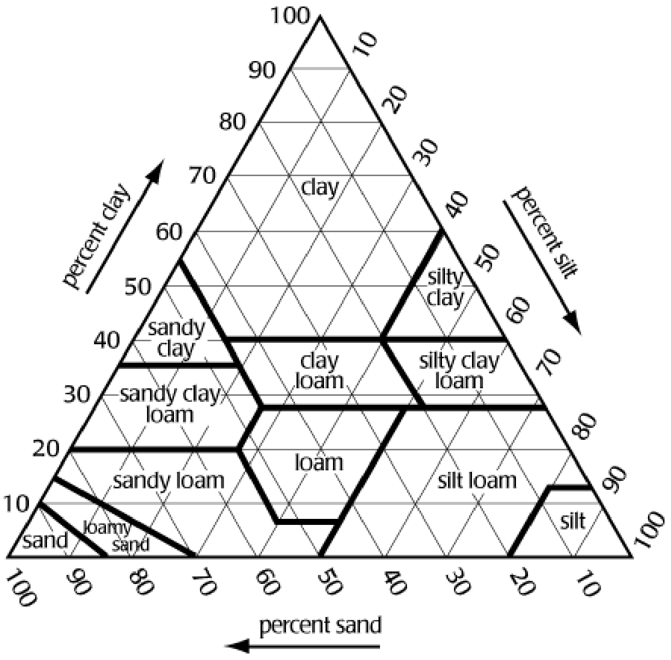


Figure 5-1

The percentages of sand, silt and clay determined by the chosen analysis techniques are then compared to the USDA Soil Texture Triangle to determine the soil texture classification (Figure 5-1 above). Under the USDA Soil Texture Triangle below, sands are considered particles between 0.05 mm and 2 mm in size, silts are between 0.05 mm and 0.002 mm and clays are less than 0.002 mm in size.

Site-specific J&E modeling using a single soil texture for the entire vadose zone requires that at least 75% of the soil vertical profile be as fine as the selected soil texture. If this criterion is not met, the coarsest soil texture must be used.

The Department's GIS has a Soil Survey Geographic Database (SSURGO) available which indicates the surface soil texture for most of New Jersey, with the exception of older urban areas (United States Department of Agriculture 1999). The SSURGO data layer should be examined in conjunction with the soil boring logs for a particular site of interest as a cross check to confirm that the correct soil texture is being used. This data may also provide a basis for requiring multiple soil boring locations per single family residence if it indicates horizontal changes in soil texture are likely across the building footprint.

When entering soil texture in the J&E spreadsheet, it must be entered in each cell where soil texture input is possible. The advanced spreadsheet (GW-ADV) has the capability of entering different textures for different soil stratums. This should be allowed only when adequate soil boring data is available to indicate that these layers are continuous across the site under investigation.

5.2.4 Soil Physical and Chemical Properties

Practical, routine field methods are not available for determination of vadose zone bulk density, porosity and soil water-filled porosity. Thus, site-specific values for these parameters may not be substituted for the default values set according to soil texture. When soil texture is entered, the soil properties should be altered by clicking on the "Lookup soil parameters" in the J&E spreadsheet.

Soil vapor permeability is not used in the calculations for the Department screening levels. This parameter would be used to calculate the soil gas entry rate, Qsoil, but this latter parameter is instead fixed at the USEPA recommended value of 5 L/min when using the J&E spreadsheet. The Department does not allow the use of soil vapor permeability measurements for determining

Qsoil or screening level values because of the high level of variability of this measurement. It is only in soils immediately surrounding the foundation (i.e. the “zone of influence”) where Qsoil is operative. Often, coarse grained fill material is placed below a building foundation, which is typically more porous than soils near the building foundation. Therefore, soil vapor permeability measurements of the soil surrounding the building are likely to be unrepresentative of the permeability conditions immediately below the foundation.

Soil organic carbon is fixed in the J&E spreadsheet at a fractional value of 0.002 and may not be changed. However, this value does not affect the screening level when the source of the contamination is the ground water (see Appendix G).

5.2.5 Building Parameters

Some building parameters may be adjusted site-specifically to calculate a site-specific ground water screening level. Note that adjustment of building parameters is an option that will result in an institutional control on the property and regular monitoring of the parameter by the responsible party to protect against future use modifications. The following parameters are allowed to be entered in the advanced version of the spreadsheet (Qsoil may also be entered in the screening version of spreadsheet).

Air exchange rate - The default air exchange rate is 0.25 exchanges/hour. This parameter may be adjusted site-specifically. The air exchange rate of the lowest floor of the building should be used. The ground water screening level is inversely proportional to the air exchange rate.

Soil gas entry rate - This parameter is dependant on many variables, including soil permeability, the building depressurization, the building perimeter, various crack parameters, and the soil vapor permeability. As discussed previously, calculation of the soil gas entry rate is subject to considerable uncertainty, particularly with regard to soil vapor permeability. Therefore, the use of the advanced J&E spreadsheet for calculation of this parameter from the soil vapor permeability is not allowed. A base value of 5 L/min is recommended by USEPA and has been adopted by the Department for a residential building. However, this value is inappropriate for larger buildings, such as industrial or commercial buildings, or for warehouses. Unfortunately, field measurements of soil gas entry rates into these types of buildings are not available. As a practical solution to the issue of building size, the base Qsoil value of 5 L/min may be scaled up to accommodate larger building sizes. The J&E model predicts that the soil gas entry rate is proportional to the perimeter of the building foundation. Therefore the building size (building perimeter) may be used to adjust the base Qsoil value as follows:

$$Qsoil = 5L/\min \times \frac{perimeter}{4000}$$

where Qsoil is the site-specific soil gas entry rate, perimeter is the length of the building perimeter in cm, and 5 L/min is the base soil gas entry rate for a default building perimeter of 4000 cm. The adjusted Qsoil value must be entered directly into the J&E spreadsheet (advanced version), rather than allowing the spreadsheet to calculate it. The building perimeter and height of the lowest floor should also be entered in order to adjust for the larger volume of the building. (The screening version of the spreadsheet allows for entry of a modified Qsoil value, but does not allow adjustment of building size.) This scale-up for building size results in a decrease in the attenuation coefficient (and a modest increase in the ground water screening level).

Procedures have been described for determining building-specific soil gas entry rates and attenuation factors from volatile tracer measurements in the sub-slab and indoor air. While such techniques may be used during vapor intrusion investigations, they are generally employed for research studies and formal guidance for their routine use is not yet available. Therefore, these techniques may be utilized to obtain additional evidence pertaining to vapor intrusion impacts, but may not be used in lieu of normal volatile contaminant sampling.

Building perimeter - If a modified soil gas entry rate is being used in the spreadsheet (see above), the correct building perimeter should be entered. The building perimeter also has a small effect on the diffusive entry of contaminant into the building, but this contribution is generally low relative to convective entry. The building perimeter may not be adjusted without also adjusting the value for Qsoil. An increasing building perimeter increases the value of Qsoil, but causes a greater increase in building volume, thus increasing the attenuation coefficient and decreasing the ground water screening level.

Building height - If a modified soil gas entry rate is being used in the spreadsheet (see above), the height of the lowest floor of the building should be entered. The building height may not be adjusted without also adjusting the values of Qsoil and the building perimeter. At a constant air exchange rate, increasing the building height increases the value of the ground water screening level.

Building depressurization - This parameter is used along with other parameters (e.g., soil vapor permeability) to calculate soil gas entry rates. Since this calculation is not allowed (see above), modification of this parameter is not allowed. EXCEPTION: HVAC systems on some commercial buildings are run under positive pressure conditions (i.e., pressure in the building interior is greater than that on the exterior). In cases such as these, soil gas entry would be eliminated, and diffusion of contaminant through the building foundation would also be inhibited. If these conditions can be demonstrated, the VI pathway in this instance may be deemed incomplete and site-specific modeling is unnecessary. This may result in no further action for the VI pathway. Note that this option will necessitate an institutional control requiring positive pressure conditions be maintained and periodic monitoring by the responsible party to protect against any changes in future use and elimination of the positive pressure control.

Floor-wall seam crack width - This parameter affects the soil gas entry rate and also affects diffusive contaminant entry. As discussed above, this parameter is not allowed to be used to calculate a modified soil gas entry rate. Furthermore, diffusive contaminant entry is generally small relative to soil gas convection. Therefore, the effect of this parameter on the attenuation coefficient is small. The Department does not allow modification of this parameter.

Enclosed floor thickness - This parameter effects diffusive transport only. Since this transport mechanism is generally insignificant relative to convective transport, modification of this parameter is unnecessary and not allowed by the Department.

Depth of the building foundation - The depth of the building foundation is only relevant in that it affects the depth interval between the building foundation and the water table. This parameter may be adjusted site-specifically in the advanced version of the J&E spreadsheet (GW-ADV), or changed to slab depth (15 cm) in the screening version of the spreadsheet. However, the appropriate depth to ground water must also be entered.

5.2.6 Depth to Ground Water

The depth to ground water has a relatively small effect on the calculated GWSL. Site-specific adjustment of this parameter, however, is allowed and does not require an institutional control on the property.

5.2.7 Summary of Site-Specific J&E Modeling for Calculation of GWSL for the VI Pathway

For the J&E spreadsheets, USEPA guidance should be consulted (USEPA 2004d). Using procedures discussed above, the parameters in Table 5-1 may be adjusted in the J&E model. Appendix G provides further discussion regarding these input parameters, including sensitivity analyses.

Unless multiple soil layers or altered building parameters are being used, the GW-SCREEN spreadsheet should be used instead of GW-ADV. If a standard building foundation depth is being used (200 cm for basement construction, 15 cm for slab on grade construction), the GW-SCREEN spreadsheet is adequate unless other building parameters are being adjusted.

When calculating site-specific VI ground water screening levels for carcinogenic compounds, the J&E model output must be multiplied by 0.74 (or 0.26 for vinyl chloride) to account for the child exposure factor unless a worker scenario is being modeled.

For possible site-specific adjustment of the GWSL beyond those discussed in this document, the Department’s case team should be consulted.

Table 5-1

Site-Specific J&E Model Parameters

Parameters	Comments
Soil texture	- When soil texture is modified, the corresponding soil properties should be selected by clicking on the “Lookup soil parameters” button in the spreadsheet. When a single soil texture is used, the GW-SCREEN J&E spreadsheet may be used. When multiple soil layers are being entered, use of the GW-ADV will be necessary.
Depth to ground water	- Adjustable in either GW-SCREEN or GW-ADV
Depth of building foundation below grade	
Building air exchange rate	- Requires use of the GW-ADV spreadsheet. - Requires institutional control on property and regular monitoring to protect against future use scenarios and change in building construction.
Qsoil	
Building perimeter	
Height of first floor	
Exposure duration and averaging time for noncarcinogens	- Adjustable in either GW-SCREEN or GW-ADV. - Requires institutional control on property and regular monitoring to protect against future use scenarios and change in building construction. - Worker scenario
Exposure frequency	
Toxicity factors	- Requires restructuring the GW-SCREEN or GW-ADV database.

5.3 Additional Site-Specific Options

The following site-specific screening options are available to the investigator in the VI evaluation of a site. These include (but are not limited to):

- Utilization of alternative soil gas sampling procedures (e.g., flux chambers, continuous monitoring, vertical depth profiling, angled direct-push sampling).
- Establish biodegradation values for hydrocarbons beneath a structure (oxygen levels in soil beneath the structure should be a minimum of 4%).
- Development of alternate attenuation factors (with sub-slab, near slab soil gas and/or indoor air data), as discussed in Chapter 6.3.
- Development of Alternate IASL as a site-specific evaluation based on chemical toxicity factor changes on IRIS or the USEPA Region III RBC table that have not yet been

reflected in the most recent NJDEP Vapor Intrusion Guidance document. Alternate IASL may also be developed based on recent changes in the risk assessment methodologies or exposure parameters that have not yet been included in the NJDEP Vapor Intrusion Guidance document.

- Implementation of other appropriate site-specific screening options.

Approval of any site-specific option should be obtained from the Department in advance of its implementation as part of a VI investigative workplan. All site-specific options must be supported by site-specific data. The workplan shall incorporate provisions (field data) to verify the effectiveness of the site-specific screening option to adequately assess the VI pathway (i.e., demonstrate the calculated result is verifiable in the site-specific situation for which it is being applied).

6.0 SAMPLING PROCEDURES AND INVESTIGATION REQUIREMENTS

6.1 Preparation of a Vapor Intrusion Workplan

If the Department requires the submission of a VI investigation workplan, the workplan shall be prepared consistent with the Technical Requirements for Site Remediation (N.J.A.C. 7:26E-4.2).

In the event that an investigator is conducting a VI investigation without departmental oversight, submittal of a workplan is not required. However, it is **highly recommended** that the investigator seek approval for any deviations from this guidance prior to conducting the sampling event. If the investigator decides to conduct the investigation without submitting a workplan and receiving approval, it should be recognized that any deviations from this guidance may result in rejection of the data. In addition, when submitting the results of the sampling event, the investigator should provide adequate rationale justifying any deviations from this guidance whether or not they were previously approved by the Department.

6.1.1 Conceptual Site Model

The CSM is the starting point for the preparation of a VI investigation workplan. As previously stated, NJDEP strongly recommends early development of a written, illustrated CSM that can be used to plan, scope, and communicate the development of a VI investigation workplan and any needed remedial actions.

The CSM will allow the investigator to better understand the source of contaminants, the pathways traveled, the receptors or entities potentially or actually exposed to contaminants, and the location of each component in relation to the others. Buildings with known sensitive populations (e.g., schools, day cares) should be identified early in the process and prioritized for investigation.

Armed with this information, a VI investigation workplan can be prepared.

6.1.2 General Issues

The most basic question an investigator asks when evaluating VI is “When do I have to assess this pathway?”

Utilizing the Decision Flow Chart (Appendix A), the initial decision points for the VI pathway are to assess the potential for VI (Stage 1) and determine whether the site necessitates a rapid action or Stage 2. An affirmative Stage 2 determination for occupied buildings will require the prompt investigation of the VI pathway to assess the necessity for remedial action. Confirmation of the VI-related exceedance of the RAL will necessitate that an interim remedial measure be implemented **immediately.**

More than likely, though, the investigator will move to the next decision point - evaluating existing data against the screening levels (Stage 3).

The Department considers ground water in excess of the NJDEP GWSL to be a potential source of VI that can adversely impact indoor air quality of nearby structures. Consistent with USEPA, the VI pathway warrants investigation when a structure is “located within approximately 100 feet laterally or vertically of known or interpolated soil gas or ground water contaminants … and the contamination occurs in the unsaturated zone and/or the uppermost saturated zone.” (USEPA 2002b) Further clarification on the distance criteria, including the adjustment for petroleum hydrocarbons, can be found in Chapter 3.

Existing soil gas (sub-slab or near slab only) or indoor air data should be compared to the NJDEP SGSL and IASL, respectively. Exceedances of these screening levels will necessitate further evaluation and possible remedial action of the VI pathway.

6.1.3 Investigative Tools

There are a number of investigative methods for assessing the VI pathway, involving ground water, soil gas and indoor air sample collection.

6.1.3.1 Ground Water Sampling

In most situations, ground water will be the first medium to be evaluated for the VI pathway (Stage 4A). A site-wide remedial investigation will require the characterization and delineation of ground water contamination. The extent of the ground water plume, as well as the concentrations of the contaminants, will allow for an initial assessment of the VI pathway. Any exceedance of the NJDEP GWSL will necessitate further evaluation and probably more field investigation.

Section 6.2 below and the Technical Requirements for Site Remediation (N.J.A.C. 7:26E) should be followed for all ground water investigations. Quality assurance issues (e.g., QA samples, analytical methods, deliverables) for ground water sampling should be consistent with the most recent version of the NJDEP Field Sampling Procedures Manual.

As a general rule, the collection of soil gas or indoor air samples is not recommended prior to a basic assessment of the site hydrogeology, including soil stratigraphy, ground water depth and flow direction, and contaminant concentrations. False assumptions may be reached on the VI pathway based on an incomplete picture of the site hydrogeology (as defined in the CSM). It should be understood, though, Stage 2 may necessitate the collection of sub-slab soil gas and/or indoor air samples prior to acquisition of sufficient ground water data due to the urgency of the potential human exposure. The presence, quantity, and location of NAPL in the vadose zone may also indicate that the collection of soil gas and/or indoor air samples should precede collection of ground water analytical data.

6.1.3.2 Soil Gas Sampling

An exceedance of the NJDEP GWSL will necessitate further investigation of the VI pathway. Soil gas sampling (Stage 4B) is the most logical next step in the VI investigative process.

In this guidance, NJDEP defines soil gas results based on the location of the sample - sub-slab (below the foundation slab), near slab (within 10 feet horizontally of the foundation), or exterior (outside of the 10-foot perimeter). In addition, data can be obtained from passive soil gas sampling procedures.

Depending on the investigative scenario encountered, different applications of soil gas sampling may be appropriate.

When ground water contamination in excess of the GWSL extends near or under a building (using the appropriate distance criteria), the Department recommends the collection of sub-slab soil gas samples to verify the presence of elevated soil gas concentrations immediately below the building foundation/slab. The sub-slab soil gas results will provide empirical data essential in properly evaluating risk to human receptors within the structure.

When the collection of sub-slab soil gas samples is not feasible, the results of near slab soil gas sampling may be utilized (with the Department's approval) to determine whether the VI pathway is currently complete for a particular building. Refer to Sections 6.3 and 6.4 (Exterior or Near Slab Soil Gas Sampling Procedures and Sub-Slab Soil Gas Sampling Procedures, respectively) for additional requirements.

Undeveloped parcels without existing structures present a unique situation for the investigation of the VI pathway. The collection of sub-slab soil gas or indoor air samples is not possible without a structure on the parcel. In this case, the Department recommends as an option that exterior soil gas samples be utilized to assess the potential for VI under a future use scenario. A grid sampling approach (approximately 100 x 100 feet) should be employed across the site and biased towards the highest concentrations within the ground water plume. The suggested soil gas depth is 8-10 feet below ground surface (equivalent to the depth of a typical basement). Site-specific modifications to the sample depth may be appropriate based on current municipal zoning, projected construction activities, or hydrogeological parameters.

Only in situations where the exterior soil gas investigation is being conducted to assess a future use scenario at an undeveloped parcel should the results be compared to the NJDEP SGSL.

Exterior soil gas samples can also be employed to assist with the delineation of the ground water plume. However, final plume delineation should be supported by the collection of confirmatory ground water samples at strategic locations. In these cases, a mobile lab employing USEPA Method 8260B (or similar methods) may expedite the investigation and allow the flexibility to modify the sampling strategy in the field (Triad approach).

The results of the sub-slab and near slab soil gas samples are compared to the NJDEP SGSL.

The NJDEP SGSL are applied to samples collected at a minimum depth of 5 feet below the ground surface and in the vadose zone no closer than one foot above the capillary fringe. A shallow ground water table may prevent the collection of representative or valid soil gas samples due to high moisture content within the gas sampled and/or dilution due to atmospheric air being drawn down from the surface. The only exception to the 5-foot depth rule is for soil gas samples collected from a central location below a shallow or at grade impermeable slab, including driveways, parking lots, building slabs, and garage floors.

In situations where contaminated unsaturated soils are the primary potential source, sub-slab or near slab soil gas samples are the principal mechanism for investigating the VI pathway (other than indoor air samples).

Underground storage tank sites or sites where chlorinated solvents are used in buildings or facilities at the surface (e.g., dry cleaners, vapor degreasers) may have contamination in the vadose zone due solely to vapor leaks. In these cases, soil and/or ground water data may not identify the VI source. Soil gas data are the preferable investigative tools where vapor leaks (or vapor clouds) are suspected. The vapor cloud phenomenon is discussed in Chapter 2.

Sites that involve contaminated unsaturated soils or vapor leaks are two examples where a vertical profile of soil gas concentrations may assist in the investigation. Vertical profiling can better clarify the source(s) of VI by evaluating the distribution of chemical concentrations over a defined depth. If a ground water plume under a structure is the suspected source, soil gas concentrations should increase as the depth of the soil collection increases. Deviations from this general assumption may suggest an alternative source, such as preferential pathways, vapor leaks or vadose zone soil contamination.

Sub-slab or near slab soil gas samples may also be more appropriate when obtaining truly representative ground water data is not possible or is impractical.

Lastly, passive soil gas sampling may be applicable to the preliminary delineation of the ground water plume. Final plume delineation should be supported by the collection of confirmatory ground water samples at strategic locations.

6.1.3.3 Indoor Air Sampling

Indoor air sampling is generally the last investigative step in the evaluation of the VI pathway (Stage 4C). Due to legitimate concerns over background sources, indoor air results provide a unique challenge to investigators (refer to Chapter 8, Background Indoor Air Contamination, for additional information). The Department recommends the collection of sub-slab and ambient air samples in conjunction with indoor air sampling events (Stage 4C) to assist in the evaluation of background contaminant sources.

Despite the problems, indoor air sampling is often necessary to properly assess whether the VI pathway is complete. These situations include:

- Exceedances of the SGSL;
- Shallow ground water table that prevents the collection of soil gas data;
- Site-specific approach is utilized which requires supplemental data in support of the conclusions;
- Preferential pathways exist that may negate or limit the usefulness of ground water or soil gas data;
- Stage 2 conditions that require a more immediate response;
- Volatiles in bedrock near or at the surface which eliminates the use of the J&E Model; and,
- Other site-specific factors.

Since indoor air sample locations are a critical issue in the ultimate assessment of the data, the VI investigation workplan should clearly identify the criteria that will be employed in this selection process. Refer to Conducting a Building Walkthrough and Survey (Section 6.5) for additional guidance on this phase of the investigation.

An ambient air sample provides background concentrations outside of the building being investigated at the time of the indoor air sampling event. When using USEPA Method TO-15, the canister used for the ambient air sample should be randomly selected from the canisters sent by the laboratory and placed outside of a building that is being sampled. The ambient air sample shall have the same sample collection time and be analyzed in the same manner as the interior sample. The investigator should clearly designate where the sample is collected and the site conditions at the time of sampling. The investigator also should be aware of the weather conditions during the sampling event. It is highly recommended that the canisters be placed in a secure outside location and not in front of a building. Ambient air samples should be taken at breathing zone height and as far from auto traffic or other potential sources as possible.

The number of ambient (outside) canisters recommended is a minimum of 1 per sampling event with the maximum of twenty (20) samples being associated with each ambient (outside) canister. However, if the sampling event occurs over multiple days, additional ambient (outside) canisters may be recommended at the discretion of NJDEP. Additionally, if the spatial arrangement of the sampling points is dispersed and background cannot be easily defined, additional ambient (outside) canisters may be recommended.

In situations where ambient levels for contaminants of concern are expected to be elevated based on the nature of the commercial/industrial/retail operation, the investigator should consider avoiding the collection of indoor air samples. For example, at active gasoline service stations, if ground water contaminant concentrations exceed the GWSL, the Department recommends the collection of sub-slab soil gas samples where possible in lieu of indoor air samples. If the sub-slab results are in excess of SGSL, an institutional control may be required at the site until it can be demonstrated the site contaminant concentrations do not represent a VI risk.

Depending on the site conditions, the volatile concentrations in ground water, and seasonal variability, one round of indoor air samples will likely not be sufficient to verify the presence/absence of the VI pathway. A second (or confirmation) round of indoor air samples may be appropriate. At a minimum, a confirmation sample is necessary to eliminate the VI pathway when the initial sample is collected outside the winter/early spring timeframe (November through March). Modifications to this provision may be appropriate based on site-specific information.

In the case of initial indoor air results that exceed RAL, confirmation samples should be collected **immediately** to verify these exceedances.

6.1.3.4 Soil Sampling

At this time, generic screening levels for soil results have not been developed. Soil gas and indoor air results can be evaluated to assess the vapor potential from contaminated soils. Otherwise, a site-specific determination will have to be made as to whether further investigation of the VI pathway is warranted for contaminated soils.

6.1.4 Preferential Pathways

Due to the nature of vapor migration, all VI investigation workplans must assess the presence of preferential pathways.

The Pennsylvania Department of Environmental Protection (2004) defines preferential pathways as:

> **“**…a natural (e.g., shallow rock or vertically fractured soil) or manmade (e.g., buried utilities) feature that creates a sufficiently direct pathway from a source to a receptor to make the use of the default model for predicting indoor air concentrations unacceptable.”

The investigator should evaluate the possibility of interconnections between ground water and any subsurface utilities (e.g., storm sewers, sanitary sewers, water lines). In these cases, the depth of the invert, the diameter of the conduit, and the construction specifications of utility lines should be determined. The investigator should also determine whether any utilities may be acting as conduits for vapor migration, either along the utility's backfill or within the utility itself. This determination should include, but not be limited to, visual inspection and the use of field screening instruments (with appropriate detection limits based on the SGSL). Additional information on assessing utility corridors as part of a VI investigation can be found in the State of Wisconsin guidance document (2000).

Based upon the results of this evaluation, the investigator may be required to canvass the immediate area of concern, locate all subsurface utilities and basements, and determine the presence/absence of organic vapors in accordance with N.J.A.C. 7:26E-4.4(h)3.viii. The exact locations of all subsurface utilities and basements should be plotted on a scaled site map. Depending on the site conditions, periodic inspections of the subsurface utilities may be required with readings of oxygen levels, and lower explosive levels (LEL). In addition, the presence of organic vapors within the utility corridors should be documented by collecting passive or active soil gas samples.

6.1.5 VI Report Requirements

The VI Report should address a series of issues related to documenting the sampling event. In addition to the requirements in N.J.A.C. 7:26E-4.8, the following provisions should be included in the VI Report:

1. Copies of the Indoor Air Building Survey and Sampling form;
2. Scaled site maps identifying the site, adjacent streets, buildings sampled (soil gas/indoor air), ambient air sample locations;
3. Photographs of sample locations (as appropriate) or other pertinent site features;
4. Readings from field instrumentation;
5. Any documentation, including scaled maps, on the assessment of preferential pathways; and,

6. Scaled floor plans that note location of indoor air and sub-slab soil gas samples, observed stains and major cracks in slabs/foundations, sumps, French drains, existing radon systems, chemical storage areas (or other potential background sources), HVAC systems, utility entrances into buildings, etc.

6.2 Ground Water Investigation and Sampling Procedures

Section 6.2 discusses: 1) saturated zone features affecting VI; 2) use of pre-existing ground water data; and 3) obtaining new ground water data to evaluate this pathway.

6.2.1. Saturated Zone Features Affecting Vapor Intrusion

Many of the concepts and properties discussed below are more applicable to subsurface formations where the ground water flow regime is relatively homogeneous (e.g., unconsolidated or sedimentary formations), however, more heterogeneous flow regimes are also addressed in several discussions. Topics include:

- Clean Water Lens
- Depth to Saturated Zone and Stratigraphy
- Fluctuations in Depth to Saturated Zone
- Complex Hydrogeologic Settings
- Proximity to Preferential Pathways
- Potential for Contaminant Degradation.

6.2.1.1 Clean Water Lens

Published and non-published research and case data indicate that ground water concentrations of volatiles in a small depth interval close to the water table are a better predictor of the presence, and relative concentrations, of volatiles in soil gas or indoor air than are volatile levels in slightly deeper saturated intervals (Fitzpatrick and Fitzgerald 2002; Hers and Rees 2005; McAlary et al. 2004; Rivett 1995; Marrin and Thompson 1987). If a clean water lens exists above the volatile contamination, it can act as a barrier to volatilization from deeper ground water (Rivett 1995). This could reduce or prevent VI into overlying buildings (see Figure 2-6).

As a ground water plume migrates downgradient from its source area it is subject to a number of processes. Some of the processes favor the formation of a clean water lens while others may prevent its formation or may eliminate such a lens soon after it forms. Where precipitation and other waters (lawn irrigation, septic systems, leaking sewer or water supply lines, etc.) can infiltrate and/or percolate to the water table through clean soil/sediments, a clean water lens is likely to form (Weaver and Wilson 2003; USEPA 2001e).

Other stratigraphic and/or hydrogeologic properties (e.g., layer with higher permeability, downward hydraulic gradient) could also cause a plume to dive in the downgradient direction (Weaver et al. 1999), possibly thickening the clean water lens as ground water migrates away from the source area. Upward hydraulic gradients and minimal infiltration of precipitation due to impermeable surface cover both discourage formation of a clean water lens. A clean water lens may form and disappear multiple times depending on factors discussed in Subsection 6.2.1.3.

Where a clean water lens is an important element of the CSM, multi-depth sampling (i.e., vertical profiling) within discrete intervals in a well or boring may be appropriate. An increase in ground water density due to contamination with DNAPL is generally not a cause for a diving plume (Schwille 1988).

A clean water lens that is thicker than the annual water table fluctuation range can be a significant barrier to off-gassing of volatiles from ground water to soil gas. If a clean water lens is thin, relative to short term, seasonal, and/or longer term drops in the water level (natural or manmade) it is likely that a falling water table will expose a plume to the vadose zone (see Figure 2-7).

6.2.1.2 Depth to Saturated Zone and Stratigraphy

The water table can be described as the shallowest depth at which ground water will freely flow into wells, or other ground water sampling devices. The depth to the regional water table and/or any perched saturated zone(s) needs to be determined in the vicinity of buildings at risk for VI. The vertical distance between the most shallow saturated zone and building foundations should also be determined. A “perched” water table is one with unsaturated materials beneath it, and usually occurs only where a low permeability layer is present in the unsaturated zone and recharge is sufficient to exceed the percolation rate through this layer.

As indicated in Section 4.2, where the top of the saturated zone is in very fine grained soil or sediments, the intergrain pores (i.e., original or primary pores) will be quite small, and as a result, the capillary fringe above the water table will be quite thick; it also can be fully saturated closer to the water table. The presence and concentration of volatiles in such a saturated interval just above the water table would greatly affect off-gassing into the vadose zone, however it may be impractical to obtain a ground water sample from that interval. In such soils, representative soil gas volatile data will likely be a much better indicator than ground water data of the VI risk. This is also likely where vadose zone soil borings indicate a thick, laterally extensive, organic rich layer (Hughes et al. 1996).

Boring or test pit logs in the area of a VI investigation should be used to:

- evaluate the soil profile, soil type and texture throughout the profile;
- look for stratigraphic changes or soil horizons indicative of high moisture content, a perched water table, or high organic carbon content; and,
- evaluate characteristics of the strata immediately below and above the water table.

The depth of the water table and/or first zone of saturation should be determined in order to:

- help determine ground water flow direction (with surveyed ground surface elevations);
- decide appropriate media for further investigation; and,
- determine the depth of ground water sampling.

6.2.1.3 Fluctuation in Depth to Saturated Zone

Changes in water table elevation may increase or decrease the risk of VI. The cause of the water level change and the proximity and nature of the source of the ground water contamination (e.g., age, size) affect the potential for VI. The water table elevation fluctuates and perched saturated zones may dry up seasonally or only exist periodically after precipitation events. If a perched saturated zone is present, extensive enough, and clean, it could prevent migration of vapors through it, or around it, from underlying contaminated ground water.

Where free product has migrated along the water table, a rising water level could increase the risk of VI to nearby structures, especially if the rise in water level was not caused by local ground water recharge (e.g., flooding near a river, swollen from rain or snow melt in locations far upstream). If the overlying soil/sediment is clean and only dissolved phase ground water contamination is present, a rise in water level due to local recharge may form a clean water lens and reduce the risk of VI.

Significant fluctuations in the water table elevation also affect the predictability of VI using analytical modeling approaches where ground water quality is the source input parameter. Proper ground water sampling design may overcome this potential limitation but use of ground water samples that represent worst case conditions and/or use of soil gas data is more acceptable to NJDEP for modeling in such situations.

6.2.1.4 Complex Hydrogeologic Settings

Heterogeneity in subsurface media could have a significant impact on whether volatiles in saturated zones become a source for VI. Information on the locations and depths of near surface features such as clay, till or gravel layers/lenses and depth to bedrock must be considered for an adequate evaluation. Such features should be taken into account when determining saturated zone sampling depth intervals and whether ground water data can be utilized to evaluate VI risk.

For example, sampling of potable wells drawing from a bedrock aquifer underlying indoor air receptors may show volatile contamination, but ground water in the overburden above the bedrock may be clean. If there is bedrock immediately beneath a building or bedrock outcrops nearby (such that it bisects the saturated zone in the overburden near the structure), vapors from the bedrock aquifer contamination may be able to migrate to the ground surface if unsaturated vertical fractures, faults, solution channels or other secondary pores/openings provide a migration conduit. In that situation, ground water quality in the bedrock near such features may be just as relevant as nearby shallow ground water quality in the overburden. However, given the difficulty and expense of bedrock investigations, subsurface gas sampling and/or indoor air sampling would be a more practical and, probably, a more accurate investigative approach where bedrock aquifer contamination is likely to cause VI.

6.2.1.5 Proximity to Preferential Pathways

Preferential pathways in the unsaturated zone (defined in Section 2.2.4) could allow rapid and/or laterally significant vapor transport. To the extent it is feasible and safe, VI investigations should consider the proximity of contaminated ground water to unsaturated preferential pathways. The 30- or 100-foot criteria (see Section 3.2) may not be adequately conservative where preferential pathways connect structures with areas of subsurface NAPL contamination or ground water/soil concentrations indicative of the presence of NAPL (e.g., plume source area with suspected residual DNAPL is more than 100 feet side gradient of structures but buried utility bedding connects it with structures). This is more likely a concern for contaminants that do not aerobically biodegrade readily.

6.2.1.6 Potential for Contaminant Degradation

Many contaminants associated with petroleum hydrocarbons, including benzene, toluene, ethylbenzene and xylene (BTEX) compounds are readily biodegraded in the vadose zone (Thompson and Marrin 1987). As such, they are less likely to complete the VI to indoor air pathway than most chlorinated VOC. Even where LNAPL occurs in close proximity to structures, rapid biodegradation in the vadose zone may preclude a complete pathway. Therefore, soil gas sampling (e.g., vertical profiling of volatiles, O_2 and CO_2) will usually be more relevant than ground water sampling for evaluating the risk of VI when GWSL are exceeded. Biodegradation of petroleum hydrocarbon contaminants is discussed in Chapter 9.

6.2.2 Use of Pre-Existing Ground Water Data

In many situations shallow ground water data that are already available prior to initiation of a VI investigation are sufficient to use as part of a VI investigation, especially if ground water contamination has been delineated and the plume has reached steady state conditions (i.e., no longer expanding). In deciding whether existing data are sufficient, consideration should be given to the site-specific CSM and the data should be from wells screened across the water table at the time of sampling. If the vertical thickness of the water column in a well is greater than 10 feet, supplemental data may be recommended on a case by case basis.

In addition, the likelihood of significant vertical changes in ground water quality near the water table, the sampling method used, the construction of existing wells sampled (e.g., screen length and placement across water table), the type of contaminants present, and heterogeneity of the vadose zone and shallow saturated zone media will likely be the most important factors in determining whether existing data are sufficient. Proposals to supplement existing ground water data with some type of soil gas data, instead of new ground water data, may also be considered.

6.2.2.1 Interpolation of Nearby Data

If ground water data immediately upgradient from the structure are not available, surrounding data points can be used to construct contaminant iso-concentration maps. However, this should only be done if data points are available on at least two sides of a structure. Complex geologic settings or the anticipated presence of steep concentration gradients warrant a denser sampling grid.

6.2.2.2 Use of Drinking Water Well Data

Since 1985, New Jersey statutes and/or regulations have required that private or public drinking water supply wells be constructed with at least 50 feet of casing. For this and other reasons it is likely that few drinking water wells in New Jersey are screened/open across the water table. It is much more likely that they draw ground water from depths at least 10 feet or more below the local water table. It is also likely that drinking water supply wells in consolidated bedrock formations are not often drawing water from water bearing zones that are in widespread, direct contact with the vadose zone immediately above the well. Therefore, the presence of volatiles in private or public drinking water wells should be considered a possible basis for further investigation, but in most situations the data should not be compared to GWSL.

6.2.3 Obtaining New Ground Water Data to Evaluate the VI Pathway

If the evaluations discussed above indicate that new or additional ground water data are needed to complete the VI investigation, the goal of the sampling effort should be to determine volatile concentrations in shallow ground water beneath or near potential structures.

Direct push sampling methods and **passive diffusion bag samplers** are two ground water sampling methods NJDEP recommends for obtaining discrete interval samples (i.e., from a distinct, defined interval) in the uppermost intervals of shallow ground water. Vertical profiling in discrete intervals within the top 10 feet (or less) of the saturated zone may be recommended (see subsection 6.2.3.2 below). **Low flow purging and sampling** may provide adequate data to evaluate this pathway in many situations. Volume-averaged purging and sample collection (i.e., conventional method) is not well suited to generate new ground water data specifically for VI evaluations.

Table 6-1

Ground Water Sampling Methods for Vapor Intrusion Investigations

Methods	Sampling Procedure Guidance documents	Advantages or Disadvantages
Direct Push and Alternate Ground Water Sampling Methods (alternate to permanent monitoring well installation)	NJDEP Field Sampling Procedures Manual (2005) Section 6.9.2.1 found at www.nj.gov/dep/srp/guidance/fspm.	• Can do vertical profiling • Can do discrete interval sampling at defined depth intervals • Rapid sampling at multiple locations • More difficult to repeat sampling in same locations • Some methods limited to unconsolidated formations
Passive Diffusion Bag Samplers (PDBS)	NJDEP Field Sampling Procedures Manual (2005) found at www.nj.gov/dep/srp/guidance/fspm.; USGS User's Guide for Polyethylene-Based PDBS to Obtain VOC Concentrations in Wells, Part 1 available at http://www.itrcweb.org/gd_DS.asp; ITRC Technical and Regulatory Guidance for Using PDBS to Monitor VOC in Groundwater available at http://www.itrcweb.org/gd_DS.asp.	Can use existing wells for: • Vertical profiling in discrete intervals • on going monitoring May not be adequate where/for: • VOC highly soluble in water (such as MTBE) • in-well vertical flow occurs • permeability is very low
Low Flow Purging and Sampling (LFPS)	NJDEP Field Sampling Procedures Manual (2005), Section 6.9.2.2 and 6.9.2.3 found at www.nj.gov/dep/srp/guidance/fspm.	• May generally target interval closer to the water table in some settings • Discrete interval sample not obtained
Volume-Averaged Purge and Sample Collection	NJDEP Field Sampling Procedures Manual (2005), Section 6.9.2.4 found at www.nj.gov/dep/srp/guidance/fspm.	Not recommended to generate new ground water data specifically for VI investigations

Sampling guidance for VI investigations may differ from other NJDEP guidance in the documents listed in Table 6-1 because of the objective to determine very shallow ground water quality.

6.2.3.1 Ground Water Sampling Location

Ground water samples should be collected as close, horizontally and vertically, to the structures as possible because concentrations are not always relatively uniform within a plume due to heterogeneities in source areas and in the subsurface media. In choosing locations horizontally, bear in mind that ground water plumes are usually elongated in the direction of ground water flow with little lateral mixing; therefore, ground water concentrations can change dramatically over short horizontal distances, especially near the lateral edges of a plume. Given the 100 and 30 foot distance criteria between vapor source and potentially affected structures, a more detailed delineation of the extent of ground water contamination may be appropriate in some situations.

Changes in surface cover that significantly affect the amount of infiltration upgradient from structures should be considered in choosing sampling locations. For example, if there is a stormwater retention pond or a transition from a mostly paved surface to a vegetated park/open field located between the upgradient edge of a plume and a structure, a sampling location downgradient of the pond or vegetated land should be selected.

6.2.3.2 Sampling Depth Intervals

An existing monitoring well should be considered adequate for evaluating the appropriate depth interval(s) if the screen/open borehole intersects the water table throughout the year (i.e., a water table well), and the thickness of the water column in the well is approximately 10 feet or less. For new water table wells installed as part of a VI investigation, a 5 to 10 foot screen is generally recommended unless this conflicts with other site investigation objectives. Additional construction recommendations are discussed below under “Installation of New Monitor Wells.”

If a perched water table exists above the regional water table, NJDEP may require that samples be collected from both the perched zone and regional shallow aquifer. Perched saturated zones that are laterally contiguous under/near structures, exist year round, and are below nearby building foundations should be sampled if they are of sufficient thickness that a sample can be obtained. Professional judgment must be used in more complex situations but, in the above scenario, sampling of the regional water table may not be vital to investigating the VI pathway.

In some situations, NJDEP will consider use of vertical profiling of volatile concentrations in ground water (within the top 6, or the top 10 feet, of the saturated zone) to determine whether or not additional investigation of the VI pathway is needed.

Vertical profiling is recommended or may be warranted where:

- A clean water lens is likely to be present;
- Certain site-specific screening options will be used; and,
- Direct push or any discrete-interval ground water sampling method is used to obtain new data to evaluate this pathway.

Sections 6.2.1.1, 2.4.3 and 2.4.4 cover the processes and site characteristics that favor the formation of a **clean water lens**. Development of the CSM should include evaluation of whether a clean water lens is likely to be present and/or if volatile levels below the GWSL are likely to be at or near the water table.

If a **site-specific** GWSL has been approved by the Department (excluding Table 3) or if ground water data will be used to develop a site-specific ground water to indoor air attenuation factor, vertical profiling may be warranted. Large vertical changes in ground water volatile concentrations often occur within a 5 to 10 foot vertical interval (Vroblesky 2001; Reilly and Gibs 1993; and Puls and Paul 1998). If a clean water lens is not present these changes are usually not relevant to whether the GWSL are exceeded because the GWSL are very conservative. These changes may be relevant if the above options are utilized. Flexibility regarding this recommendation is reasonable based on site-specific characteristics or data (e.g., existing site data may indicate that vertical changes in volatile concentrations are likely to be negligible).

Vertical profiling is recommended however if a site-specific GWSL has been approved by the Department (not including the levels in Table 3) and if ground water data will be used to develop a site-specific ground water to indoor air attenuation factor.

If **discrete-interval ground water sampling methods** are used, vertical profiling may oftern be appropriate. However, site-specific data may suggest that significant vertical changes are unlikely or could not be detected by some methodologies due to site conditions (e.g., vertical flow within a well screen/open hole saturated interval).

Where vertical contaminant profiling is done, NJDEP generally recommends sampling within, at least, the top 6 feet of the saturated zone, and possibly the top 10 feet. Site-specific considerations may warrant altering the total depth interval for profiling.

Changes in regional water-table elevation (~1 to 3 feet) are relatively common. Profiling should extend to 10 feet below the water table (bwt) in situations where/when significant drops in the water table elevation (more than about 4 feet) are likely. Significant decline in the water level elevation may be caused by shallow or deeper zone ground water withdrawals, changes in surface cover or management of stormwater runoff, and prolonged drought.

The exact depth intervals below the water table that should be targeted as part of vertical profiling depend on sampling methodology and site-specific information. Generally, at least two different depth intervals within the top 6 feet of the saturated zone should be targeted for sampling. Method specific guidance is given below. If profiling extends to 10 feet bwt, one sample from the 6 to 10 foot interval is generally recommended for any method utilized.

Profiling should be done in at least one boring or well. Multiple borings/well locations may be recommended where a large number of structures overlie a large plume.

Vertical profiles of shallow ground water contamination may enable a more precise evaluation of the current and potential future risk of VI in some situations.

6.2.3.3 Direct Push and Alternative Ground Water Sampling Methods

Where the geologic formation allows it, NJDEP may accept data obtained using direct push methods or other alternate/temporary ground water sampling techniques as part of the VI investigation. Due to the advantages listed in the above table, alternate and direct push sampling methods are often well suited for VI investigations especially if attempting to determine the depth of the interface between a shallow clean water lens and an underlying plume.

Obtaining samples that target the 0 to 3-foot and 3 to 6-foot intervals from the top of the saturated zone may be sufficient. However, as discussed above, one additional sample from the 6 to 10 foot interval bwt should be obtained where significant changes in the water table elevation are likely. Small changes of these intervals are appropriate if a sufficient volume of water can not be obtained or if site-specific data supports sampling alternate intervals. The intervals sampled should be documented and justified as part of the vapor intrusion work plan.

Direct push/alternate sampling locations should be accurately mapped and documented. The boring location should be marked, if possible, to facilitate subsequent re-sampling. Repeated sampling over time at the same locations may be necessary for some sites to determine if shallow ground water quality has changed due to water table elevation fluctuations or other factors. Ongoing monitoring recommendations are discussed below.

6.2.3.4 Monitoring Well Sampling Methods for VI Investigations

As stated in subsection 6.2.3.2, only water table wells should be used in most situations. Well sampling methods that can target the upper few feet of the screened interval (or open borehole) are recommended for gathering new data, but are not necessary in every situation in order to adequately address the VI pathway. As previously discussed, if a site’s conceptual model and/or other information indicate that a vertical profile should be obtained, PDBS can be used for well sampling if appropriate as specified below.

Passive Diffusion Bag Samplers (PDBS). The NJDEP FSPM (Section 6.9.2.5.1) should be the initial source for information on PDBS.

PDBS should not be used for acetone, styrene, methyl-tert-butyl ether (MTBE), and 4-methyl-2-pentanone (MIBK). PDBS that are about 20 inches long should be used for a VI investigation. A minimum of two, but potentially three PDBS should be strung together to evaluate the vertical profile of ground water quality in the top six feet of the saturated zone. If profiling should extend to the 6 to 10 foot interval bwt, usually one PDBS deployed in the central portion of that interval will be sufficient. This guidance differs from the vertical profiling provisions of the FSPM due to the specific VI objective of determining very shallow ground water quality.

PDBS may be deployed in a well for a minimum of two weeks to equilibrate with the well water. Significant water table fluctuations during that period will affect the appropriate depth intervals for the samplers. If the water level drops below the uppermost sampler transfer of volatiles from the sampler water into less contaminated well air space would occur. If the upper sampler is exposed to the air space, the upper sampler should be resuspended two feet below the current water level and retrieved after an additional two-week equilibration period.

As indicated in subsection 6.2.3.2, sampling that includes the 0 to 2-foot interval below the water table would provide a better indicator of the potential for VI. Where periodic water level data are available, the uppermost PDB sampler should be set within the 1 to 2-foot interval below the current water level if the historic water level data indicate it will remain submerged. Otherwise, it should be set at least 2 feet bwt. In wells where there is likely to be more significant lowering of the water level during PDBS deployment, the upper sampler should be set so that it remains submerged during the entire equilibration period. Measuring water levels in a well before and several times following significant precipitation events may help investigators anticipate the degree of fluctuation to expect. Avoid initial placement of the samplers immediately after precipitation or snow melting events, if possible. NJDEP encourages innovative approaches to allow sampling the shallowest interval while avoiding exposure of the uppermost sampler. In any event, the depth to water in the well should be measured when the PDBS are installed and removed, and the position of the samplers relative to the water level should be clearly described in the report presenting the PDBS data.

Currently, PDBS are not recommended for sampling in formations with a hydraulic conductivity of less than 1×10^{-6} cm/s because testing in such tight formations has not been conducted. In lower permeability formations, horizontal flow through the well screen would be relatively slow. Thus the rate of vapor diffusion in the well across the water/air interface may be significantly greater than the rate of off-gassing of volatiles in the adjacent formation across the saturated zone/vadose zone interface. This may cause a low concentration bias for diffusion bags placed in the shallowest interval. If the uppermost sampler is placed 2 feet below the current water level, this bias would likely be negligible. However, if the sampler is placed within the 0 to 2 foot interval, placement of a contaminant free, floating, partial plug designed to minimize off gassing may be proposed for VI investigations in low permeability settings.

In some instances, vertical flow can be present within the well. Site-specific guidance from NJDEP should be obtained in this situation but it may be possible to place packers between the PDBS to isolate the targeted depth interval.

Low Flow Purging and Sampling (LFPS). Unless vertical contaminant profiling is recommended, the LFPS procedures in the NJDEP Field Sampling Procedures Manual (2005) is acceptable for VI investigations if the vertical thickness of the water column in the well is 10 feet or less.

If evaluating the VI pathway is the only sampling objective, NJDEP recommends two modifications to the LFPS procedure.

- Set the pump intake level as close to the water table as possible without significant risk that the water level will drop and expose the pump intake. For wells in formations with average or high permeability, about 1.5 to 2 feet below the static water level should be an adequate intake location.
- The purging objective is to flush two volumes of ground water through the sampling array (tubing and pump, etc.). Measuring water quality indicator parameters is not necessary.

These two deviations from procedures recommended in the NJDEP's guidance apply only to new sampling done exclusively for a VI investigation. In some hydrogeological settings these modifications may result in more of the sampled water coming from the interval just below the water table (Vroblesky 2001). The resulting sample would still represent a weighted average and may draw water from the entire screened interval of the well, but these modifications help maximize the probability that much of the sample will be from a depth interval close to the depth of the pump intake.

If sampling is being done for multiple objectives, only the procedures in the NJDEP FSPM should be followed.

Other Discrete Interval Well Sampling Methods. Other discrete interval well sampling devices or methods (such as use of packers between PDBS) may be considered on a site-specific basis according to N.J.A.C. 7:26E-4.4(d) and 1.6(c). Use of such methods without prior NJDEP approval is not recommended since at risk sampling of this nature may result in the data being considered invalid by NJDEP. For general NJDEP policy on Point Source (No Purge) Sampling, refer to the FSPM, Section 6.9.2.5.

Volume-Averaged Purge and Sample Collection. This method is not recommended when obtaining new data specifically geared for a VI investigation.

6.2.3.5 Installation of New Monitor Wells

If the investigator determines new wells are needed to evaluate the VI Pathway, the following guidance is provided. In New Jersey, fluctuations in the short-term water table elevation between 1 to 3 feet appear to be fairly common. Larger changes have also been observed across the state over seasonal and longer time frames in various geologic settings. Site-specific data quality objectives (DQO) and information should be used in choosing well construction specifications.

In unconsolidated formations, monitoring wells should be screened across the water table. Two crucial well design objectives are: ensuring that the well is screened across the water table throughout the expected monitoring time frame; and minimizing saturated screen length with respect to historical high and low water table events for the immediate area of concern. If little water table elevation data are available, consider whether the water table is likely to rise or fall after the time of well design/installation. Screen lengths between 5 and 10 feet are preferred for evaluating VI. However, screen lengths of 15 feet, placed such that the total depth of the water column will be approximately 10 feet or less (i.e., 5 or more feet of screen above the water table) are more appropriate for wells designed for multiple DQOs.

If bedrock wells are installed as part of a VI investigation, open hole intervals should generally be 10 feet or less and should target the most shallow water bearing zone. In highly weathered/fractured bedrock formations, shallow ground water flow and contaminant migration can exhibit patterns more typical of unconsolidated formations. In those situations, local heterogeneity of the bedrock may not have as much influence on whether volatiles in ground water can off-gas into the vadose zone and diffuse up to structures at the surface. Therefore, construction of monitoring wells in such settings can be a part of a VI investigation.

Where consolidated, competent, heterogeneous bedrock aquifers contain the uppermost water bearing zones, monitor well installation and ground water sampling are not considered the most reliable approach for a VI investigation, nor are they practical or cost-effective. Sub-slab (or possibly near slab) soil gas sampling is recommended in such complex geologic settings.

It is not uncommon that the water table, or a perched water table, is located within the transition zone between unconsolidated overburden and a consolidated formation or competent bedrock. Constructing a well to monitor the top few feet of the saturated zone in such a setting requires approval of a deviation from the regulations governing monitoring well construction at N.J.A.C. 7:9D-2.1 et al. New Jersey licensed well drillers must request a deviation from the construction standards as specified at N.J.A.C. 7:9D-2.8. Discussion with, and approval from, the NJDEP case manager is recommended prior to requesting such a deviation from the well construction regulations.

6.2.3.6 Ongoing Ground Water Monitoring

After an initial VI investigation has been completed, long term ground water monitoring to reevaluate the VI pathway may be appropriate in some situations although monitoring other media can potentially substitute for ground water monitoring. Ground water monitoring should be done where ground water exceeding the GWSL is close to, but not currently within the applicable distance criterion from a potential structure if it is likely to migrate to within the distance criterion.

Installing a monitoring well or wells near the structure(s) may be the best way to monitor whether water levels and/or ground water quality have changed in a way that warrants additional investigation. Direct push or alternate ground water sampling methods could also potentially be utilized and may be a good choice where vertical contaminant profiling is recommended but a low sampling frequency is appropriate. Additional guidance concerning ongoing monitoring can be found in Section 7.3.

Ground water remedial action workplans for sites where a VI investigation was conducted should include at least a periodic evaluation of whether any changes in site conditions have increased the risk of VI.

6.3 Exterior or Near Slab Soil Gas Sampling Procedures

One of the most common methods for assessing the VI pathway is the collection of exterior or near slab soil gas samples.

The distinction between exterior and near slab soil gas sampling is critical for the investigation of the VI pathway. While both procedures involve the collection of soil gas samples outside a structure, near slab specifically refers to the collection of soil gas samples within 10 feet horizontally of a building's foundation. Conversely, exterior soil gas samples are collected beyond the 10-foot perimeter surrounding the building footprint. The applicability of the soil gas results is significantly different from the Department's perspective (see below). Therefore, the distinction between near slab and exterior soil gas sampling is important.

6.3.1 Application

Exterior and near slab soil gas sampling can be useful to an environmental investigator from several perspectives.

6.3.1.1 Stand-Alone assessment of the VI pathway (Near Slab Only)

In general, exterior soil gas sampling is not acceptable as the exclusive determinant in the assessment of the VI pathway. The Department's preference is for the collection of sub-slab over near slab soil gas samples. The investigator should make every effort to obtain soil gas data from below the slab. However, the cooperation of the building occupants and/or owners is not guaranteed. They are often reluctant to allow someone to drill a hole in the basement slab, especially if it's a finished basement. Thus, near slab soil gas sampling becomes an alternative to sub-slab sampling when situations dictate a supplementary approach.

Analytical results from near slab soil gas sampling may be utilized (with the Department's approval) to determine whether the VI pathway is currently complete for a particular building. However, the Department does **not** accept the results from exterior soil gas sampling as a stand-alone factor in the assessment of the VI pathway. Concerns over false negative results (due to soil types, soil moisture, etc.) make exterior soil gas data more appropriate as a field screening tool.

Many of the same factors that make exterior soil gas sampling inappropriate as a stand-alone determination of VI also apply to some extent to near slab soil gas sampling. Therefore, the Department should approve the utilization of near slab soil gas sampling in advance of the sampling event. Justification shall be provided to the Department as to why the sub-slab soil gas sampling method is not feasible.

In order for the near slab soil gas results to be acceptable to the Department in any stand-alone assessment of the VI pathway, the following criteria must be met:

- The soil gas samples should be collected at the depth corresponding to the range between 2 feet and 5 feet below the depth of the slab (and a minimum of 5 feet below the ground surface);
- The soil gas sample should be collected in the vadose zone, at least one foot above the capillary fringe;

- Soil gas samples should be collected at a minimum from two sides of the building being investigated (biased towards the delineated ground water plume or soil contaminant source);
- All sampling procedures provided in this guidance and the NJDEP's Field Sampling Procedures Manual (latest edition) should be followed for the collection of soil gas samples; and
- A lab certified for an appropriate air method must analyze the samples (USEPA Method TO-15 using 1-Liter or 6-Liter stainless steel canisters is the most common method).

As with sub-slab soil gas sampling, it is important to understand the stratigraphy in the area of the building. Low permeability layers under buildings (either natural or as part of construction) may act as an impediment to significant vertical vapor migration from the ground water contamination. The presence of such a layer may explain why random or irregular soil gas results occur when comparing data from several sample locations around a building. The soil gas results may not be consistent with the concentrations found in the underlying ground water plume. Always refer back to the CSM when evaluating data and making any conclusions on the VI pathway.

The Department does not allow the results of the soil gas samples to be averaged across the subsurface around a building. Therefore, each data point should be evaluated independently of each other.

6.3.1.2 Field screening

Exterior soil gas sampling is a screening tool used to rapidly and cost effectively identify and delineate volatiles in the subsurface. It should be noted that a soil gas survey is not intended to be a substitute for conventional methodology (e.g., ground water sampling), but instead as a screening tool to enable conventional methods to be used more effectively. A certified mobile laboratory may be utilized as part of this investigation.

6.3.1.3 Evaluating contaminant patterns

Analytical data from near slab (and to a lesser extent exterior) soil gas samples should be assessed to identify any patterns in particular chemicals, groups of chemicals, and/or their concentrations (both individually and collectively). When combined with data from other matrices (e.g., ground water, indoor air, and ambient air), these patterns may assist in distinguishing likely sources of indoor air contaminants and their pathways. This is important when background sources located within the structure generate the same volatile organic compounds identified as contaminants of concern associated with the site investigation.

6.3.1.4 Assessing background contamination

Similar to sub-slab soil gas samples, one specific area where near slab (and to a lesser extent exterior) soil gas results are useful is in the differentiation of background contamination in indoor air. By comparing the specific chemicals detected in the soil gas sample with the ground water or soil contaminants associated with the site investigation, a verification of the contaminants of concern can be made. This determination validates the designation of background contaminants and thus limits any remedial action to site related contaminants.

6.3.2 Sampling Procedure

6.3.2.1 Site Conditions

The first step in conducting a soil gas investigation is to determine the site conditions.

According to the NJDEP Field Sampling Procedures Manual (2005), one of the most important factors in the movement of vapors through soil is the soil permeability. The soil permeability is the measure of the ease at which a gas or liquid can move through rock, soil or sediment. Soil permeability is related to the grain size and the amount of water in the soil. Soils with smaller grain sizes are less permeable unless secondary porosity (e.g., fractured clays) increases permeability. When soils contain clay size particles, soil gas movement is severely limited. If the soils are poorly sorted with increased fine grained material content, the pore space is decreased. The presence of moisture in the soil decreases the rate of vapor migration. This occurs because as the volume of soil water increases, the soil airspace decreases thereby inhibiting vapor movement. The most retarding layer will dictate the rate of diffusion of vapors in the vadose zone.

Heterogeneous soil conditions across a site under investigation can lead to poor delineation and misinterpretation of site contaminants due to the interference from the different soil conditions. Data from areas of horizontal low permeability zones within the vadose zone could be interpreted as being an area of low contamination, when the level of contamination could be the same or higher. Conversely, data from an area of high permeability in an otherwise low permeability area can be interpreted as an area of high contamination. High porosity areas such as sewer and utility trenches can serve as conduits for rapid vapor or gas migration, giving a false indication of high contamination areas. In situations where little or no soil data is available, several soil borings should be logged to aid in the interpretation of the generated soil gas data.

The investigator should properly determine the site conditions as part of any VI investigative workplan.

6.3.2.2 Soil Gas Sampling

Active soil gas collection methods involve “pulling” a vapor sample through a temporary or permanent probe to a collection or analytical device. Samples are then transported to a laboratory for analysis or analyzed onsite so real time data can be obtained and used for directing the investigation.

Manually or hydraulically driven soil vapor probes should be constructed of steel and equipped with a hardened drop-off or retractable steel tip. The probes are nominally 3-5 feet long and threaded together to reach multiple depths. The probe is used for obtaining soil gas samples at discrete depths with few failures due to hole clogging. A small diameter inert tube can be inserted through the center of the rod and connected to the drive point (Hartman 2004). When the probe is retracted or pulled up, the probe is "open" for soil gas sampling.

In general, soil gas sampling events should be avoided after sizeable rainfall.

Exterior and near slab soil gas samples should be collected at a minimum depth of 5 feet below the ground surface. In situations where the ground water table is less than 5 feet, alternative sampling protocols may have to be employed. The investigator may propose collecting soil gas samples from below existing large impervious surfaces where vapor accumulation may occur, including garage floors, patios, parking lots, roads and driveways. Approval for alternative approaches to the 5-foot depth provision should be requested in advance from the Department.

6.3.2.3 Annular Seal and Tracer Gas

The annular seal is maintained by the soil against the probe rods. Therefore the drive tip cannot be larger than the probe rods or there will be no annular seal provided when the probe is pulled back to open the probe. Probes or rods, which have an irregular shape, will not allow for a competent seal and can lead to sample dilution and erroneous results.

To verify the integrity of the seal, the investigator should utilize a tracer compound, typically iso-propanol, butane, helium, sulfur hexafluoride, or difluoroethane. The tracer is placed around the base of the probe and at the various connections in the sampling system prior to sample collection. Liquid tracers are easily employed by wetting a paper towel and wrapping it around the test locations (Hartman 2004). The presence of the tracer compound in the analysis (generally in excess of 1,000 μg/L) confirms a leak and another sample should be collected until no leak is detected.

Another method employs a shroud or plastic sheeting placed around the sample probe. An inert tracer gas (such as helium) is released under the sheeting. The initial soil gas samples (after purging) can be monitored using field-screening instruments for elevated concentrations (>5%)

of the tracer gas (based on the original tracer gas concentration in the shroud). Tracer gases are discussed in more detail in the State of New York draft guidance document (NYDOH 2005).

Multiple insertions of the drive rods into a single hole during depth profiling will result in too much "play" in the rods and will not provide a competent annular seal. Therefore, a new hole is required for each sample point.

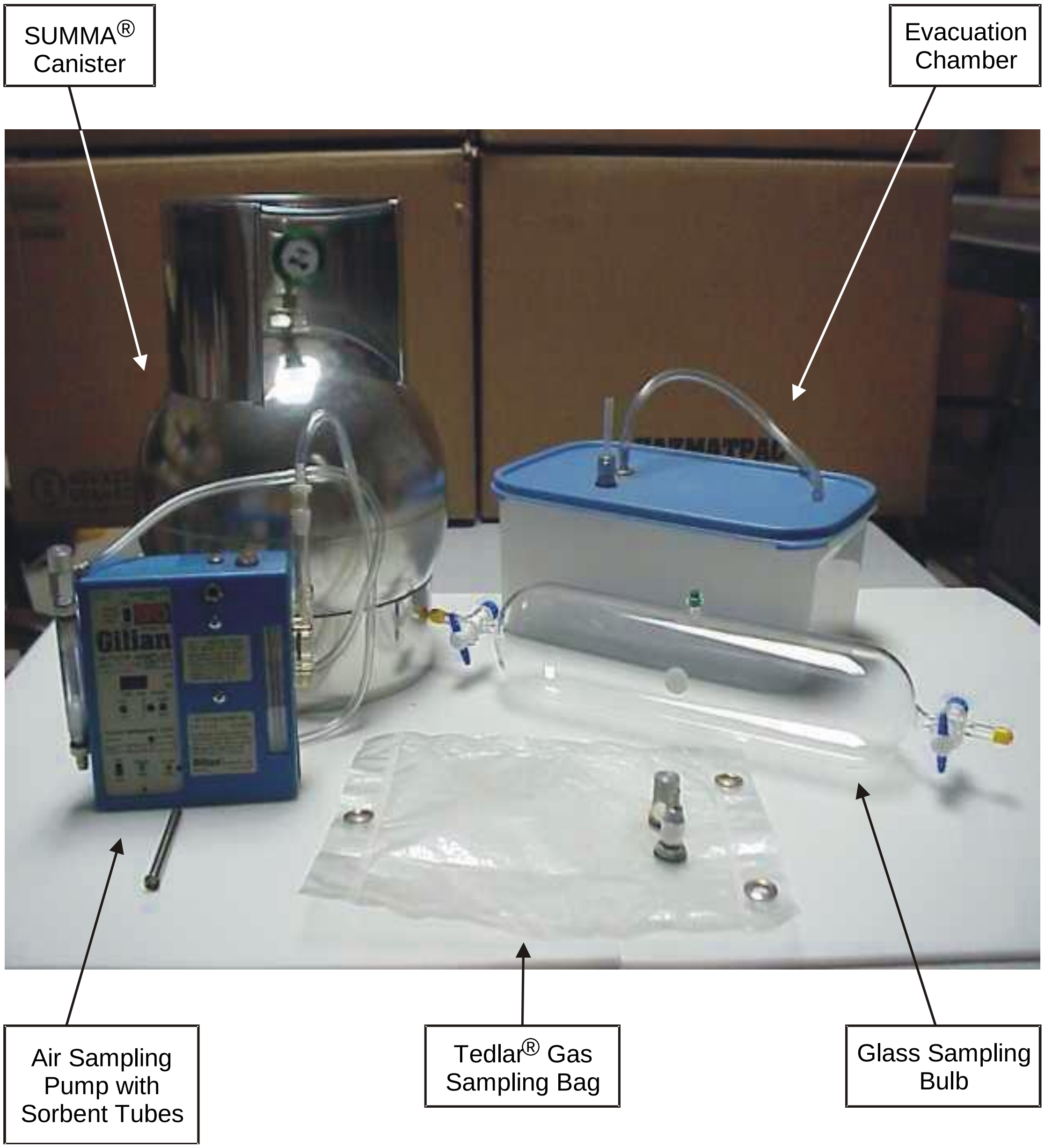
Depending on the circumstances, permanent soil gas probes may be employed. Permanent soil gas probes are constructed so soil gas samples can be obtained from the same location over time. They are used to obtain data on changes in soil gas concentrations over time. Single or multiple probes may be installed into a single borehole to obtain vertical profile data. Permanent probes are recommended for projects requiring more than one soil gas sampling event to monitor subsurface gas conditions for gas migration control or to monitor remediation activities. Please refer to the NJDEP Field Sampling Procedures Manual (2005) for additional information on permanent soil gas probes.

6.3.2.4 Sample Containers and Analytical Methods

The primary sample container recommended for the collection of near slab or exterior soil gas samples is stainless steel canisters. Either 1-Liter or 6-Liter canisters may be employed. However, the Department recommends that smaller sample containers be utilized for soil gas sampling to avoid short-circuiting or dilution of the sample with atmospheric air. The sub-slab soil gas samples shall be analyzed using USEPA Method TO-15 when stainless steel canisters are employed.

Sample containers other than stainless steel canisters can be employed when screening or preliminary results are appropriate. The investigator can utilize a gas sample bag (Tedlar®, Teflon®, metal-coated Tedlar®, etc.) with an evacuation chamber. The use of an evacuation chamber allows an air sample to be collected without the sample passing through a pump. Samples collected in gas sample bags are analyzed with a field GC or mobile laboratory.

AIR SAMPLING EQUIPMENT



Consistent with the NJDEP Field Sampling Procedures Manual (2005), the holding time for Tedlar bags should not exceed 3 hours.

Alternately, syringes can be used to withdraw a soil gas sample from a probe and then the sample is immediately injected directly into an analytical instrument for onsite analysis. Syringes come in varying volumes, materials of construction and designs to meet the analytical criteria. Syringe samples should be analyzed with a field GC or mobile laboratory and they have a short holding time (minutes).

A less common sample container is a glass cylinder or sampling bulb which has openings at each end and with a septum port to withdraw sample aliquots with a syringe. The air sample is collected by connecting one end of the bulb to the probe and the other to a pump. Sample holding times for the glass bulbs is 24 hours (NJDEP, 2005).

The analytical method used for the alternative sample containers is not stipulated in this guidance. However, USEPA SW-846 Method 8260B is the most common method utilized for field screening of soil gas samples.

If the purpose of the near slab soil gas sampling is as a stand-alone assessment of the VI pathway, a certified laboratory must be employed. At this time, that would require the use of 1-Liter or 6-Liter canister samples analyzed with USEPA Method TO-15.

The Department may entertain the utilization of a mobile laboratory certified in an appropriate air method as a stand-alone assessment. However, detection limits shall meet the NJDEP SGSL. In addition, 10% of the air samples should be collected as duplicates using stainless steel canisters and analyzed at a fixed laboratory for USEPA Method TO-15. The duplicate samples should be collected from locations containing a range of volatile concentrations.

The initial rounds of soil gas samples should be analyzed for the full suite of volatiles based on the approved method. Subsequent phases of soil gas sampling can employ a reduced parameter list as part of an approved VI investigation workplan.

6.3.2.5 Purge Volumes

Prior to attaching the sample container, the vapor probe should be purged by drawing 3.0 volumes of air through the probe and connecting tubing. The volume is calculated as follows:

$$PurgeVolume = 3.0\pi r^2 h$$

where r is the inner radius of the probe and connecting tubing, and h is the length of the probe and connecting tubing. The investigator should use a low purge rate at a maximum of 200 ml per minute (based on professional judgment).

Alternately, the vapor probe or soil gas well can be purged until field-screening parameters are stabilized. This approach typically employs 3-Liter Tedlar bags and a lung box to collect the purged air samples, which are then analyzed for O_2, CO_2, and PID/FID readings. The investigator should avoid excessive purging of the subsurface environment.

6.3.2.6 Sample Flow Rate

When a gas sample bag or syringe is utilized in combination with a field GC or mobile laboratory, the length of time for sample collection should be a maximum of 200 milliliters per minute (based on the professional judgment of the investigator). Care should be taken to avoid short circuiting or drawing in outside air along preferential pathways. Thus, instantaneous or grab samples are not acceptable due to the increased possibility of short circuiting leading to an invalid sample.

For stainless steel canisters, the sample flow rate should be a maximum of 200 milliliters per minute, which corresponds to a sample time of 5 minutes for 1-Liter canisters. This maximum flow rate has been established due to the larger volume of stainless steel canisters and the concern over short-circuiting.

The certified laboratory provides stainless steel canisters with pre-set regulators (based on the sample time prescribed by the investigator). Therefore, the sample time must be established in advance of the sampling event. Investigators can determine a draw rate prior to the soil gas sampling event through the installation of a test probe and subsequent draw rate determination with a purge pump.

6.3.2.7 Sample Locations

If near slab soil gas samples are being collected as a stand-alone assessment of the VI pathway, samples should be collected from at least two sides of the building in question. Precise locations will be in part dictated by the existing conditions around the building perimeter (e.g., other structures, landscaping, access issues) and the precise location of the ground water plume. The VI investigation workplan shall identify specific sample locations and provide technical justification for their selection.

Conversely, if the purpose of the soil gas sampling event is for any other purpose including field screening, the sample locations should be determined based on the end use of the data. The VI investigation workplan should define the goal of the soil gas sampling approach and how the proposed locations meet that need.

6.3.2.8 Number of Samples

In general, the number of samples recommended for the VI investigation is dictated by the sample spacing necessary. Samples should be spaced horizontally at a minimum of two to three times the depth to ground water. For a typical single family dwelling of 1,500 ft^2, one sample on each of two sides would be a minimum number of near slab soil gas samples. However, larger multi-family residential units and commercial, industrial or retail buildings may require additional samples spaced equidistant from each other (consistent with the depth to water table rule above).

If two soil gas sample locations have two to three orders of magnitude difference in concentration, at least one sample should be collected between the two points. Reducing the sample intervals below this distance across a site will not necessarily provide for better resolution of contamination. It may only indicate the variability in the soil horizon rather than changes in volatile concentrations. Soil gas sampling is not a high resolution technique for contamination delineation and should not be used for this type of interpretation (NJDEP Field Sampling Procedures Manual 2005).

Any decision on the number of soil gas sample points should start with an evaluation of the CSM. If there are indications from the ground water characterization that there could be large lateral changes in concentrations over short distances near a structure, there may be a case for increasing the number of sample points.

6.3.2.9 Sample Frequency

As discussed in Chapter 6.6 (Indoor Air Sampling Procedures), seasonal variability in vapor concentrations necessitates (in most circumstances) collecting more than one round of indoor air samples. Similar variability is not apparent in soil gas samples. However, if near slab soil gas samples are being collected as a stand-alone determination of the VI pathway, a second confirmation sample may be necessary.

The Department recommends the collection of sub-slab soil gas samples whenever indoor air samples are obtained. Therefore, multiple rounds of sub-slab soil gas samples may be dictated by the sampling requirements of indoor air. For indoor air, one of the two sampling events should take place during the months between November and March, since these are generally “worst case” conditions for VI (see Chapter 6.6, Indoor Air Sampling Procedures).

In situations where near slab or exterior soil gas sampling is being done to evaluate contaminant patterns or assess background contamination, a decision on the frequency of sampling should be determined on a site-specific basis.

6.3.2.10 Underground Utilities

Many accidents in subsurface investigations are due to encountering subsurface utilities. Prior to mobilizing for any soil gas investigation, health and safety concerns must be answered. Of greatest concern would be to locate any underground utilities. NJ One Call is a free service and can be contacted at 1-800-272-1000 (out of State call 908-232-1232). They will contact all utility companies that may have services in the area of investigation. Calls must not be made less than 3 full working days and not more than 10 working days prior to the planned work. If work is delayed past the 10 days, you are required to renew your ticket. “One Call” legislation mandates that all owners of underground infrastructures become New Jersey One Call members.

6.3.2.11 License Requirements

The license requirement for performing a soil gas survey is for the installation of the soil gas probes used for the collection of a soil gas sample. The requirement is based on depth and diameter of the boring and the length of time a probe will remain in the hole. Please consult N.J.A.C. 7:9D-*Well Construction; Maintenance and Sealing of Abandoned Wells* for further information. A copy is available through the Bureau of Water Allocation 609-984-6831.

6.3.2.12 Passive Sample Collection Methodologies

According to the NJDEP Field Sampling Procedures Manual (NJDEP 2005), Passive sample collection includes two general sample collection techniques. These techniques include the passive collection of contaminants onto sorbent material placed in the vadose zone and a whole air passive collection technique for collecting vapors emissions from the soil surface using an emission isolation flux chamber.

Passive sorbent sample collection utilizes diffusion and adsorption for soil gas collection onto a sorbent collection device over time. The soil gas data will delineate the nature and extent of subsurface contamination. The soil gas data at one location can be compared relative to the soil gas data from other sample locations in the survey. The mass levels will show patterns of the spatial distribution indicating areas of greatest subsurface impact. These areas can then be targeted for further investigation.

Since the passive sorbent samplers provide results in mass concentration, their use is limited to field screening only during the investigation of the VI pathway.

The flux chamber is an enclosure device used to sample gaseous emissions from a defined surface area. These data can be used to develop emission rates for a given source for predictive modeling of population exposure assessments. The data can also be used to develop emission factors for remedial action designs.

The emission isolation flux chamber is a dome superimposed on a cylinder. This shape provides efficient mixing since no corners are present and thereby minimizing dead spaces. Clean dry sweep air is added to the chamber at a controlled volumetric flow rate. The gaseous emissions are swept through the exit port where the concentration is monitored by a real time or discrete analyzer. Real time measurements are typically performed with portable survey instruments to determine relative measurements of flux chamber steady state operation and hot zones. Discrete samples are taken when absolute measurements are required for steady state concentrations and emission rate levels. The emission rate is calculated based upon the surface area isolated, sweep airflow rate, and the gas concentration. An estimated average emission rate for the source area is calculated based upon statistical or biased sampling of a defined total area.

The approval to utilize flux chamber sampling should be requested from the Department in advance of the sampling event as part of a Site-Specific Assessment (Stage 6). Justification should be provided to the Department as to why the emission isolation flux chamber method is more appropriate for this particular phase of the investigation.

6.3.2.13 Undeveloped Parcels and Future Use

When the potential for VI extends to undeveloped parcels, a VI investigation must be implemented to assess the impact on future use. A generic approach to investigating an undeveloped parcel would be conducting soil gas sampling on a 100-foot grid at a minimum depth of 5 feet. This grid method is approximately equal to the average New Jersey residential housing tract of ¼ acres. In situations where the future use is restricted by an institutional control, an alternative approach may be proposed, possibly postponing investigation to some point in the future when development is being considered.

6.3.2.14 Data Evaluation

Near slab soil gas results are generally utilized for comparison to other data sets (e.g., ground water, indoor air, and ambient air). For the most part, these data allow the investigator to determine patterns in the results and differentiate site-related compounds from other potential sources. Like sub-slab results, near slab soil gas data can be compared to the NJDEP SGSL.

6.4 Sub-Slab Soil Gas Sampling Procedures

The collection of sub-slab soil gas is an effective investigative tool when assessing the VI pathway. The procedure involves drilling through the building's concrete slab and collecting a soil gas sample for field or laboratory analysis. Sub-slab soil gas samples are often collected concurrently with indoor air samples to assess VI and potential background contaminant sources.

In situations where an earthen floor exists (instead of concrete), the provisions for sub-slab soil gas sampling may not be appropriate. Structures are often built with partial or full crawl spaces that extend the entire building footprint and utilize gravel or dirt. In other situations, the basement may be unfinished without a concrete floor. As a general rule, sub-slab soil gas sampling should be employed when the basement slab covers 50% or more of the building footprint. In these situations, it may be prudent to collect a combination of sub-slab soil gas samples from the concrete area and indoor air samples from the crawl space.

It is also important to understand the differences between sub-slab and exterior soil gas sampling. Sub-slab refers to soil gas samples collected from below a slab (typically in the basement of a building). Exterior, on the other hand, involves collecting soil gas samples from below the ground surface outside of a structure, utilizing a Geoprobe or slam bar. The soil gas samples collected from the earthen areas should be collected according to the procedures for near slab or exterior soil gas sampling found in Chapter 6.3 (Exterior and Near Slab Soil Gas Sampling Procedures).

The utilization of sub-slab soil gas sampling is also questionable when a high water table exists near the base of the sub-floor (less than 2 feet). Typically, vapors migrate through the most coarse and/or driest material. Depending on the analytical method, high moisture content in the soil gas sample can "mask" results, particularly polar compounds. Additionally, reduced permeability of the soil in the capillary fringe area may limit the movement of soil gas.

Specifically, sub-slab soil gas samples can be collected when ground water is as close as two feet below the building foundation if:

1) The seasonal high water table does not reach the building foundation; and
2) The water table does not extend into fill material directly under the building foundation; and
3) The capillary zone does not reach the building foundation.

The Department may be consulted for additional information in these situations.

6.4.1 Application

Sub-slab soil gas sampling can be useful to an environmental investigator from several perspectives.

6.4.1.1 Stand-Alone Assessment of the VI Pathway

Under the right circumstances, the results of sub-slab soil gas sampling may be utilized to determine whether the VI pathway is currently complete for a particular building. This is appropriate when the source of the vapors is a contaminated ground water plume under or in close proximity to the building in question. Investigators may want to collect sub-slab soil gas samples as an alternative to indoor air sampling in situations where indoor sources are likely to significantly affect indoor air quality.

While the Department recognizes the role of sub-slab soil gas sampling in assessing the VI pathway, there are a number of factors that have to be considered when utilizing these data. Sub-slab soil gas is not as likely to be definitive when the vapor source is solely subsurface contaminated soil (vadose zone). For example, there may be situations where vapors migrate laterally and do not collect under the building's slab (depending on the building construction, the depth of the soil contamination, and the slab's depth below the surface). In addition, preferential pathways, such as utility trenches, allow horizontal movement of the vapors. In these cases, infiltration of vapors through openings in the sidewalls of a basement may represent the primary pathway for VI. As a result, sub-slab soil gas results may be low or marginal, while indoor air data can still exceed health-based levels. Under these conditions, near slab soil gas samples collected between the zone of soil contamination and the structure's foundation may be more appropriate than sub-slab samples.

It is important to understand the stratigraphy in the area of the building. Low permeability layers under buildings (either natural or as part of construction) may act as an impediment to significant vertical vapor migration from the ground water contamination. The presence of such a layer may explain why relatively clean sub-slab samples can occur even though underlying ground water is contaminated. However, vapors may still enter the building through utility trenches or other preferential pathways if they bisect or circumvent the low permeability layer.

The presence of elevated contaminant vapors in the sub-slab soil gas is generally a positive indicator of VI when applying an attenuation factor (discussed below). However, the reverse circumstances (low contaminated levels in the sub-slab soil gas) do not automatically imply that the vapor pathway is incomplete. Site-specific conditions, such as distance from any vadose zone sources and depth of those sources (see the CSM section) should be evaluated before reaching any conclusions on the VI pathway.

6.4.1.2 Evaluating Contaminant Patterns

Analytical data from sub-slab soil gas samples should be assessed to identify any patterns in particular chemicals, groups of chemicals and/or their concentrations (both individually and collectively). When combined with data from other matrices (e.g., ground water, indoor air, and ambient air), these patterns may assist in distinguishing likely sources of indoor air contaminants and their pathways. For a further discussion on this topic, see Chapter 7, Evaluation of Analytical Results and Risk.

In addition, the investigator may want to evaluate the vertical depth profile of the contaminated soil gas. Vertical profiling is considered a site-specific procedure (see Chapter 5 for more information).

6.4.1.3 Assessing Background Contamination

One specific area where sub-slab soil gas results are particularly useful is in the differentiation of background contamination in indoor air. By comparing the specific chemicals (and their concentrations) detected in the indoor air sample with the sub-slab soil gas sample, a determination may be possible on the likely role of background sources. In addition, the end user should consider the horizontal movement of vapors as a potential contributor to the indoor air quality (as discussed in Section 6.4.1.1, above).

6.4.2 Sampling Procedure

Two different basic procedures for sub-slab soil gas sampling are provided below.

The first method employs a permanent sample point with stainless steel tubing and fittings. This method is recommended for long term monitoring of sub-slab soil gas as part of a remedial action. The approved Remedial Action Workplan shall include a VI monitoring plan to assess the changing concentration of contaminants of concern over time. Any decision to terminate a remedial action involving VI will most likely be made in part based on the sub-slab soil gas results.

The second procedure utilizes Teflon, metal (or similar) tubing for a temporary sample point. This method is more appropriate during the initial phases of investigation when the VI pathway is being evaluated. However, the investigator may want to use permanent sample points as part of the remedial investigation.

Alternative procedures for the collection of sub-slab soil gas samples should be submitted and approved by the Department in advance of the field activities.

Irrespective of the sampling method, the investigator should provide a detailed description of the site-specific conditions, including the type of sub-slab soil and backfill, the presence/absence of water, and the thickness of flooring (tile, concrete, etc.). The general condition of the slab and walls should be documented as part of the Building Survey form (which should be filled out during all sub-slab soil gas sampling events). The investigator should note the presence of sumps, cleanouts and floor drains.

In addition, the sub-slab sampling points should be installed in such a manner so as to provide a tight seal around the sampling point which serves to isolate the sub-slab environment from the inside of the building and allow for collection of samples which are representative of sub-slab vapor conditions.

Figure 6-2
Grouted Hole with Vapor Probe
(DiGiulio et al. 2005)

One note of caution: Be aware of the subsurface conditions under the slab before you drill. What is the depth to the high water table? Are underground utilities (e.g., electric, gas, water or sewer lines) located below the slab? You don’t want to create a preferential pathway for ground water to move into the living space. Also, question the occupants about whether a vapor barrier may already exist under the slab. Avoid puncturing the vapor barrier unless you are equipped to repair it afterwards. When a vapor barrier is present under the slab, the investigator should consider installing a leak-free permanent sampling probe.

6.4.2.1 Permanent Sample Point Approach

- Remove carpeting, if present (this may require cutting a small ½” square flap that can be glued back down after the sampling event is completed).

- Drill a 3/8” diameter hole through the concrete slab using an electric drill.
- Advance the drill bit approximately 3” into the subslab material (gravel or soil) to create an open cavity.
- Overdrill the top 1” (vertical) of the probe hole to a diameter of 1”.
- Insert the vapor probe flush with the top of the concrete slab and add a non-volatile emitting surface sealing material (e.g., portland cement) to seal the annular space.
- Allow the test points to cure for at least 1 hour (portland cement will likely take longer).
- Connect the vapor probe to a “T” fitting made of a stainless steel flexible line (or similar inert material) and an in-line valve.
- Purge the vapor probes and sampling lines (see discussion below on purge volumes).
- Close valve on the vacuum pump line.
- Open the valve to collect a sub-slab soil gas sample.

A typical vapor probe is constructed from small diameter (e.g., 0.64 cm or ¼ 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 ¼ in OD x 0.32 cm or ⅛ in NPT Swagelok female thread connectors) (DiGiulio et al. 2005). It is imperative that the vapor probe is completed flush with the concrete surface to avoid problems for the occupants of the building. It should be noted that the dimensions of the vapor probe and the corresponding hole, as well as the materials utilized in the sampling apparatus, are guides and are not suppose to be prescriptive. Minor modifications may be appropriate. Alternative methods utilizing established protocols (e.g., ASTM) may be considered.

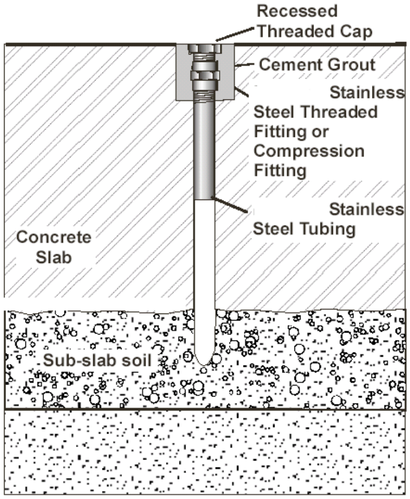


Figure 6-3
General Schematic for Installation of Sub-Slab Vapor Probes
(DiGiulio et al., 2005

Ideally, the vapor probes should remain in the concrete slab beyond their initial use. It may be necessary to collect additional rounds of sub-slab soil gas to properly assess the VI pathway. Furthermore, the vapor probes may assist with any potential remedial actions involving sub-slab depressurization systems. The building owners should be encouraged to allow the vapor probes to remain in place for the foreseeable future.

6.4.2.2 Temporary Sample Point Approach

Depending on the particular circumstances (e.g., occupant's preferences, early investigative phase, and urgency of sample collection), a temporary or less permanent probe may be utilized. Instead of the stainless steel tubing and fittings, 1/8 to 3/8 in tubing (Teflon, nylaflow, metal or similar materials) may be substituted. The tubing should be wrapped with Teflon tape to create a snug fit when the tubing is twisted into the hole. The drill hole should be smooth wall to minimize potential for leaks. Modeling clay, beeswax or other non-volatile emitting and non-shrinking materials may be utilized.

The objective with a temporary sample point is to use tubing that is only slightly smaller in diameter than the drill hole. Do NOT overdrill the top 1" (vertical) of the probe hole – as with a permanent sample point. Since portland cement is not being used, the sample points can be set up the same day as the sub-slab soil gas sampling (Hers and Rees 2005). Purging and sample collection (with a stainless steel canister) should be conducted similarly to the permanent sample point procedures above.

6.4.2.3 Sample Containers and Analytical Methods

The primary sample container recommended for the collection of sub-slab soil gas samples is stainless steel canisters. Either 1-Liter or 6-Liter canisters may be employed. The sub-slab soil gas samples should be analyzed using USEPA Method TO-15 (or other appropriate certified methods).

Sample containers other than stainless steel canisters can be employed when screening or preliminary results are appropriate. The investigator can utilize a Tedlar bag for sample collection and analyze the samples with a field GC or mobile laboratory. Alternately, a 60 - 500 cubic centimeter (cc) syringe can be used. As with the Tedlar bags, syringe samples should be analyzed with a field GC or mobile laboratory. It should be noted that the holding time for Tedlar bags should not exceed 3 hours.

The analytical method used for the alternative sample containers is not stipulated in this guidance. However, USEPA SW-846 Method 8260B is the most common method utilized for field screening of air samples.

If the purpose of the sub-slab soil gas sampling is as a stand-alone assessment of the VI pathway, a certified laboratory using USEPA Method TO-15 or TO-17 must be employed.

6.4.2.4 Sample Flow Rate

When a Tedlar bag or syringe is utilized in combination with a field GC or mobile laboratory, the length of time for sample collection should be a maximum of 200 milliliters per minute (based on the professional judgment of the investigator). Care should be taken to avoid short circuiting or drawing in outside air along preferential pathways. In addition, a proper seal between the sample point and slab must be established to prevent indoor air from mixing with the soil gas sample. For these reasons, instantaneous or grab samples are not acceptable.

For stainless steel canisters, the sample flow rate should be a maximum of 200 milliliters per minute, which corresponds to a sample time of 5 minutes for 1-Liter canisters. This maximum flow rate has been established due to the larger volume of stainless steel canisters and the concern over short circuiting. The investigator may want to collect the sub-slab soil gas sample over a 24 hour period, especially when indoor air samples are being done concurrently. However, samples times up to 24 hours are acceptable (excluding instantaneous or grab samples).

The certified laboratory provides 6-Liter stainless steel canisters with pre-set regulators (based on the sample time prescribed by the investigator). Therefore, the sample time must be established in advance of the sampling event. Investigators can determine a draw rate prior to the sub-slab soil gas sampling event through the installation of a test probe and subsequent draw rate determination with a purge pump.

6.4.2.5 Calculating Purge Volumes

Prior to attaching the sample container, the vapor probe should be purged by drawing 3.0 volumes through the probe and connecting tubing. The volume is calculated as follows:

$$PurgeVolume = 3.0\pi r^2 h$$

where r is the inner radius of the probe and connecting tubing, and h is the length of the probe and connecting tubing. The investigator should use a low purge rate with a maximum of 200-ml per minute.

6.4.2.6 Sample Location

Vapor probes should be installed in a central location on the slab. Positions near the perimeter of the slab are subject to dilution and should be avoided. The selected location(s) should be chosen in consultation with the property owner. To minimize potential damage to flooring, it may be necessary to select a location in a closet or utility room (where carpeting or tiles are less visible or not present at all).

6.4.2.7 Number of Sample Points

The number of sub-slab samples collected is directly related to the goal of the investigation. For a typical single family residential dwelling (approximately 1500 ft^2), one vapor probe installed near the center of the slab should adequately document the chemical composition of the sub-slab soil gas. Significantly larger dwellings (or other unique conditions in the subfloor or construction of the foundation) will require additional vapor probes.

Multi-family residential units and commercial or retail buildings will require a more careful review of the building features. Consideration should be given when the building has more than one tenant. Subsurface structures may be present that would facilitate VI and thus degrade indoor air quality in one portion of the building and not another. Any sampling approach should take into account the different exposure scenarios (e.g., day care, medical facilities) that exist within the building and any sensitive populations that may be exposed to the contaminated vapors.

Multiple vapor probes are necessary for multi-family residential units and commercial or retail buildings. The number and placement of those test points should be determined on a site-specific basis with deliberation given to occupied spaces, segmented areas within larger areas, and potential future use.

Any decision on the number of sub-slab sample points should start with an evaluation of the CSM. If there are indications from the ground water characterization that there could be large lateral changes in concentrations over short distances near a structure, there may be a case for multiple sample points or targeting the worst case areas.

6.4.2.8 Sample Frequency

If sub-slab soil gas samples are being collected as a stand-alone determination of the VI pathway, a second confirmation sample may be necessary. Supplemental environmental data (e.g., ground water, indoor air, or near slab soil gas data) may eliminate the need for a second round of sub-slab soil gas sampling. In addition, the Department may accept a single round of sampling in those cases where the analytical results are an order of magnitude below the appropriate screening level.

In situations where sub-slab soil gas sampling is being done to evaluate contaminant patterns or assess background contamination, a decision on the frequency of sampling should be determined on a site-specific basis.

6.4.3 Data Evaluation

Sub-slab soil gas results are generally utilized for comparison to other data sets (e.g., ground water, indoor air, and ambient air). For the most part, these data allow the investigator to determine patterns in the results and differentiate site related compounds from other potential sources. Results from a sub-slab soil gas investigation should be compared to the NJDEP SGSL. These values were generated from the NJDEP IASL by utilizing an attenuation factor of 0.02. While this factor can be used for a generic screening, a more site-specific evaluation may be appropriate, especially for petroleum hydrocarbon compounds.

For crawl space air samples, the Department has determined that an attenuation factor of 1.0 is applicable, consistent with the USEPA (2002b). Therefore, crawl space indoor air samples can be compared directly to the IASL.

6.5 Conducting A Building Walkthrough and Survey

Preparation is an important aspect for any VI investigation. However, when indoor air samples are going to be collected as part of the investigation, preparation takes on a new level of importance.

A building walkthrough is a critical element of any VI investigation workplan that includes indoor air and/or sub-slab soil gas sampling as an investigative tool. There are several components of a building walkthrough that should be addressed:

- Detection of potential background sources of volatile organic compounds.
- Determination of the building construction
- Recognition of points of VI in a structure
- Identification of possible sample locations
- Education of the occupants on VI and sampling procedures

Ideally, the building walkthrough should be conducted at least one week before the actual indoor air or sub-slab soil gas sampling event. This advance timeframe allows the investigator to identify and eliminate (to the extent practical) potential background sources of indoor air contamination. It also permits the investigator to confirm the sample locations with the occupants and NJDEP ahead of the scheduled sampling episode.

6.5.1 Detection of Potential Background Sources

As discussed in Chapter 8, investigating the VI pathway is greatly complicated by the impact of background contaminant sources. Differentiating the common household sources of poor indoor air quality from those associated with contaminated ground water or subsurface soil is a legal and fiscal dilemma facing both regulatory agencies and potential responsible parties throughout the country.

One of the tools that the Department utilizes in identifying background sources in the indoor air environment is the *Indoor Air Building Survey and Sampling Form* (Appendix B). The survey form allows the investigator to document various information on the building, the occupants, and potential sources of indoor air contamination. The questionnaire was originally developed by NJDEP in 1997 and has since been revised for this guidance document using several similar survey forms prepared by New Hampshire Department of Environmental Services, New York State Department of Health, Vermont Department of Health, and Massachusetts Department of Environmental Protection.

The *Indoor Air Building Survey and Sampling Form* is broken down into eight sections:

- Part I - Basic information on the Occupants of the building, including address, contact’s name and phone number, owner’s name (if different), and a breakdown of the occupant’s ages.
- Part II - The Building Characteristics of the structure under investigation, including building and foundation type, number of floors, heating and ventilation systems, fuel utilized in the building, and the presence/absence of septic systems, sumps, irrigation/private wells, or existing subsurface depressurization systems.
- Part III - Identification of any Outside Contaminant Sources that may exist near the structure being investigated.
- Part IV - Identification of all potential Indoor Contaminant Sources found in the building, the location of the source, and whether the item was removed from the building prior to the indoor air or sub-slab soil gas sampling event. This section also documents remodeling activities, including painting, new carpeting or flooring, and

new furniture. It may be necessary to include additional sheets to inventory all the household products stored within the structure.

- Part V - Survey of Miscellaneous Items related to household activities that may impact indoor air quality, including smoking, dry cleaning clothes, and applying pesticides on the property.
- Part VI - Documentation of Sampling Information, including sample numbers and locations, start time and end times for the sampling event, and the name of the sample technician. This section will be completed on the date of the sampling event.
- Part VII - Existing Weather Conditions during the sampling event should be documented on the survey form. As noted in Chapter 2, weather conditions (especially temperature, barometric pressure, and precipitation) can affect the sample collection and interpretation of the data.
- Part VIII - This section allows the technician to document any General Observations noted during the sampling event that do not fit into the categories noted above.

Another essential tool for pinpointing background sources of indoor air contaminants is the use of handheld field screening instruments. Field portable instrumentation provides useful information for critical decisions in the field. Almost all projects require screening or semi-quantitative data collection during the field-screening phase of the site investigation. These instruments are hand held, rugged, and offer rapid results in the field (NJDEP 2005).

For the purpose of a VI investigation, one of the most important factors in selecting the appropriate field screening instrument is its method detection limits (MDLs). Preferably, the MDLs should be below the action level or levels of concern (NJDEP IASL) for the indoor air.

Recent advances have been made in the development of field portable instrumentation. Photo-ionization detectors (PID) are now providing parts per billion (ppb) detection, making them appropriate for building walkthroughs and surveys during VI investigations. With a ppb detecting PID, individual cans of solvents can be identified as vapor sources and removed from the building in advance of the sampling event.

When household or background sources of indoor air contamination are identified and removed from a building, it may be necessary to ventilate the rooms affected in advance of the air sampling event. This ventilation should be completed at least 24 hours before the commencement of the indoor air sampling event.

6.5.2 Recognition of Points of Vapor Intrusion in a Structure

The entry of organic vapors into a structure is due to the infiltration of contaminants through the floor and walls that are in contact with the soil. Usually, vapors enter a building through poorly sealed utility lines that penetrate the foundation. Other contaminant pathways are through cracks in the walls and floors, sumps, around the wall/floor juncture of floating floor construction or other breaches in the walls or slab.

The *Indoor Air Building Survey and Sampling Form* asks a series of questions that are designed to assist in the identification of potential points of VI. Part II inquires about the type of building foundation, construction of the basement floor, and the presence of sumps. Any obvious breaches in the walls or slab in the basement (or lowest floor) should be noted in Part VIII (General Observations) of the *Indoor Air Building Survey and Sampling Form*. The investigator should also examine the point at which all utility lines enter the structure.

6.5.3 Identification of Possible Sample Locations

The building walkthrough is a perfect time for the investigator to identify possible sample locations that fit the defined investigative goals of the VI investigation workplan.

Sub-slab soil gas samples should be collected from a central location on the slab. Positions near the perimeter of the slab are subject to dilution and should be avoided. To minimize potential damage to flooring, it may be necessary to select a location in a closet or utility room (where carpeting or tiles are less visible or not present at all). The selected location(s) should be chosen in consultation with the property owner during the building walkthrough.

Indoor air samples are generally collected from more than one floor within a structure to address varying risk exposures and as part of the process to distinguish contaminants related to VI from background sources. Thus, the location and position of the sample container will vary depending on which floor the sampling event takes place.

Ground floor (living space) samples should be located to approximate human risk exposure. Thus, these indoor air samples are generally placed at breathing zone height (3-5'). Consideration should also be given on a case specific basis to those situations (such as a day care facility) where a different sampling height may also be appropriate to evaluate a unique setting or population. The basement sample(s) are primarily designed to investigate “worst case” situations within a structure. Therefore, basement samples are positioned as close as possible to the source area (e.g., sumps, major cracks in foundation).

Hence, the building walkthrough allows the investigator to identify potential sample locations for both sub-slab soil gas and indoor air samples. It is recommended that the final locations be selected in consultation with the department’s technical staff.

6.5.4 Education of the Occupants on Vapor Intrusion and Sampling Procedures

One of the responsibilities of the investigator when collecting samples within a structure is to educate the occupants on the VI pathway. Unlike other environmental matrices (soil, ground water, surface water, or sediments), indoor air quality can have an immediate and possible long term affect on human health that is not easily addressed by simple avoidance of the contaminated material.

During the building walkthrough, occupants are likely to raise a number of issues that the investigator should be prepared to answer. Refer to Chapter 11 for a discussion on how to conduct community outreach during the investigation of the VI pathway. In addition, two fact sheets, *Evaluating Indoor Air near VOC Contaminated Sites* (Appendix D) and *Subsurface Depressurization Systems* (Appendix E) may provide further assistance.

The Department has prepared a one page advisory paper entitled *Instructions for Occupants - Indoor Air Sampling Events* (Appendix C). The instructions provide the occupants with a list of actions that should be avoided before and during the sampling event. *The Instructions for Occupants - Indoor Air Sampling Events* sheet should be made available to the occupants at least one week in advance. The paper can be presented during the building walkthrough (assuming the timeframe is met). Any deviation from the instructions noted during the sampling event should be documented on the *Indoor Air Building Survey and Sampling Form*.

6.6 Indoor Air Sampling Procedures

When compared to the other investigative tools available, indoor air sampling (Stage 4C) represents the most direct measure of human health exposure for the VI pathway.

Utilization of the J&E model to extrapolate potential vapor concentrations within a structure based on ground water data can be adversely influenced by numerous geophysical parameters. Data from sub-slab or near slab soil gas sampling employs an attenuation factor that can **estimate** indoor air concentrations resulting from VI. These procedures do not provide actual analytical data on the indoor air quality. Yet, indoor air sampling is not without its problems.

Indoor air quality is affected by a multitude of sources that originate both inside and outside any building. Background contamination should be properly assessed whenever indoor air samples are collected. A detailed discussion on background contamination can be found in Chapter 8. In addition, a variety of meteorological, temporal, and structural factors can influence indoor air concentrations resulting from VI (as discussed in Chapter 2).

Despite these shortcomings, the Department recommends the collection of indoor air samples whenever the potential for VI exists and other investigative tools can not eliminate the pathway. In addition, indoor air samples are appropriate for remedial confirmation purposes.

6.6.1 Application

Analytical results from indoor air sampling events are applicable to the assessment of the VI pathway in several ways.

6.6.1.1 Stand-Alone assessment of the vapor intrusion pathway

Analytical results from indoor air sampling may be utilized to determine whether the VI pathway is currently complete for a particular building.

In order for the indoor air results to be acceptable to the Department in any stand-alone assessment of the VI pathway, all sampling procedures provided in this guidance should be followed for the collection of indoor air samples.

The Department does not accept averaging of the results of the indoor air samples within a building. Therefore, each data point should be evaluated independently of each other. Always refer back to the CSM when evaluating data and making any conclusions on the VI pathway.

6.6.1.2 Evaluating contaminant patterns

Analytical data from indoor air samples collected from different floors within a structure should be assessed to identify any patterns in particular chemicals, groups of chemicals, and/or their concentrations (both individually and collectively). When combined with data from other matrices (e.g., ground water, soil gas, and ambient air), these patterns may assist in distinguishing likely sources of indoor air contaminants and their pathways. This is important when background sources located within the structure generate the same volatile organic compounds identified as contaminants of concern associated with the site investigation. (For a further discussion on this topic, see Chapter 8.)

6.6.1.3 Assessing background contamination

Indoor air samples should be collected concurrently with ambient air and sub-slab soil gas samples. The analytical results are useful in the differentiation of background contamination in indoor air. By comparing the site-specific contaminants of concern detected in the soil gas sample with the indoor air and ambient air results, the investigator can validate the designation of background contaminants and thus limit any remedial action.

6.6.2 Sampling Procedures and Analytical Methods

Analysis of indoor air samples must utilize a laboratory holding a current certification/accreditation from NJDEP Office of Quality Assurance (OQA). At present, there are only two analytical methods where certification is offered - USEPA Method TO-15 and TO-17. Both of these methods analyze for volatile organic compounds. The Department is investigating other analytical methods for possible certification that will expand the list of parameters beyond the standard volatile organics, including naphthalene, formaldehyde, and semivolatile organic compounds.

The first analytical method - TO-15 - employs stainless steel canisters to collect whole air samples. Volatile organic compounds (both polar and non-polar) are concentrated on a solid multisorbent trap, refocused on a second trap, separated on a gas chromatograph column, and passed to a mass spectrometer for identification and quantitation. TO-15 is the principal method used for indoor air samples primarily due to the ease of use for the investigator and the limited obstruction for the occupants of the building (compared to other sampling equipment).

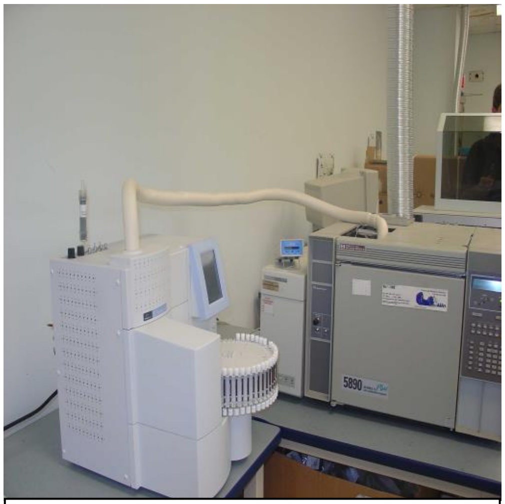


Figure 6-4
Autosampler GC/MS for TO-17 analysis
(courtesy of Severn Trent Laboratories)

TO-17 uses sorbent tubes for the collection of air samples in the field. There is a large selection of sorbents that can be matched to the contaminants of concern. The tubes are thermally desorbed into a gas chromatogram/mass spectrometer instrument system. The method requires specific collection procedures and states that after desorption on to the column the samples are to be analyzed in accordance with USEPA Method TO-15.

Additional information on these two analytical methods can be found in Appendix I, Quality Assurance Requirements. Alternative methodologies for the collection and analysis of indoor air samples should be submitted and approved by the Department in advance of the field activities.

Regardless of the analytical method, it is recommended that the investigator complete the NJDEP *Indoor Air Building Survey and Sampling Form* (Appendix B). The survey form should be completed as part of the building walkthrough (conducted prior to the sampling event) and include information obtained during the actual sampling episode. Similar to the sub-slab sampling procedures, the general condition of the structure should be documented, including the presence of sumps, cleanouts and floor drains. Refer to Section 6.5 for additional information on the building walkthrough and the survey form.

In light of recent events related to homeland security, it is highly recommended that suitable precautions be taken whenever VI investigations include outside air sampling. The sampling equipment (e.g., stainless steel canisters) and related devices are not familiar to most individuals and may be misinterpreted as a safety concern. Therefore, notification about the sampling event should be provided to the local police and fire departments, in addition to the municipal officials. It may be necessary to demonstrate the operations of the sampling equipment to these officials. A label should be affixed to the sampling device explaining the nature of the equipment and all appropriate contact information in case there are further questions. The individuals collecting the indoor air samples should be prepared to provide proper identification to the building occupants.

6.6.2.1 TO-15 Requirements

- The sampling event should be conducted by collecting a minimum of one indoor air sample from the ground floor (living space) at each property using 6-Liter stainless SUMMA canisters (or other specially prepared stainless steel canisters) and analyzed for VOC using USEPA Method TO-15. If a basement or crawlspace exists, a second canister air sample should be collected as part of the minimum requirements. Breathing zone height (3-5') will be appropriate for the ground floor sample collection, whereas the basement sample should be positioned as close as possible to the source area (e.g., sumps, major cracks in foundation). Additional canister air samples may be necessary for larger buildings to properly assess indoor air quality. The rationale for the final number of air samples collected per building should be provided in the VI investigation workplan.

Figure 6-5
Stainless steel canister

- In general, one ambient (outdoor) sample should be taken per sampling event concurrently with indoor samples to assist in evaluating background contaminant levels. This ambient air sample should be taken at breathing zone height and located in a reasonably representative area (e.g., not immediately next to auto traffic or other potential sources). See Section 6.1.3.3 for additional guidance on the appropriate number of ambient air samples.
- Air samples should be collected over a 24-hour period (a <u>minimum</u> 8 hour sample may be substituted with proper justification, if necessary).
- Air Filters are recommended for each canister to prevent clogging of the orifice during sample collection.
- All results are to be reported in ppbv. The laboratory should also report the data in $\mu g/m^3$ in a separate column from the ppbv results.
- For USEPA Method TO-15, 6-Liter stainless steel canisters should be used for the indoor air sample collection. Alternative sizes or types of sample containers are not acceptable for indoor air samples.

6.6.2.2 TO-17 Requirements

- The sampling event should be conducted by collecting a minimum of one indoor air sample from the ground floor (living space) at each property and analyzed for VOC using USEPA Method TO-17. If a basement or crawlspace exists, a second sample should be collected as part of the minimum requirements. Breathing zone height (3-5') will be appropriate for the ground floor sample collection, whereas the basement sample should be positioned as close as possible to the source area (e.g., sumps, major cracks in foundation). Additional air samples may be necessary for larger buildings to properly assess indoor air quality. The rationale for the final number of air samples collected per building should be provided in the VI investigation workplan.

- For each sampling point, the investigator will be required to collect two sorbent tubes for each sampling point in parallel. The sorbent material in each tube must be the same material.
- In general, one ambient (outdoor) sample should be taken per sampling event concurrently with indoor samples to assist in evaluating background contaminant levels. This ambient air sample should be taken at breathing zone height and located in a reasonably representative area (e.g., not immediately next to auto traffic or other potential sources). See Section 6.1.3.3 for additional guidance on the appropriate number of ambient air samples.
- The pump rate must be set so that the final calculated reporting limit used by the laboratory shall be less than or equal to 0.5 ppb.
- The minimum sample collection time for the sorbent tubes has been established by NJDEP as eight (8) hours. A twenty-four (24) hour sample collection time is the preferred sampling time, since it provides a longer time weighted average for exposure.
- The choice of sampling apparatus and sorbent material is left to the investigator. However, the apparatus must conform to Section 6.3.1 of Method TO-17, which requires accommodations for two sampling tubes with the capability of independent control for sampling rate at a settable value in the range of 10 to 200 ml/min.
- All quality assurance provisions stipulated in Appendix I (Quality Assurance Requirements) shall be followed for USEPA Method TO-17.
- All results are to be reported in ppbv. The laboratory shall also report the data in $\mu g/m^3$ in a separate column from the ppbv results.

6.6.2.3 Number of Sample Locations

As previously stated above, a typical single family residential dwelling (approximately 1,500 ft^2) should have one indoor air sample collected from the first floor and one from the basement or crawl space (if present). Significantly larger dwellings may require additional samples.

Multi-family residential units and commercial or retail buildings will require a more careful review of the building features. Consideration should be given when the building has more than one tenant. Subsurface structures may be present that would facilitate VI and thus degrade indoor air quality in one portion of the building and not another. Any sampling approach should take into account the different exposure scenarios (e.g., day care, medical facilities) that exist within the building and any sensitive populations that may be exposed to the contaminated vapors. Multiple indoor air sample locations are necessary for multi-family residential units and commercial or retail buildings.

6.6.2.4 Sample Frequency

As discussed in Chapter 2, seasonal variability in vapor concentrations necessitates (in most circumstances) collecting more than one round of indoor air samples.

If indoor air samples are being collected as a stand-alone determination of the VI pathway, a second confirmation sample may be necessary. One of the two sampling events should take place during the months between November and March, since these are generally “worst case” conditions for VI. However, the Department will accept a single round of sampling (irrespective of the seasonal timing of the sample event) in those cases where the results are an order of magnitude below the appropriate screening level.

6.6.2.5 Pressure and Temperature Issues

The laboratory prepares the canisters and establishes the flow rate of the regulators based on the barometric (atmospheric) pressure and temperature inside of the laboratory. The canister pressure must be set at approximately –30 inches of mercury at the laboratory prior to shipment. Once in the field, temperature and atmospheric pressure changes that occur over the sample collection time will affect the rate of sample collection. A sharp decrease in the temperature (from the temperature at which the regulators are set in the laboratory) during the period of sample collection will increase the flow rate into the canister, while an increase in temperature will slow the flow rate.

Thus, the Department recommends the collection of ambient temperature and pressure readings during the collection of all air samples.

For an exterior ambient sample, there are two ways to obtain this information. Atmospheric pressure and temperature can be acquired from the nearest weather reporting station. Two websites that may be useful to the investigator are the National Oceanic and Atmospheric Administration, National Weather Service website at http://www.weather.gov or Weather Underground at http://www.wunderground.com/. Alternately, the investigator can bring portable meteorological instrumentation on site to obtain the information real time.

Temperature for interior samples should be obtained using portable meteorological instrumentation with readings taken inside the structure. For all indoor air samples, individual temperature readings will be necessary for each sample location. Larger commercial buildings may also require barometric pressure readings for each sample.

6.6.3 Data Evaluation

Indoor air results are compared to the NJDEP IASL**.** Ideally, the data will establish patterns in the contaminant distribution, both within the structure (basement verses first and second floors, etc.) and outside the structure (ambient verses indoor air concentrations). In addition, comparisons should also be made between the indoor air results and other data sets (e.g., ground water, indoor air, and ambient air). For the most part, these data allow the investigator to determine patterns in the results and differentiate site-related compounds from other potential sources.

The results of air samples collected within a building’s crawl space should be compared to the NJDEP IASL.

7.0 EVALUATION OF ANALYTICAL RESULTS

Once the data packages have been validated, the investigator should evaluate the analytical results by comparing the soil gas, ground water, and indoor air results to the appropriate screening levels.

7.1 Background Sources

One of the most critical steps during a VI investigation is the evaluation of analytical data - particularly as it relates to source identification. Unlike other pathways, the potential for background contamination is significant. The investigator should follow the framework for distinguishing background sources found in Chapter 8.

NJDEP relies on a *multiple lines of evidence* approach when assessing potential background sources of indoor air contamination, employing a series of primary and secondary factors. The primary factors are the identification of site-specific contaminants of concern, collection of sub-slab soil gas and ambient air data, and the evaluation of the results. The secondary factors include completion of the *Indoor Air Building Survey and Sampling Form*, review of indoor air background databases, and collection of exterior soil gas data. As a general point, remedial action will not be required when the site-specific ambient air results are in excess of the indoor air results. In these cases, the Department should assess the validity of the ambient air results.

An assessment of potential background sources should be included in any data evaluation process.

7.2 Ground Water Samples

Assuming the samples are collected consistent with the procedures and recommendations in Section 6.2, the data should be compared to the applicable NJDEP GWSL. The exceedance of these screening levels for any volatile will necessitate further investigation. However, it should not be assumed that elevated ground water concentrations automatically indicate that unacceptable levels of vapors are currently entering the structure. If exceedances of GWSL are minor and sporadic, appropriate statistical analytical methods may be considered for data evaluation.

The ground water data shall be evaluated to determine whether the contaminant plume has been delineated to the extent needed to assess the VI pathway. If it is determined that the plume has not been sufficiently delineated, additional ground water samples will be required to complete the delineation as it pertains to this pathway. All existing buildings that are located within 100 feet horizontally of the shallow plume’s perimeter should be identified. The Department does utilize a 30-foot distance criterion (both horizontal and vertical) for petroleum related contamination (see Chapter 9 for further discussions). Depending on the soil type, the presence of preferential pathways, and/or certain hydrogeologic features, the two distance criteria may have to be modified. The results of this effort will highlight those structures that will necessitate further investigation for the VI pathway.

7.3 Vertical Ground Water Contaminant Profile

At sites where a clean water lens is investigated, vertical profiles of volatile levels in ground water may reveal various patterns that are likely to have different implications for the current and future risk of vapor intrusion. The following guidelines can be used to interpret the data.

A **six foot thick lens** of ground water with contaminants below the GWSL can be considered sufficient justification to conclude the plume is not a source for vapor intrusion in the immediate vicinity. Additional ground water sampling for a VI investigation should not be required where such a lens exists unless conditions change, or are expected to change to include any circumstances that will cause the water table elevation to decrease significantly. However, ongoing monitoring as part of an approved remedial action may be required.

If a **lens between three and six feet thick,** not exceeding the GWSL, exists between the vadose zone and the part of the plume that does exceed GWSL, significant off-gassing into the vadose zone is unlikely. However, in this situation ongoing, periodic water level and/or ground water monitoring should be performed to confirm the continuing presence of a “below GWSL lens” of at least 3 feet in thickness. If water level data or other information strongly suggest that a below GWSL lens at least 3 feet thick is not present throughout the year, additional investigation of the VI pathway (soil gas and/or indoor air sampling) is recommended. If possible, the additional investigation should be done during, or immediately after, a time period when a below GWSL lens was not present.

A below GWSL **lens less than 3 feet thick** overlying a plume which exceeds the GWSL should trigger additional investigation of the VI pathway and possibly ongoing ground water monitoring. Conditions which should be considered in designing the next investigative step include: types of contaminants present; concentrations of contaminants in the various depth intervals sampled; and thickness of the below GWSL lens in the vertical profile nearest to the structure.

7.4 Sub-Slab Soil Gas Samples

The compounds detected in the sub-slab (or near slab, when approved) soil gas results should be compared with the site-specific contaminants of concern (including degradation products) identified from the contaminated ground water or soil. The compounds should be similar. If additional compounds are seen in the soil gas results, a secondary VI source may be present. A supplemental investigation of the local soils may be warranted.

The analytical results of the sub-slab soil gas samples should be compared to the NJDEP SGSL. The NJDEP SGSL were prepared using the NJDEP IASL with an attenuation factor of 0.02. The investigator may propose an alternative attenuation factor consistent with the procedures for a Site-Specific Screening Process (Stage 6).

If the soil gas results exceed the applicable NJDEP SGSL, additional investigation of the VI pathway is necessary. Unless the investigator is proposing a site-specific approach that is acceptable to the Department, indoor air sampling will be necessary.

In those situations where the soil gas results do not exceed the NJDEP SGSL but ground water quality exceeds the generic GWSL, a site-specific determination can potentially be made that no additional VI investigation is needed. This determination should be based on an accurate CSM and representative ground water data which indicates:

- that shallow ground water concentrations are unlikely to increase in the future; and,
- other site conditions at the time of sampling (e.g., soil moisture, % oxygen in vadose zone) are unlikely to change enough to result in higher soil gas volatile levels.

Consideration should be given to whether volatile levels in ground water greatly or only slightly exceed the GWSL. Also consider whether the ground water plume is still growing, at steady-state conditions, or in the process of attenuating. In the situation where the ground water plume is still growing, additional investigation is apt to be necessary. If known, the vertical distribution of contaminant concentrations in ground water may also be relevant to this decision.

Based on the sampling plan, multiple sub-slab soil gas samples may have to be collected. In general, the Department does not allow the results of the sub-slab soil gas samples to be averaged across the subsurface of a building. Therefore, each data point should be evaluated independently of each other.

7.5 Indoor Air Samples from the Basement

The analytical results of the indoor air samples should be compared to the NJDEP IASL. The investigator may propose alternative screening levels consistent with the procedures for a Site-Specific Screening Process.

If the indoor air results exceed the applicable NJDEP IASL, additional investigation of the VI pathway is necessary to confirm the results. Once confirmed, the investigator should propose an appropriate remedial action, as discussed in Chapter 10.

Multiple samples collected from different locations on the same floor may identify probable background sources when combined with a building walkthrough and survey. Compare the locations of suspect consumer products (e.g., paints, thinners) or household activities (e.g., hobbies, smoking) with the indoor air sample results. Evaluate whether particular volatile organic compounds are higher or lower in certain portions of a building and if they correlate with identified background sources. Additionally, determine if the site-specific contaminants of concern compare to the indoor air compounds detected in the sample results. The need to collect multiple indoor air samples from the same level is a site-specific determination based on the likelihood of significant background sources within a structure.

In addition, compare the analytical results with potential VI routes through the building slab or foundation (e.g., sumps, utility lines, major cracks). Depending on the ventilation system in the basement, differences in concentrations of site-specific contaminants of concern between multiple sample points may be related to their relative position near VI points (and not background sources).

7.6 Multiple Indoor Air Samples from Different Floors

Ideally, indoor air samples should be collected from at least two separate floors within a structure, preferably the basement (or lowest floor) and the level immediately above it. In part, the rationale for this approach is to provide the investigator with analytical results that may assist in the assessment of potential background contaminant sources. This is critical in situations where sub-slab soil gas samples are NOT collected.

Compare the results for individual compounds on each floor. In general, the concentrations should decrease as you move away from the source. Thus, if VI from contaminated ground water or subsurface soil is the main source, the highest concentrations should be in the basement (or lowest floor) and decrease as you move up to the first or second floor. Conversely, if the higher concentrations are found in the upper floors (when compared to the basement results), a background source unrelated to the site is probably located within the building on the floor with the highest concentrations. Deviations from this general understanding of vapor movement may exist in situations where a vertical pathway allows vapors to move quickly from one floor to the next (e.g., elevator shafts, laundry chutes).

The first step in differentiating background contamination during indoor air sampling events is to identify the site-specific contaminants of concern (based on ground water or subsurface soil data). When these contaminants of concern are found in potential background sources located within the building under investigation, results from multiple indoor air samples can be compared to the relative concentrations of related contaminants.

For example, benzene, ethylbenzene, toluene and xylenes (BTEX) are common contaminants associated with gasoline. Compare the concentrations of each of these contaminants relative to each other. Evaluate whether a similar relationship exists between the contaminants detected in other samples collected either on the same or different floors of the building. If benzene and toluene generally have a 1:1 ratio in the basement and the 2nd floor samples have 3x as much toluene as benzene, it is probable that a secondary background source of toluene is located on the 2nd floor (e.g., nail polish).

7.7 Indoor Air and Sub-Slab Soil Gas Samples

The Department recommends that the collection of indoor air and sub-slab soil gas samples be conducted concurrently during the investigation of the VI pathway. The combination of indoor air and sub-slab soil gas results will assist in identifying likely background indoor air sources and verify whether a VI source exists below the building (instead of extrapolating contaminated ground water or subsurface soil results from indoor air).

The Department has developed a Remediation Decision Matrix (part of the Decision Flow Chart - Appendix A) to assist the investigator in assessing the VI pathway. Specifically, the Remediation Decision Matrix evaluates the relationship between the sub-slab soil gas and indoor air sample results, providing guidance on the appropriate action (e.g., no action, monitoring, further investigation, and mitigation).

Frequently, contaminants will be found in the indoor air, but not the sub-slab soil gas samples. The compounds are likely originating from background sources unrelated to VI (especially if they are not site-specific contaminants of concern). In these cases, the Remediation Decision Matrix directs the investigator to evaluate vadose zone (soil) contamination and preferential pathways as potential contributors to indoor air contamination that might not be detected in the subsurface soil gas results. Once it is established that VI is not contributing to the indoor air contamination, no further action is necessary for this pathway.

The investigator will identify cases where the indoor air concentrations are below the IASL, but the sub-slab soil gas results are elevated, indicating a potential source in the subsurface. In these situations, the Remediation Decision Matrix differentiates between elevated sub-slab soil gas results that are less than or more than 10 times the SGSL.

For sub-slab soil gas results that are 10 times or less the SGSL, the options are no further action or continued monitoring. The higher the sub-slab soil gas exceedance, the more probable it is that monitoring will be necessary.

If the sub-slab soil gas results are greater than 10 times the SGSL, the option of no further action is not available. In these cases, the investigator should either continue monitoring the sub-slab soil gas concentrations or implement a remedial action. The change in remedial options is due to the increased likelihood that vapor intrusion will occur in the future if the source of the high soil gas concentrations is not addressed.

When more than one option is available in the Remediation Decision Matrix (decision points), the investigator should use professional judgment when determining which action is appropriate. Factors to be considered at these decision points include:

- the relative exceedance of the screening level,
- the ratio of the sub-slab soil gas and indoor air results,
- the current building construction (e.g., 1st floor garages, sub-slab vapor barriers, etc.),
- possible effects of background sources of contamination, and
- sampling errors.

In many situations, both the sub-slab soil gas and the indoor air results will exceed the applicable screening levels. If the sub-slab soil gas data exceeds the SGSL by more than 10 times (with indoor air results exceeding the IASL), the investigator should implement a remedial action to address the VI pathway. The evidence clearly points to VI impacting the indoor air quality of the structure.

Another decision point occurs, however, when the sub-slab soil gas results exceed the SGSL by 10 times or less and the indoor air results are greater than the IASL. In these situations, the investigator should use professional judgment to determine whether the appropriate action is to investigate the VI pathway further or execute a remedial action. An evaluation of the sub-slab soil gas and indoor air results should be conducted to assess the relative exceedance in comparison to the screening level.

The investigator should look at the exceedance multipliers (analytical results divided by the applicable screening level) for both soil gas and indoor air. If the VI pathway is complete, the soil gas multiplier should be similar to or higher than the indoor air multiplier, which necessitates mitigation. In situations where the indoor air multiplier is notably higher than the soil gas multiplier, further investigation is warranted to assess whether an indoor background source is present. This scenario, however, does not eliminate the possibility that the VI pathway may still be impacting to the air quality within the structure and should be addressed.

The clearest picture of the contribution of background indoor air sources, though, is observed when sub-slab soil gas results are combined with indoor air data collected from different floors and/or various locations on each floor.

The summary table below presents soil gas and indoor air results collected during an investigation of a gasoline plume in the coastal plains of New Jersey. Even though free product is found adjacent to the building, numerous gasoline-related compounds are non-detect in the sub-slab soil gas samples - probably due to biodegradation. Other gasoline related compounds, namely cyclohexane, MTBE, and 2,2,4-trimethylpentane, are detected at high concentrations in the sub-slab soil gas with decreasing levels in the basement and first floor. This strongly supports the assumption that the VI pathway is complete. In fact, the sub-slab soil gas multiplier is greater than 10 times the applicable SGSL and the IASL are exceeded. Thus, mitigation is necessary (consistent with the Remediation Decision Matrix) to address the VI pathway.

There are, however, contaminants that are present in the basement or first floor indoor air samples and not in the sub-slab soil gas. Had MTBE not been present, the Remediation Decision Matrix would recommend no further action. A review of the building survey form in this particular case reveals that the occupants utilize various solvents as part of their operations, including methylene chloride, toluene, and xylenes. These indoor air contaminants originate from background sources and should not be factored into any NJDEP approved remedial actions related to site contaminants. For an example of how multiple lines of evidence are applied in the determination of vapor intrusion, consult Sanders & Hers (2005).

Table 7-1

Illustrative Example of Sub-Slab Soil Gas and Indoor Air Results

Chemical	Soil Gas Results Sub-slab	IA Results Basement	IA Results 1st Floor
Benzene	ND	ND	ND
Cyclohexane	15,000	120	25
Ethylbenzene	ND	ND	10
4-Ethyltoluene	ND	ND	19
Methylene chloride	ND	ND	100
MTBE	18,000	140	50
Toluene	ND	ND	45
1,2,4-Trimethylbenzene	ND	ND	17
1,3,5-Trimethylbenzene	ND	ND	5.9
2,2,4-Trimethylpentane	93,000	700	160
Xylenes *(m & p)*	ND	14	39
Xylenes *(o)*	ND	ND	17

Results in µg/m^3 ND - non-detect

7.8 Indoor Air Data Evaluation

As discussed in Section 4.3, indoor air analytical results are compared to the Table 1 IASL. If VI related indoor air concentrations exceed the IASL, additional actions are indicated to address the VI pathway. These actions may include further investigation/evaluation of the potential source of the VI and/or the development of a plan of action to mitigate potential impacts to the indoor air quality of the building.

Confirmatory sampling should be conducted to verify the presence of elevated contaminant levels in a building and to substantiate the occurrence of VI (distinct from background contaminant sources). Confirmatory sampling should include indoor air, sub-slab or near slab soil gas, and ambient air samples.

In addition, indoor air analytical results are compared to the RAL found in Table 2. Initial sample results exceeding the RAL will require that confirmatory samples be collected **immediately** upon receipt of the data. Implementation of an interim remedial measure (IRM), such as the installation of a subsurface depressurization system, is necessary when VI related indoor air concentrations exceeding the RAL are confirmed. The **rapid** implementation of the IRM is essential to address the potential for adverse impacts to public health.

Health Department Notification Levels (HDNL), developed in consultation with the NJDHSS, are also listed in Table 2. These values, when exceeded in occupied buildings, represent levels that trigger the Department's referral of a site to the local health department or NJDHSS. The local health department or NJDHSS would then have the information necessary to make a decision in consultation with the NJDEP regarding the need for any emergency actions, such as the evacuation of an occupied building. On a case by case basis, the health departments may also be notified when elevated indoor air levels below the HDNL are present in an occupied school, day care center, health care facility, or other structure with sensitive receptors.

Should the driver chemical at a site be one of the contaminants that does not currently have an RAL or HDNL value, the Department's Environmental Toxicology and Risk Assessment (ETRA) unit may be contacted at 609-633-1348 to identify an applicable level.

7.9 Official Notification

Although investigators may elect to forward results (or be bound to do so by property access agreements), it is NJDEP’s policy to officially notify property owners about their indoor air and/or soil gas analytical results whenever a oversight document is in place. The Department will also notify current tenants about the analytical results. However, it is ultimately the property owner’s responsibility to ensure that all potentially impacted current and future building occupants are informed.

The written reports from NJDEP will consist of a cover letter explaining the findings and a table summarizing the analytical results. The letter should include language informing the property owner of the Property Condition Disclosure requirements as per N.J.A.C. 13:45A-29.1.

In cases where the compounds are concluded to be originating from background sources unrelated to VI, the occupants will be directed to consult with the local health department on ways to reduce background contamination. Refer to Chapter 11 for guidance on community outreach and the communication of investigative results to building occupants/owners.

8.0 BACKGROUND CONTAMINATION

One of the most difficult facets of investigating the VI pathway is assessing the impact of background contaminant sources. Indoor air quality is affected by a multitude of sources that originate both inside and outside any building.

VI from a discharged hazardous substance, hazardous waste, or pollutant to ground water or soil is a regulatory concern of the Department. However, other contaminant sources (e.g., ambient outdoor air, consumer products, building materials) that may impact indoor air quality are the responsibility of different programs within NJDEP, the New Jersey Department of Health and Senior Services (NJDHSS), and/or the federal government.

According to the USEPA, background refers to constituents that are not influenced by the releases from a site, and is usually described as naturally occurring or anthropogenic (USEPA 2002a). For the intentions of this guidance document, background will refer to any contaminants not directly resulting from subsurface VI related to a discharge. In many cases, individual contaminants found in indoor air may result from both subsurface VI and background sources.

Despite the varying sources impacting indoor air quality and the numerous regulatory groups overseeing them, it is imperative that all the results of any VI investigation be reported to the occupants, irrespective of the ultimate responsibility for the indoor air contaminants.

8.1 Background Investigations

Once the decision has been made to conduct indoor air sampling (consistent with the guidance found in Chapter 6), the investigator should consider the proper exploratory tactic to distinguish site related VI from background contamination.

Individual states, such as Colorado and Massachusetts, have long recognized the risk to human health from VI. Now, this exposure pathway is being assessed at a multitude of RCRA, Superfund, Underground Storage Tank programs and state lead sites nationwide, along with the more traditional dermal and ingestion exposure pathways.

Yet, there are major differences in the method of investigating VI that distinguish it from the other pathways. One of those dissimilarities is the assessment of background contamination.

Background contamination is typically identified through the collection of upgradient or upstream samples for ground water and surface water respectively. With soil investigations, background samples are collected from areas of the site not impacted by current or historic operations and having similar soil characteristics. Building interiors do not generally provide for “upgradient” or “non-impacted” sampling locations in order to establish background indoor air concentrations. Thus, an alternative approach is necessary for indoor air assessments to distinguish background contamination from site related VI.

8.2 Background Indoor Air Sources

Sources of background indoor air contamination can be broken down into several categories – household activities, consumer products, building materials and furnishings, and ambient air pollution. The conveniences of life that people often take for granted greatly impact indoor air quality. With the average American spending over 90 percent of their time inside where contaminant concentrations are often much higher than outside (USEPA 2001c), the numerous sources impacting the air quality of buildings warrants closer scrutiny.

Smoking tobacco products, parking a car in an attached garage, using a kerosene heater, burning scented candles, dry cleaning clothes - all these household activities contribute to potentially unhealthful contaminant concentrations in the indoor air. Over 50 carcinogenic compounds are found in tobacco smoke alone (Cal EPA 1997). In fact, cigarettes account for 45% of the benzene found in indoor air (Ott and Roberts 1998).

Consumer products represent a second source of indoor air contamination that should be evaluated when assessing the contribution from VI. Mothballs (1,4-dichlorobenzene), nail polish remover (acetone), rug spot cleaner (tetrachloroethene), floor polish (xylenes), drain cleaner (1,1,1-trichloroethane), and gasoline (benzene, toluene, ethylbenzene, and xylenes) are just a few of the examples. (Refer to Appendix H, *Common Household Sources of Background Indoor Air Contamination*, for additional information). With the proprietary nature of consumer products today, it is often impossible to determine what chemicals are contained in most products. Either the labels are silent on the ingredients or they will refer to some generic constituent, such as "petroleum products."

Building materials and furnishings are another source of indoor air contamination, particularly when they are new. Whether it's carpeting, shower curtains, fabrics and draperies, furniture, building insulation, or pressed wood products (particleboard, hardwood plywood, and medium density fiberboard), indoor air quality can be significantly affected by volatile organic compounds and formaldehyde emanating from these products.

Numerous materials found in buildings, such as carpeting, fabrics, and wallpapered gypsum board, can act as "sinks" that retain indoor air pollutants and subsequently release them over a prolonged period of time (Won et al. 2000). This process is called sorptive interaction, based in part on the work at the University of Texas at Austin - the Texas Institute for the Indoor Environment. Carpets represent a significant sink for non-polar volatiles, while virgin gypsum board interacts primarily with highly polar volatiles.

Outdoor air typically enters a structure through infiltration, natural ventilation, and mechanical ventilation. Yet, studies have shown that common organic pollutants are 2 to 5 times higher inside a structure compared to levels in the ambient air (USEPA 1987). Over the last three decades since the passage of the Clean Air Act in 1970, the pollutant concentrations in the outdoors have been greatly reduced. Despite this turnaround, ambient air in urban environments (and other unique circumstances) does require careful consideration when evaluating indoor air results.

8.3 Methods to Address Background Sources

NJDEP relies on a multiple lines of evidence approach when assessing potential background sources of indoor air contamination. This approach employs a series of primary and secondary factors that collectively gauge the often confounding contaminants found in indoor air and determine with reasonable certainty the contribution from VI.

Utilizing this methodology, the primary factors (discussed below) provide more significant evidence when compared to the secondary factors (a "weighted" average). The multiple lines of evidence approach is not designed to be a mathematical calculation, but rather a professional judgment based on a progression of empirical facts, some more relevant that others.

8.3.1 Primary Factors

The primary factors (in no particular order) for assessing background contamination in indoor air are provided below.

8.3.1.1 Site-Specific Contaminants of Concern

A well delineated ground water plume (or subsurface soil contamination) with identified chemical contaminants can greatly limit the scope of any investigation. Potential degradation products must be included in the contaminants of concern list. However, indoor air investigations are often conducted with just basic information where ground water or subsurface soil data are seldom extensive or complete. Thus, insufficient data may exist preventing contaminants of concern from being determined prior to the collection of indoor air samples. It should be noted that the Department requires indoor air samples collected during initial rounds to be analyzed for the full list of parameters (based on the methodology) and not a reduced list. Subsequent phases of soil gas sampling can employ a reduced parameter list as part of an approved VI investigation workplan.

8.3.1.2 Sub-slab soil gas sampling

Collecting vapor samples from below the structure’s slab is an excellent tool for differentiating contaminants originating in ground water and subsurface soils from those associated with background sources. The Department’s procedures for collecting sub-slab soil gas samples, as outlined in Chapter 6.4, should be followed in order to utilize the data in the evaluation of background contamination.

Sub-slab soil gas samples, collected concurrently with indoor air samples from the same structure, will allow for a comparison between the data. The investigator should evaluate the contaminants of concern found in the ground water and subsurface soils (and their concentration ratios relative to each other). Do they correlate with the results from the sub-slab soil gas and indoor air samples? Correlation between these different sets of data would indicate that the VI pathway is complete.

Frequently, contaminants will be found in the indoor air, but not the sub-slab samples. In these cases, the compounds are likely originating from background sources unrelated to VI, and the occupants will be directed to consult with the local health department on ways to reduce background contamination.

A concentration gradient between the sub-slab and indoor air samples (greater than 20x higher in the sub-slab) strongly suggests that the VI pathway is complete. Conversely, higher concentrations within the structure (when compared to sub-slab results) would indicate that a secondary background source is likely present inside. This scenario, however, doesn’t eliminate the fact that the VI pathway may still be contributing to the poor indoor air quality within the structure.

The investigator must consider the presence of preferential pathways. The VI pathway may be complete even though low sub-slab concentrations are detected. Vapors, particularly from contaminated soils, may migrate along preferential pathways above the depth of the structure’s slab. Thus, contaminated vapors may adversely impact a structure's indoor air quality without the presence of elevated sub-slab vapors.

8.3.1.3 Ambient (outdoor) air sampling

NJDEP recommends the collection of a minimum of one ambient air sample during every indoor air sampling episode. The results of the ambient air sample can be utilized to evaluate the influence of outside air on the indoor air quality. This provision is particularly important for urban settings due to the industrial and automotive emissions typical of larger cities. In general, remedial action will not be required when the site-specific ambient air results are in excess of the indoor air results. In these cases, the Department should assess the validity of the ambient air results.

NJDEP Air Toxics Program measures a suite of toxic VOC, semivolatile compounds and metals at four monitoring sites – Camden, Elizabeth, Chester and New Brunswick. These four sites in the Air Toxics Monitoring Network provide information on the spatial variation of air toxic concentrations in the state.

While data from the NJ Air Toxics Monitoring Network can not replace site-specific results, it does provide a general indicator of potential ambient air concentrations in a region of New Jersey.

8.3.2 Secondary Factors

The secondary factors for assessing background contamination in indoor air provided below.

8.3.2.1 Building survey

NJDEP utilizes the *Indoor Air Building Survey and Sampling Form* (Appendix B) when collecting sub-slab soil gas and indoor air samples. This questionnaire covers numerous issues, including building characteristics, indoor contaminant sources, miscellaneous items (such as "do you smoke or dry clean clothes?"), sampling information, and weather conditions.

When the questionnaire is completed in advance of the indoor air sampling event and as part of the building walkthrough, potential background sources can be identified and removed/eliminated prior to sampling.

8.3.2.2 Indoor air background databases

Utilization of local, regional, national, or international indoor air background databases is a secondary method for assessing background contamination. The USEPA National Ambient VOC Database Update (USEPA 1988) is one resource for determining typical background concentrations in buildings.

In addition, NJDEP has conducted a literature review to determine available information regarding ambient levels of VOC in homes and other structures (Appendix F). Much of this information was drawn from studies designed to determine personal exposures to these chemicals, but many of them included dedicated indoor air sampling where measurements were taken at an indoor fixed location. Most of these studies were done in urban areas throughout the United States, including many in New Jersey. While several chemicals were commonly observed in indoor air, many other volatiles regulated by New Jersey have never been evaluated. It is likely that many of them would not be found; however, this needs to be confirmed via analytical methods that determine all regulated compounds of interest. Therefore, the Department is conducting research to confirm the presence or absence of all regulated VOC using stainless steel canisters and USEPA method TO-15.

Care should be taken to avoid placing too much emphasis on background literature values. They are just one of many tools that can be used when assessing indoor air contamination.

8.3.2.3 Exterior soil gas sampling

Department experience has shown exterior soil gas sampling to be an effective screening tool when selecting monitor well locations for ground water delineation of contaminant plumes. However, its success in VI investigations has been suspect. Concerns over false negative results have limited the use of exterior soil gas sampling in determining the presence/absence of a VI problem affecting indoor air quality.

Exterior soil gas sampling may be appropriate, though, when differentiating VI from background contaminant sources as part of an indoor air sampling event. While the Department recommends utilizing sub-slab soil gas sampling for this purpose, occupants are not always receptive to drilling a hole in their slab. Collecting soil gas samples from the foundation perimeter (near slab) is a reasonable alternative in this circumstance.

8.3.3 Other Issues

Besides the primary and secondary factors, there is additional information that may assist in the evaluation of potential background indoor air sources.

It is important to understand the structure where samples are being collected. HVAC systems that generate positive air pressure can reasonably be expected to prevent or minimize VI within the structure. Conversely, a dirt floor (or poorly vented crawlspace) instead of a concrete slab may significantly increase contaminant concentrations within the structure above levels normally calculated using attenuation factors or the J&E model.

Additionally, it is imperative that data quality be assessed before, during and after the sampling event. Select a laboratory that is competent to analyze the soil gas/indoor air samples and is familiar with the analytical method. In New Jersey, the investigator shall utilize a laboratory from the state’s laboratory certification program for USEPA Method TO-15 and TO-17 to ensure quality data. Collect the appropriate quality control samples (blanks, duplicates, etc.). Once the laboratory submits the results, validate the data packages. Laboratory contaminants can occur during the analysis of indoor air samples, particularly with polar compounds.

In order to collect an indoor air sample that is both representative of indoor conditions and avoids the common sources of background air contamination, the occupants are instructed as to the do's and don'ts of indoor air sampling. These directions are contained in the *Instructions for Occupants - Indoor Air Sampling Events*, found in Appendix C. This precautionary step may eliminate potential background sources and avoid the process of distinguishing contaminant causes in indoor air samples.

Finally, the assessment of VI and indoor air results should take into account the appropriate application of federal and state policies relating to the role of background. USEPA policy recommends that contaminant concentrations attributable to background sources not be eliminated from the risk assessment process (USEPA 2002a). This allows for the total risk to be properly assessed, even though the remedial action ultimately may not address the background sources. Unlike some states (e.g., Massachusetts, Connecticut), New Jersey does not factor chemical specific background values into their indoor air screening criteria.

While the Department does not subtract background air concentrations from the analytical results, site-specific background sources may be considered when interpreting indoor air data. Background contaminant levels, particularly ambient air results, supercede the Table 1 values when higher since the Department does not require remediation to levels below background concentrations. Background determinations are made on a site-specific basis in consultation with the Department and as part of the overall multiple lines of evidence approach.

9.0 PETROLEUM HYDROCARBONS

9.1 Introduction

As defined in the Underground Storage of Hazardous Substances Rules (N.J.A.C. 7:14 B):

> *petroleum or petroleum products means all hydrocarbons which are liquid at one atmosphere pressure (760 millimeters or 29.92 inches Hg) and temperatures between -20°F and 120° F (-29° C and 49° C), and all hydrocarbons which are discharged in a liquid state at or nearly at atmospheric pressure at temperatures in excess of 120° F (49° C) including, but not limited to, gasoline, kerosene, fuel oil, oil sludge, oil refuse, oil mixed with other wastes, crude oil, and purified hydrocarbons that have been refined, re-refined, or otherwise processed for the purpose of being burned as a fuel to produce heat or useable energy or which is suitable for use as a motor fuel or lubricant in the operation or maintenance of an engine.*

Hydrocarbons as a whole consist of hundreds of chemical compounds that range through volatile, semivolatile, and nonvolatile organic fractions.

Within this document, the Department has indicated a chemical can be considered a source of VI if it has sufficient volatility and toxicity in the subsurface with sufficient mass and/or concentrations to pose a possible inhalation risk within occupied overlying structures. When comparing the two definitions, it is apparent not all petroleum related chemical compounds represent a VI risk. The primary VI risks are associated with the chemical compounds that make up the lighter (shorter carbon chain) petroleum fractions, such as gasoline, diesel fuel, No. 2 heating oil, kerosene and aviation fuel.

The IASL Table (Table 1) lists 52 target volatile organic which are able to be analyzed via USEPA TO-15 method and for which toxicological data exists. Eleven chemicals within this list are routinely associated with one or more of the lighter petroleum fractions discussed above: benzene, toluene, ethylbenzene, xylenes, methyl tertiary butyl ether (MTBE), n-hexane, 1,2,4-

trimethylbenzene, 1,3,5–trimethylbenzene, cyclohexane, 2,2,4-trimethylpentane, and tertiary butyl alcohol.

9.2 **Biodegradation**

Each of the aforementioned compounds is known to biodegrade under aerobic conditions. Numerous studies have been completed confirming aerobic biodegradation of these chemicals in soil and ground water. However, the rate of attenuation is different for each chemical and, if groups of compounds are present, microbial activity will selectively degrade one chemical ahead of another (e.g., benzene will be preferentially degraded in an aerobic environment ahead of MTBE). The rate of degradation in the vapor phase of each of these chemicals has not been quantified.

At the time this document was prepared, limited studies have been presented to support a biodegradation factor for these chemicals under aerobic conditions. However, as indicated in Section 4.2, Calculation of Ground Water Screening Levels for the Vapor Intrusion Pathway, several resources have suggested values for establishing a degradation factor for benzene, toluene, ethylbenzene, and xylenes ranging from 1 to 35,000. Until additional data is generated, the Department has selected an additional attenuation factor for benzene, toluene, ethylbenzene, and xylenes of 10 times the ground water to indoor air value calculated using the J&E model. Use of the additional attenuation factor assumes a minimum of 4% oxygen exists in the soil column beneath the structure. A biodegradation factor for MTBE, n-hexane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, cyclohexane, 2,2,4-trimethylpentane, and tertiary butyl alcohol has not been included due to uncertainty over the rate of attenuation in the vapor phase.

As noted in Section 6.1 and consistent with USEPA, the VI pathway warrants investigation when a structure is “located within 100 feet laterally or vertically of a known or interpolated soil gas or ground water contaminants…and the contamination occurs in the unsaturated zone and/or the uppermost saturated zone.” (USEPA 2002b). The 100-foot horizontal or vertical distance criterion for investigating the VI pathway does not consider the degradability of the petroleum hydrocarbon compounds. As such the Department will utilize a 30-foot horizontal and vertical distance criterion for all petroleum related contamination provided non-aqueous phase product is not present. When non-aqueous phase petroleum hydrocarbons are present within 100 feet horizontally or vertically of a structure, the VI pathway warrants investigation.

9.3 Site Evaluation

When a petroleum release occurs and a ground water site investigation is triggered, one or more of the aforementioned 11 chemicals or non-aqueous phase hydrocarbons may be present in ground water in excess of the Department's Ground Water Quality Standards. In these circumstances, as the ground water remedial investigation proceeds an evaluation of the VI risk to receptors must proceed concurrently. The Department has established GWSL for the 11 petroleum-related chemicals (Table 1). If NAPL (as defined in N.J.A.C. 7:26E) is located or suspected within 100 feet of a structure or one of the aforementioned petroleum related contaminants is present in the dissolved phase in excess of the GWSL within 30 feet of a structure, an evaluation of the VI pathway is necessary. For active gasoline service stations, if ground water contaminant concentrations exceed the GWSL, the Department recommends the collection of sub-slab soil gas samples where possible in lieu of indoor air samples. If the sub-slab results are in excess of the SGSL, an institutional control may be required at the site until it can be demonstrated the site contaminant concentrations do not represent a VI risk.

10.0 REMEDIAL ACTION

Remedial action techniques need to be considered when it is determined that the VI pathway is complete and may adversely impact human health. The objective of these remedial techniques is to eliminate the pathway between the source (contaminated ground water and/or subsurface soils) and the receptors (building occupants). Ultimately, though, the NJDEP's primary goal is to remediate the source of the vapor contamination (ground water and/or subsurface soil) such that the risk of VI is eliminated.

This section discusses the various remedial actions appropriate for VI and the operations, monitoring and maintenance provisions associated with these remedial actions. Due to the similarities between VI related to volatile organic compounds and radon, many of the remedial actions discussed below originate from guidance documents addressing radon mitigation.

10.1 Remedial Action Techniques

While remedial investigation and remedial action of the vapor source are ongoing, remedial action techniques should be implemented to prevent VI. The NJDEP generally does not review engineering design specifications for VI remedial systems. The investigator or entities responsible for implementing the VI remedial system shall demonstrate the effectiveness of the remedial action by collecting verification samples (see 10.3.2.1). Some remedial action techniques are listed below; the first three of which are typically implemented at a minimum:

- Sealing openings and cracks with caulk or expanding foam (preferably volatile-free)
- Repairing compromised areas of the slab or foundation
- Covering and sealing exposed earth and sump pits
- Installing a sealed vapor barrier (e.g., plastic sheeting, liquid membrane) over earthen, gravel, etc. floors or crawlspaces
- Utilizing natural ventilation
- Installing a subsurface depressurization system
- Installing a pressurized air curtain

- Utilizing house pressurization
- Utilizing heat recovery ventilation
- Installing a soil vapor extraction system

Subsurface depressurization systems are the most common remedial action technique and as such are discussed in detail below.

10.1.1 Subsurface Depressurization Systems:

There are various types of subsurface depressurization systems as discussed below and in more detail in the USEPA's Radon Reduction Techniques for Existing Detached Houses - Technical Guidance (USEPA 1993). The objective of the subsurface depressurization system is to apply a negative pressure field or vacuum beneath and/or around the building of concern, thereby preventing VI into the building. Subsurface depressurization systems can be either passive or active, however NJDEP only accepts active systems for remediating VI in existing buildings (see Section 10.2.4 for pre-construction options). Active subsurface depressurization systems utilize a fan to create the negative pressure field (vacuum).

1. Sub-Slab Depressurization can be used when a building has a slab (e.g., concrete) floor. Piping is installed in the subsurface beneath the slab and a fan is used to create a negative pressure field in the sub-slab area and discharge any vapor outside the building. Depending on the size of the slab and the characteristics of the sub-slab material, piping may have to be installed beneath the slab in multiple locations in order to create a negative pressure field across the entire sub-slab area. Piping configurations depend on the construction and design of the building of concern however piping is typically inserted vertically through the existing slab. In a new construction scenario, lateral perforated piping can be installed prior to installation of the slab. See Figure 10-2 for more details.

2. Sub-Membrane Depressurization can be used when a building has an earthen (or gravel, etc.) floor or crawlspace, as opposed to a slab. A membrane such as plastic sheeting is

used to cover the earthen floor or crawlspace area and, similar to Sub-Slab Depressurization, a negative pressure field is created beneath the membrane thereby preventing VI across the membrane. The membrane needs to be properly sealed to the building walls, etc. and kept intact in order to maintain the negative pressure field. The piping that is used to create the negative pressure field beneath the membrane can be configured in various ways. Piping can be inserted vertically through the membrane in multiple locations or perforated piping can be laid horizontally beneath the membrane. See Figure 10-3 for more details.

3. Block-Wall Depressurization can be utilized when a building has a block wall foundation. In this scenario the negative pressure field is created via piping inserted through the voids in the block wall. Any openings in the top of the block wall and all openings or cracks on the interior surface of the wall should be sealed. This technique is typically used in conjunction with one of the other depressurization techniques. See Figure 10-4 for more details.

4. Drain Tile Depressurization can be utilized when a building has a loop of perforated drain tiles (piping) adjacent to the building footers for water drainage. If the drain tiles discharge to a sump pit, the sump pit is sealed and the negative pressure field is applied to the sump pit. If the drain tiles discharge to an outdoor location the negative pressure field is applied to the drain tile loop at an outdoor location. See Figure 10-5 for more details.

10.2 Remedial Action Implementation

10.2.1 Remedial Action System Requirements

Subsurface Depressurization System requirements in USEPA's Radon Mitigation Standards (USEPA 1994), http://www.epa.gov/radon/pubs/mitstds.html) detail system design, installation and evaluation guidance. As detailed in USEPA Radon Guidance, the subsurface depressurization system should be designed to prevent backdrafting of combustion products into a structure. Additionally, as a safety precaution, the depressurization system fan should be located outside of the building as the fan housing is the most likely location for a leak to occur in the system. NJDEP recommends subsurface depressurization systems contain the following:

- A pressure gauge (u-tube manometer) for determining operational efficiency;
- An alarm that informs building occupants in case the system malfunctions;
- Labeling that indicates the purpose of the system along with the name, address and telephone number of the entity to contact for questions, repairs, etc.

10.2.2 Qualifications

NJDEP recommends that a New Jersey Certified Radon Mitigation Business (http://www.nj.gov/dep/rpp/radon/certmit2.htm) or licensed Professional Engineer be consulted for the design, installation, monitoring and maintenance of vapor remediation systems. The proposed vapor remediation system shall be certified (by the aforementioned persons or firms) as being effective for addressing VI.

10.2.3 Permits

Permits (e.g., Air Pollution Control, Electrical, Plumbing) shall be obtained from the appropriate regulatory authority, as necessary, prior to installation of the remediation system.

An air permit is required from NJDEP for subsurface depressurization systems installed in certain buildings. One or two family dwellings and a dwelling of six or less family units, one of which is owner occupied, are exempt from obtaining an Air Pollution Control Permit and Certificate pursuant to N.J.S.A. 26:2C-9.2.d. An Air Pollution Control Permit and Certificate however is required at other locations (e.g., large apartment buildings, retail and industrial establishments) pursuant to N.J.A.C. 7:27-8.2(c)16. For further details, contact the appropriate regional NJDEP Air Enforcement Regional Office (http://www.nj.gov/dep/enforcement/air.html or 609-633-7994) to determine if your system requires an Air Pollution Control Permit and Certificate.

NJDEP Air Enforcement staff are located at four regional offices throughout the state of New Jersey as follows:

Metro Region
(973) 656-4444
Jurisdiction: Bergen, Essex, Hudson Counties

Northern Region
(973) 656-4480
Jurisdiction: Hunterdon, Morris, Passaic, Somerset, Sussex, Warren Counties

Central Region
(609) 584-4100
Jurisdiction: Mercer, Middlesex, Monmouth, Ocean, Union Counties

Southern Region
(856) 614-3601
Jurisdiction: Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Salem Counties

10.2.4 Pre-Construction Considerations

As previously stated, the NJDEP's primary goal is to remediate the source of the vapor contamination (ground water and/or subsurface soil) such that the risk of VI is eliminated. However, it is often not technically possible or feasible to complete such remediation in a timely manner. Therefore, if a property designated for development has a potential for vapor intrusion risk, the Department recommends that proactive measures (vapor barrier, vapor barrier with passive depressurization system, active depressurization system, etc.) be designed into the building. These proactive measures are relatively inexpensive, especially compared to the cost of retrofitting them after the building is constructed.

For planned building construction projects (e.g., Brownfield Redevelopment Sites), USEPA's Building Radon Out: A Step-by-Step Guide on how to build Radon-Resistant Homes (USEPA 2001d) provides technical guidance on preventative measures that should be considered prior to building construction. This document is available on the Internet at http://www.epa.gov/iaq/radon/images/buildradonout.pdf.

Additionally, New Jersey Department of Community Affairs (N.J.A.C. 5:23-10.1 et seq.) requires particular building specifications for new homes built in Tier 1 radon areas (http://www.nj.gov/dep/rpp/radon/radonin.htm). These requirements include constructing the building with a layer of gravel and a vapor barrier under the foundation, installing piping for a mitigation system, sealing all openings with a non-cracking polyurethane caulk and installing a roughout for an electrical junction box. Also, if the foundation walls are made of cinder block or other hollow masonry, the tops of the foundation walls should be capped or the voids of the blocks should be completely filled.

10.3 Remedial Action Operation, Monitoring and Maintenance

A Remedial Action Workplan (RAW) that addresses the items below shall be submitted to NJDEP in accordance with N.J.A.C. 7:26E.

10.3.1 Institutional and Engineering Controls

The investigator shall consult the Technical Requirements for Site Remediation (N.J.A.C. 7:26E-8) for detailed institutional and engineering control requirements, if appropriate.

Remedial actions (or interim remedial measures) that involve the installation of subsurface systems, vapor barriers, or other similar devices or engineering controls (including but not limited to those actions discussed in Section 10.1) do not require an institutional control, provided official notification of the property owner/occupant is provided (see Section 7.9). The responsible party, however, is accountable for the system verification sampling, monitoring and maintenance requirements noted in Section 10.3.2, below.

For undeveloped properties/parcels that contain source concentrations above the generic screening levels (GWSL or SGSL), official notification of the property owner is necessary. Institutional controls will be required upon request for closure by the responsible party.

The option to use the nonresidential screening levels (SGSL, IASL, or OSHA values where appropriate) is contingent upon the responsible party obtaining an agreement with the property owner and the implementation of an institutional control at the affected structure/property. The agreement should be submitted as part of the RAW. This provision is necessary to address future modifications in the land use (e.g., conversions to residential use).

Likewise, the option to use site-specific building parameters (e.g., ventilation rate changes, building size modifications, positive pressure controls) would necessitate an agreement with the property owner and the implementation of an institutional control at the affected structure/property. Utilization of the GWSL for Alternate Soil Textures does NOT require an institutional control.

Depending on the type of institutional control employed, the responsible party may have to monitor change in ownership and building conditions every six months and inform the NJDEP of these observations periodically through RA Progress Reports, biennial certification, or other appropriate mechanisms. This is critical in situations where nonresidential screening levels or site-specific building parameters are utilized.

10.3.2 Remedial Action System Verification Sampling, Monitoring and Maintenance

10.3.2.1 Verification Procedures

After the remedial system is operational, confirmation indoor air sampling should be conducted. Indoor air sampling should be conducted approximately two to four weeks after the remedial system is operational to verify the effectiveness of the system. Indoor air sampling events that do not occur during the winter or early spring (November through March) should necessitate a second round of indoor air sampling during this timeframe. However, the Department will accept a single round of sampling (irrespective of the seasonal timing of the sample event) in those cases where the results are an order of magnitude below the appropriate screening level.

If the indoor sampling data for the contaminants of concern are above the NJDEP’s IASL (with consideration of background sources), modifications or supplementation to the existing remedial action system will be required. Additional indoor air sampling will be necessary to verify the effectiveness of the remedial system if it has been modified. Once indoor air data collected during the winter or early spring are below the NJDEP’s IASL (or site-specific background concentrations), additional indoor air sampling may not be necessary until system termination sampling takes place.

If subsurface depressurization systems are the chosen remedial system, in addition to indoor air sampling, it should be demonstrated, immediately after system startup, that a negative pressure field exists beneath the building, or appropriate portion of the building, of concern. This information should be collected by an entity with the qualifications detailed in section 10.2.2 and submitted with the verification indoor air sampling results. These diagnostic provisions should be incorporated into the original design of the subsurface depressurization system to avoid modifications to the remedial system after installation. Additional information on diagnostic testing can be found in the State of Massachusetts Guidelines for the Design, Installation, and Operation of Sub-Slab Depressurization Systems (MassDEP 1995).

10.3.2.2 Monitoring and Maintenance

A monitoring and maintenance plan shall be submitted for NJDEP review and approval. For subsurface depressurization systems, the pressure gauge (typically a U-tube manometer) should be monitored quarterly to determine if the system is operating efficiently. A reduced monitoring frequency may be appropriate after one year of successful operation of the remedial system. If the pressure gauge indicates the system is not operating efficiently the system should be diagnosed and repaired. The pressure gauge measurements should be recorded over time in tabular format and updated with each submittal to NJDEP.

Figure 10-1
Photo of a U-tube

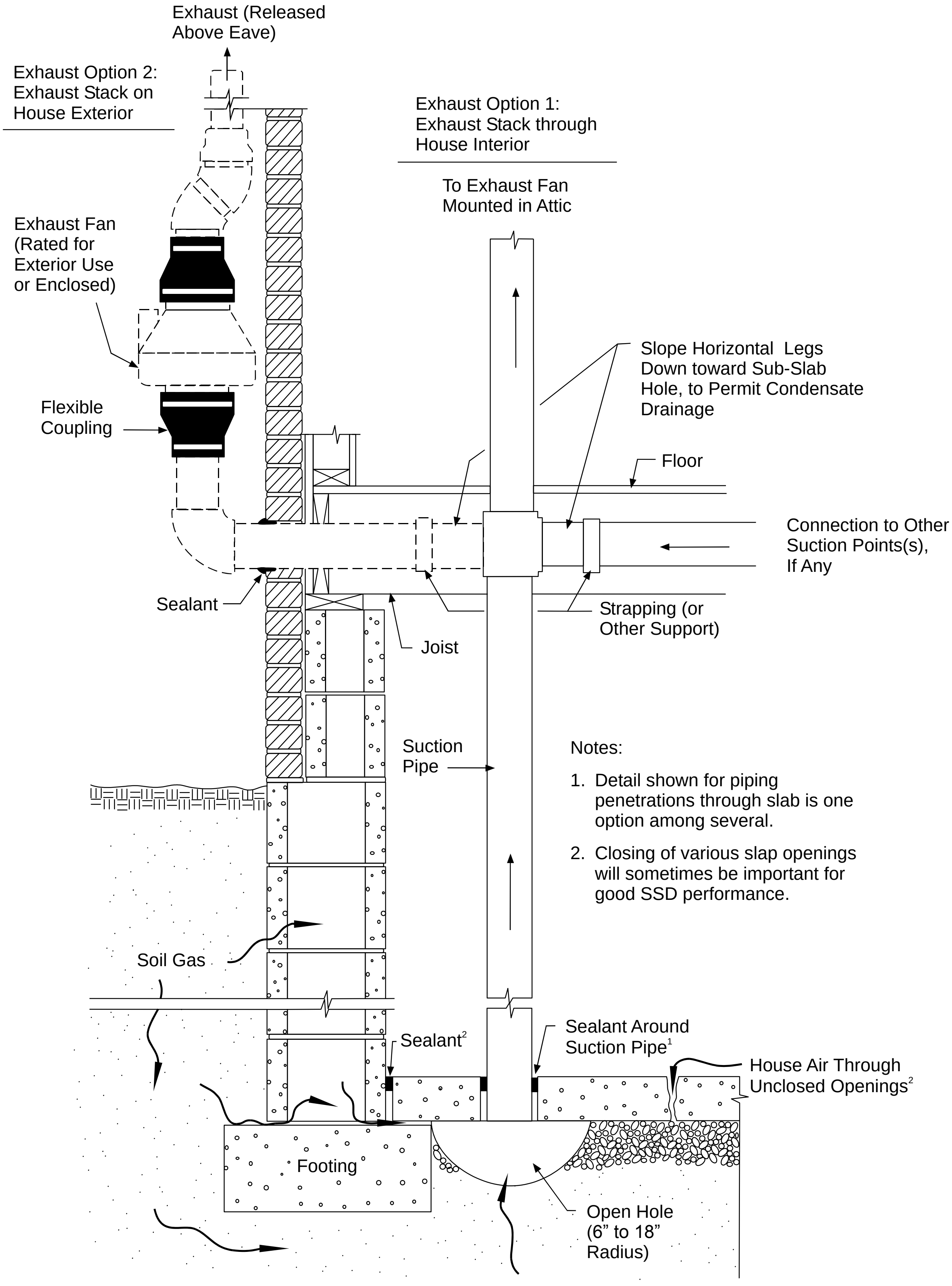
An inspection should be conducted semiannually to determine if any new or existing areas (e.g., cracks, holes, sump pit covers, earthen crawlspaces) need to be sealed, caulked, and/or covered, etc. If repairs are necessary they should be conducted and documented in the next submission to NJDEP. A reduced inspection frequency may be appropriate after one year of efficient operation of the remedial system.

10.3.2.3 Remedial Action Progress Report Submission

Remedial Action Progress Reports shall be submitted in accordance with The Technical Requirements for Site Remediation (N.J.A.C. 7:26E).

10.3.2.4 System Termination Sampling

Once the investigator concludes that the VI source (ground water, soil gas, etc.) has been properly remediated to the point where the VI pathway is not complete, a proposal may be submitted to NJDEP to cease operation of the VI remedial system. Upon approval from NJDEP, system termination sampling of indoor air and sub-slab soil gas should be collected. The system termination sampling should occur during the winter and early spring (November through March). Sampling should be conducted as outlined in Section 6.4 (Sub-Slab Soil Gas Sampling Procedures) and Section 6.6 (Indoor Air Sampling Procedures). The system termination indoor air and sub-slab analytical results should be submitted in a Remedial Action Progress Report for NJDEP review. Note subsequent sampling rounds may be required on a case by case basis to verify the appropriateness of system termination. Analytical parameters for the system termination samples should include the contaminants of concern analyzed after the initial startup of the remedial system. However, additional analytical parameters may be required on a case by case basis.



Notes:

1. Detail shown for piping penetrations through slab is one option among several.
2. Closing of various slap openings will sometimes be important for good SSD performance.

Figure 10-2: Example of a Sub-Slab Depressurization System

Notes:

1. The specific configuration depicted for the pipe penetration through the membrane is one of a number of alternatives.

2. The membrane seams must always be sealed near the suction point. Sealing of more remote seams may not always be necessary, but is advisable.

3. The membrane can often be effectively sealed against the foundation wall using a continuous bead of properly selected sealant (urethane caulk for cross-laminated polyethylenes, other adhesive for regular polyethylenes).

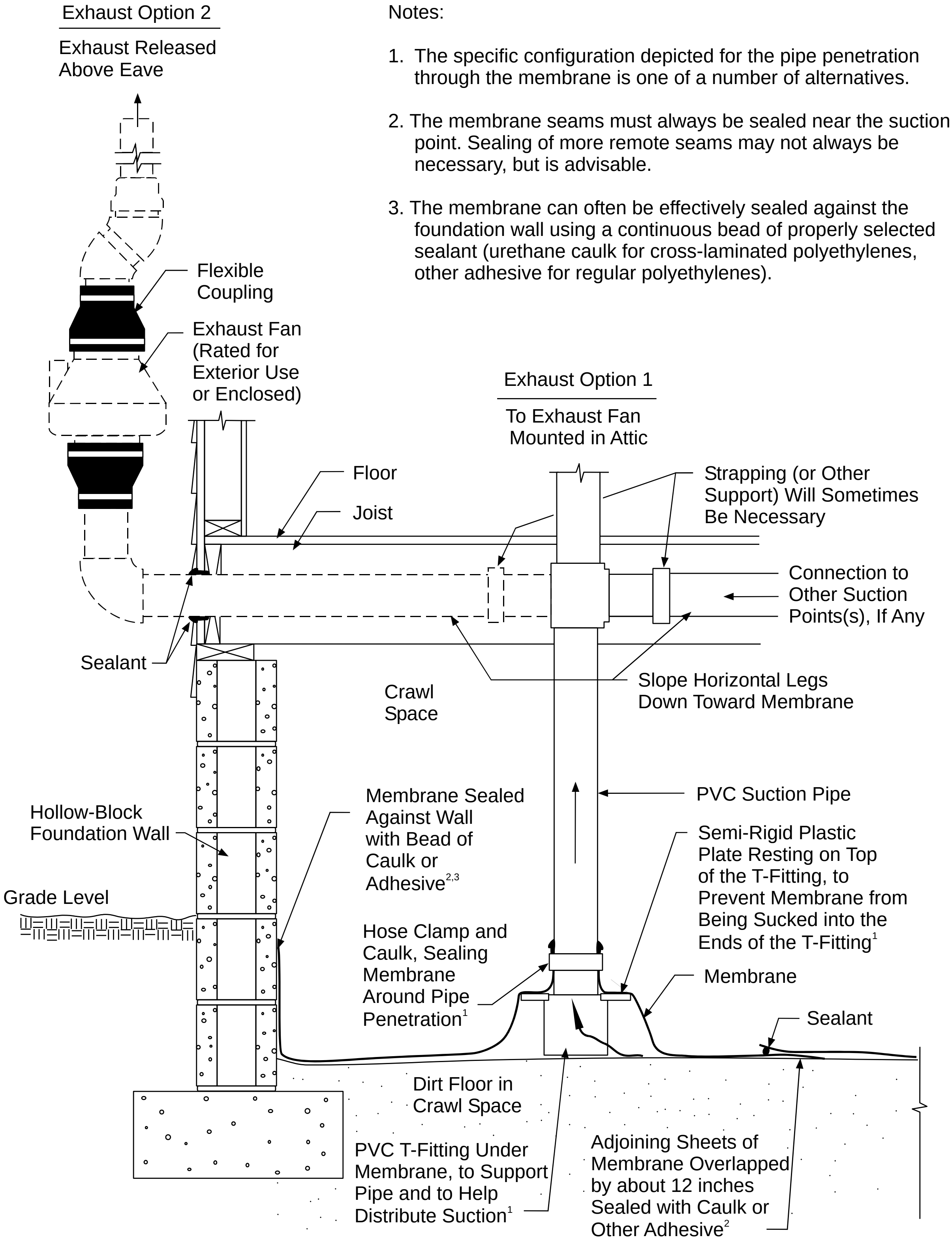
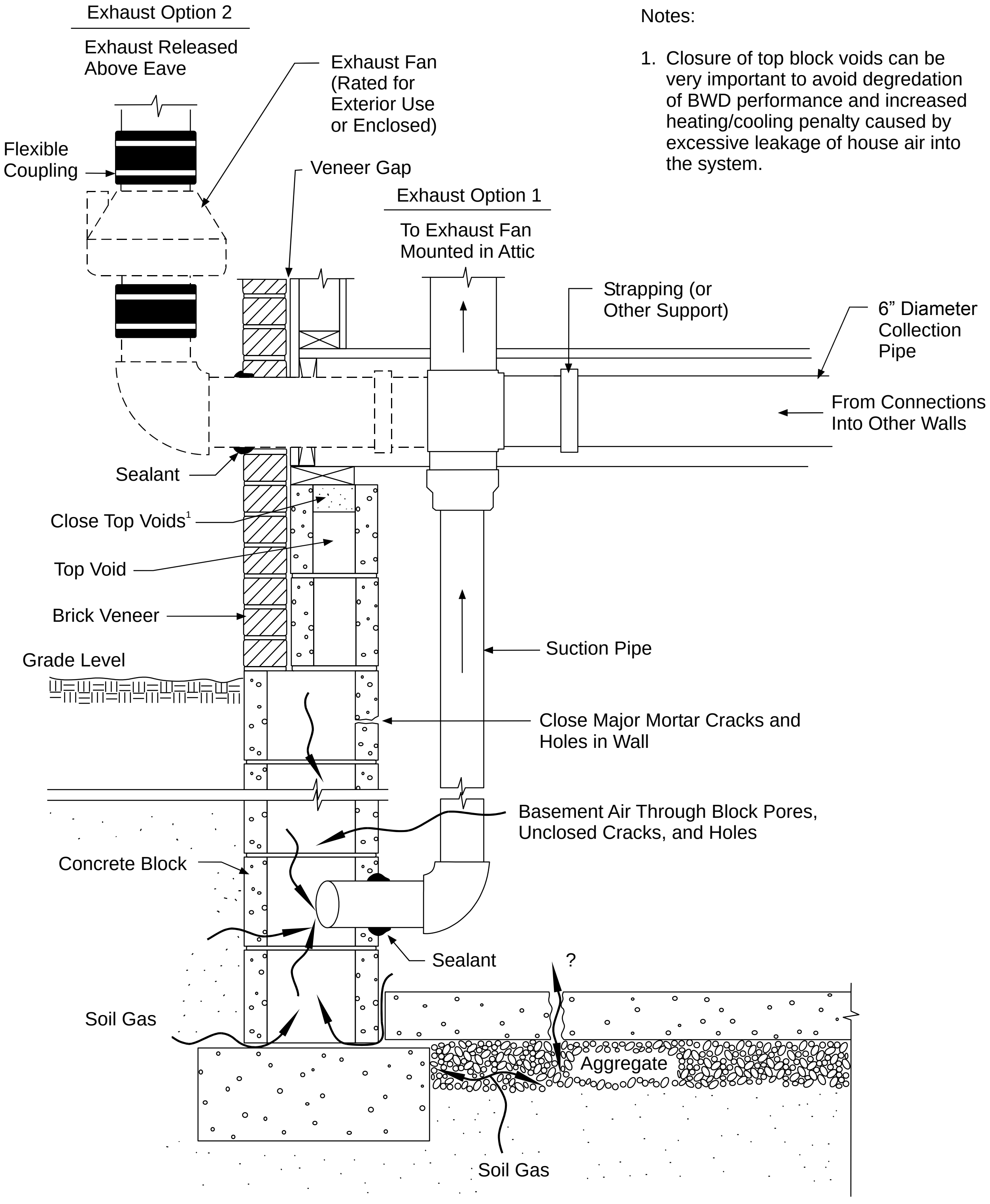


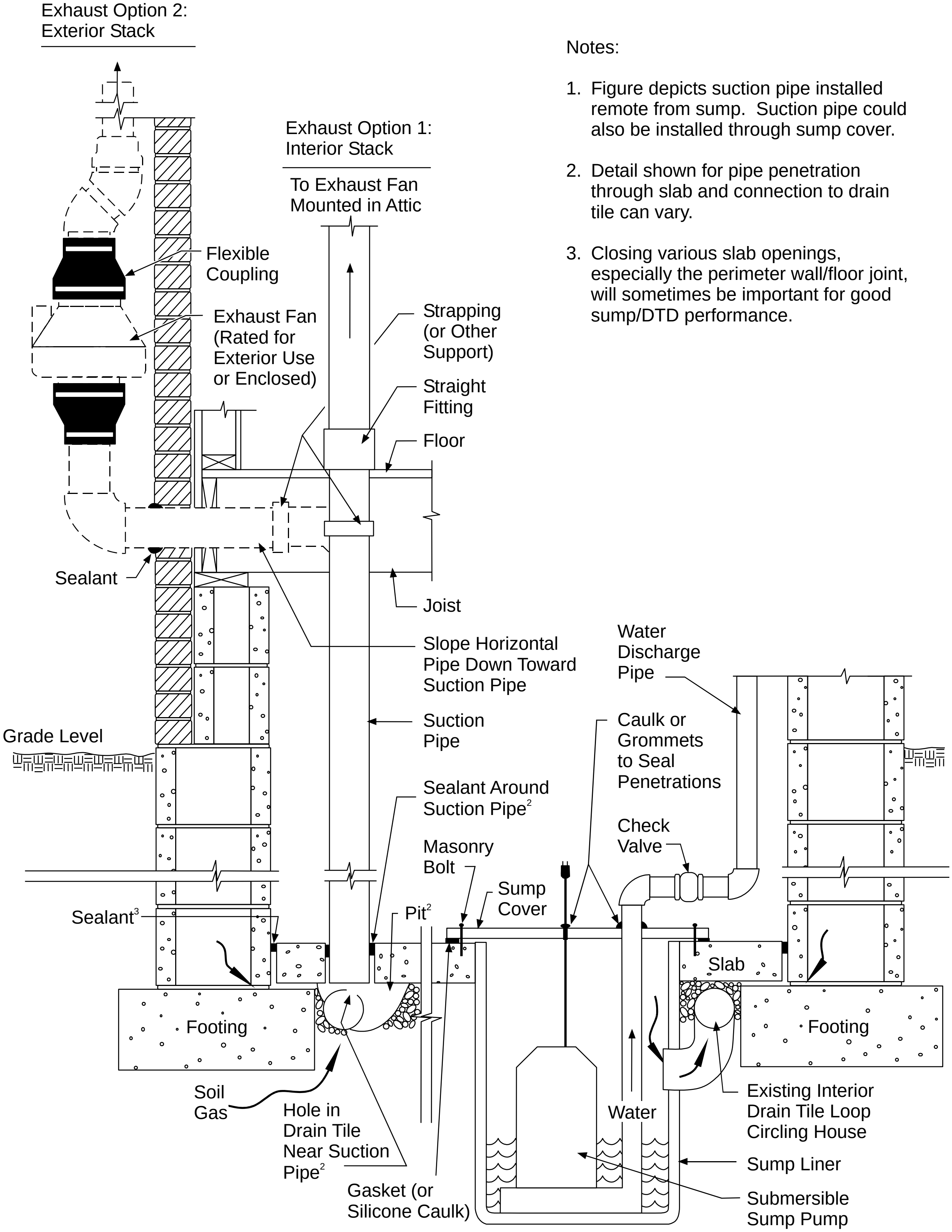
Figure 10-3: Example of a Sub-Membrane Depressurization System



Notes:

1. Closure of top block voids can be very important to avoid degredation of BWD performance and increased heating/cooling penalty caused by excessive leakage of house air into the system.

Figure 10-4: Example of a Block-Wall Depressurization System



Notes:

1. Figure depicts suction pipe installed remote from sump. Suction pipe could also be installed through sump cover.
2. Detail shown for pipe penetration through slab and connection to drain tile can vary.
3. Closing various slab openings, especially the perimeter wall/floor joint, will sometimes be important for good sump/DTD performance.

Figure 10-5: Example of Drain-Tile Depressurization System

11.0 COMMUNITY OUTREACH FOR VAPOR INTRUSION SITES

11.1 About the Office of Community Relations

NJDEP's Office of Community Relations (OCR) is responsible for facilitating open dialogue with communities about site investigations and cleanups in their neighborhoods. OCR has developed the following recommendations for NJDEP staff, responsible parties and environmental investigators to consider when conducting community outreach for VI sites. While each site will be different and therefore have unique community outreach needs, this guidance addresses general issues and concerns encountered at most VI sites.

NJDEP encourages responsible parties and their consultants to contact OCR before initiating a community outreach program so the appropriate roles of all parties can be determined. For contact information, please refer to the OCR web page at www.nj.gov/dep/srp/community.

11.2 Why Do Community Outreach?

Early, two way communication with residents, business owners and local officials affected by a contaminated property can be critical to a successful investigation and cleanup. When citizens are well informed about the issues surrounding a site, their questions and concerns can be more easily addressed. This builds trust and credibility and allows the remedial process to proceed most efficiently.

An effective outreach strategy that anticipates the needs and concerns of the community will be particularly important to a VI investigation. In most cases, the parties conducting the investigation will need to arrange sampling testing appointments with residents/property owners, collect indoor air and soil gas samples, and report the findings. At some properties sub-surface depressurization systems may be required. Public meetings may be necessary to ensure the general public is properly informed about the investigation and remedial actions. Those involved in a VI investigation will want to develop their community outreach strategy before the actual work begins to ensure the most successful outcome.

11.3 Communicating with the Public about Vapor Intrusion

When initiating a VI investigation, there are at least two key groups that need to be notified: the local officials and the general public. The media may emerge as a third group if the site becomes high profile. Below are some tips on how and when to communicate with these parties for maximum effectiveness.

11.3.1 Local Officials

Before beginning a VI investigation, notify the municipal officials (e.g., municipal clerk, township administrator, mayor) and the local health officer that indoor air and/or soil gas sampling is going to be conducted in their area and why it is being done. As the elected or appointed leaders of the community, the media or residents will likely contact them for information. (If site activities include going door to door to collect information from residents or any other type of canvassing, the local police department should also be notified.)

Establish a working relationship with the local officials early in the process so they can be involved as needed later on. Provide local officials with copies of the *Evaluating Indoor Air near VOC Contaminated Sites* and *Subsurface Depressurization Systems* fact sheets and inform them of the availability of this guidance document on NJDEP's web site, http://www.nj.gov/dep/srp/guidance/vaporintrusion/. Let them know that you may be copying them on correspondence to residents regarding the VI investigation.

11.3.2 General Public

When communicating with the general public about the investigation, remember that the nature of VI, how it is evaluated, sources of background contamination, possible health effects and potential remedies will likely be unfamiliar concepts. Expect to expend significant effort educating residents/property owners and local officials about these topics **before** conducting an indoor air investigation. If there is a large population of sensitive individuals (e.g., small children in school or daycare) in the area being investigated, or if there has already been significant media attention focused on the site, it may be helpful to hold a public meeting before the VI investigation work begins. Section 11.8 has information on holding public meetings.

When discussing VI, be sure to define technical jargon and explain complex concepts in a manner that can be easily understood. Provide supplemental literature, such as fact sheets, or identify a web site they can go to for more information about the site. Ask for feedback to ensure the public understands the information. In addition, find out how they would like to be notified about developments in the future.

Since people living in indoor air contamination areas are directly affected by the site, the investigator should be prepared to engage in frequent contact with the residents/property owners (phone calls, letters, meetings, etc.).

Finally, some residents may feel that owning a home affected by VI carries a stigma. Acknowledge these concerns and explain the level of confidentiality they can expect regarding their indoor air results and any remedial actions that may be taken at their homes.

11.3.3 Media

A site does not have to be particularly large or complex to garner attention from local newspapers, television stations, or other media outlets. In cases where the media have focused on the VI investigation, it is always advisable to make background material available (as long as the confidentiality of individual test results is maintained). If a site is or may become controversial, it may be a good idea to take the initiative to release information about the VI investigation rather than wait for a news story to break.

11.4 Arranging Sample Appointments

The Department recommends a two step approach when initially contacting residents/property owners to obtain permission to conduct an VI investigation at their buildings. First, send an introductory letter to the residents/property owners to inform them of the proposed VI investigation at their buildings. Follow up with phone calls to the residents to arrange sampling appointments.

11.4.1 Letters

Send the introductory letters several weeks ahead of the sampling event. For rental properties, send the letters to both the property owners and tenants. Write the letters in non-technical terms and include the following information:

- an explanation for the reason for the sampling
- the name of the contaminant(s) of concern
- the anticipated sampling date (or approximate timeframe)
- who will be doing the sampling
- what the sampling will involve
- the phone numbers of NJDEP case manager, Community Relations coordinator and/or other contacts.

Also include the following attachments, which are available from this guidance document and on NJDEP web page [http://www.nj.gov/dep/srp/guidance/vaporintrusion/]:

- *Evaluating Indoor Air near VOC Contaminated Sites* (Appendix D)
- *Instructions for Occupants – Indoor Air Sampling Events* (Appendix C [English] and C1 [Spanish])
- *Indoor Air Building Survey and Sampling Form* (Appendix B)

It may also be helpful to enclose specific information about the contaminant(s) of concern, such as ToxFAQ^{TM} fact sheet(s) about the chemical(s) from the Agency for Toxic Substance and Disease Registry (ASTDR) web page [http://www.atsdr.cdc.gov/atsdrhome.html].

Finally, if plans include collecting sub-slab or near slab soil gas samples, attach an access agreement for the recipient to sign and return. For rental properties, the access agreement need only be attached to the letter to the property owner.

Note: It is important to keep municipal officials apprised of your activities at this stage. Provide them with a sample introductory letter and a list of the names and addresses of the residents/property owners that have been contacted to request an indoor air investigation.

11.4.2 Phone Calls

Call the occupants of the buildings to arrange the sampling appointments at least two weeks prior to the scheduled sampling event. Ask local contacts to help get in touch with occupants that are not available or responsive. When calling to arrange the appointments, be prepared to discuss the following:

- the contaminant(s) of concern, including the NJDEP Indoor Air Screening Level(s)
- general health issues - direct specific health questions to the local health department
- how the sample(s) will be collected and analyzed
- when the analytical results will be available and possible remedial actions
- how to prepare for the sampling and what to avoid when sampling is being conducted, as outlined in *Instructions for Occupants – Indoor Air Sampling Events*

In addition, review the *Indoor Air Building Survey and Sampling Form* with the occupant. Inform the occupant that someone knowledgeable about the property should be available on the day of sampling to help the sampling team to fill out the form. If that is not possible, try to fill out the form over the phone with the occupant.

When arranging follow up indoor testing appointments (such as confirmation sampling or sampling to check the effectiveness of a remedial action), it is only necessary to contact the residents/property owners by telephone. As a courtesy, try to give residents/property owners at least two weeks notice of the planned sampling. When scheduling follow up appointments, always review the recommendations outlined in *Instructions for Occupants – Indoor Air Sampling Events* with the residents/property owners to remind them about how to prepare for the sampling and what to avoid while the sampling is being conducted.

11.5 Collecting Samples

When entering homes and other private buildings to conduct air sampling, NJDEP recommends sending a team of two people. Each sampling team member should bring identification for verification by the residents should it be requested. If a Community Relations coordinator is assigned to the site, that person should be present on the first day to meet the occupants of the buildings, help fill out the building survey and answer questions. If a Community Relations coordinator is not assigned to the site, the sampling team should be prepared to provide the occupants with the name and telephone number of a contact person to whom they can direct questions.

Note: In light of recent concerns about homeland security, it is highly recommended that precautions be taken whenever the VI investigation includes outside air sampling. The sampling equipment (stainless steel canisters) and related devices are not familiar to most people and may be misinterpreted as a safety concern. Therefore, the local police and fire departments should be notified of the sampling event in addition to the municipal officials. It may be useful to demonstrate the operation of the sampling equipment to these officials. A label should be affixed to the sampling device explaining the nature of the equipment and contact information in case there are further questions.

11.6 Reporting Sample Results

Although investigators may elect to forward results (or be bound to do so by an access agreement), NJDEP is responsible for officially notifying property owners/occupants about their sampling results when there is an oversight document. The written reports from NJDEP will consist of a cover letter explaining the findings and a table summarizing the analytical results.

In addition to written results, the NJDEP may first call the residents/property owners to report results under the following scenarios:

- The analytical results indicate that VI is causing one or more contaminants of concern to exceed the NJDEP RAL. This will give the occupant/property owner the opportunity to discuss the results as soon as they become aware of them.
- Very high levels of background contaminants are found in the indoor air. This may allow the resident/property owner to take immediate measures to reduce their exposure to these contaminants by addressing the source. Occupants/property owners should be referred to their local health department if they have specific health questions about non-site related contaminants.
- A significant period of time has elapsed (more than eight weeks) since the testing was conducted. Residents who are anxious about their results will appreciate receiving them verbally if it speeds the process.

11.6.1 Verbal Reports

When reporting indoor air results verbally, NJDEP will provide the results directly to the property owner and/or resident, since leaving the information on an answering machine or with another person can lead to a misunderstanding of the findings and/or breach confidentiality.

Once residents/property owners know their indoor air testing results, NJDEP will explain the next action, if any, and when they can expect to receive written copies of their results. NJDEP will also provide the name and phone number of a contact person in case the resident/property owner has follow up questions.

11.6.2 Written Reports

The written reports from NJDEP will consist of a cover letter explaining the findings and a table summarizing the analytical results. The purpose of the cover letter is to put the results in a context that the resident/property owner can easily understand. In the case of rental properties, the findings should be reported in writing to both the tenant and the property owner. The local health officer will be copied on all letters to residents.

<u>Note</u>: If the sampling reveals that vapor intrusion may be occurring at the property, the letter should include language informing the owner of the Property Condition Disclosure requirements as per N.J.A.C. 13:45A-29.1.

The cover letter should be written in non-technical terms and include the information listed below.

- The date the sampling was conducted
- Who conducted the sampling (e.g., name of government agency or private contractor)
- The site for which the sampling was conducted (if applicable)
- The sample location/address, including the block and lot
- An explanation of the findings with the contaminant(s) of concern highlighted
- The next action, if any, for the property (e.g., another round of sampling or a remedial action)
- A brief discussion of the indoor air contaminants detected that are not related to the site. (Refer the resident/property owner to their local health department if they have questions about non-site related indoor air contaminants.)
- Name and telephone number of a NJDEP contact person and a representative from the local health department.

Also attach copies of the *Common Household Sources of Background Indoor Air Contamination* (Appendix H) and the *Subsurface Depressurization Systems* fact sheet (Appendix E), if applicable.

The analytical results summary table should be in a format that is easy to understand. Enclosing the summary tables from the laboratory analytical data package is *not* recommended, as these are often very technical. The table should include all of the compounds that were analyzed for, the IASL for each compound and the concentration of each compound that was detected during the indoor air sampling (both reported in $\mu g/m^3$).

11.7 Community Outreach during Remedial Actions

Most of the community outreach conducted during the Remedial Action phase will entail acting as a point of contact between the occupant/property owner and the contractor or state regulators. This can include scheduling the installation of the remedial system, relaying the property owner's concerns to the appropriate individuals, and ensuring that every effort is made to resolve issues or concerns related to the remedial action.

As stated earlier, some people may feel that owning a home with vapor intrusion carries a stigma. Before beginning the remedial work, make sure the occupant/property owner is comfortable with the final design. In all cases, the finished remedial system should be as inconspicuous as possible.

Finally, as part of the community outreach for a VI investigation/remedial action, measures should be taken to ensure that the property owner understands that it is his responsibility to inform current and future occupants of the building about the vapor intrusion issues at the property.

11.8 Meeting with the Public

When VI sites generate significant community interest, public meetings can be useful forums for disseminating information and answering questions (see options below). These are held in coordination with NJDEP at a municipal building, school or other public building in the area near the site.

Consult with local officials to determine the best day and time and give the public several weeks notice of the meeting date. Weekday evenings are usually the most convenient times for such meetings. After a date and time has been selected, ask the local council to announce the upcoming meeting at their meetings. Mail notices of the meeting to residences abutting and near the site. It is also advisable to publish a notice of the meeting in the local newspaper.

There are three possible formats for the public meeting. The first is in conjunction with a local council meeting. Engage local assistance on how to notify the public of the presentation, how long it should be, how questions will be asked, and other issues pertaining to the presentation.

The second type of meeting is a formal presentation with a question and answer period. The investigating party makes all of the arrangements for this type of meeting after getting input from local officials. The investigating party establishes the format of the meeting and runs the meeting.

The third more informal format is a public availability session or “open house.” As with the more formal presentation, the investigating party arranges the meeting after conferring with the local officials. This type of meeting is largely unstructured, allowing the public to speak one to one with the professionals involved in the investigation in a relatively private setting. A short presentation may be included if desired.

The panelists for the public meeting should include geologists, public health officials, toxicologists, case team members and others knowledgeable about the site and its potential health effects. When presenting data about the site to the public, remember confidentiality may be an issue for some residents/property owners. For this reason, maps or other documents identifying specific homes with indoor air contamination may not be suitable presentation materials.

During the meeting, note concerns and issues raised by the public and local officials that cannot be answered or addressed immediately. Provide responses to these concerns and issues as quickly as possible once the public meeting or public availability session is over. In the weeks and months following the meeting, continue to periodically update the residents and local officials on the VI investigation and any remedial actions through fact sheets, letters and telephone calls.

11.9 Additional Information

Both NJDEP and USEPA offer guidance on risk communication. The NJDEP report Establishing Dialogue AND Planning Success: A Guide to Effective Communication Planning is available at www.state.nj.us/dep/dsr/pub.htm. For USEPA's guidance, see [www.epa.gov/superfund/tools/pdfs/37riskcom.pdf]. NJDEP strongly recommends that parties investigating VI sites familiarize themselves with the concepts in these documents, particularly USEPA's The Seven Cardinal Rules of Risk Communication, when preparing their community outreach activities for VI sites.

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TABLES

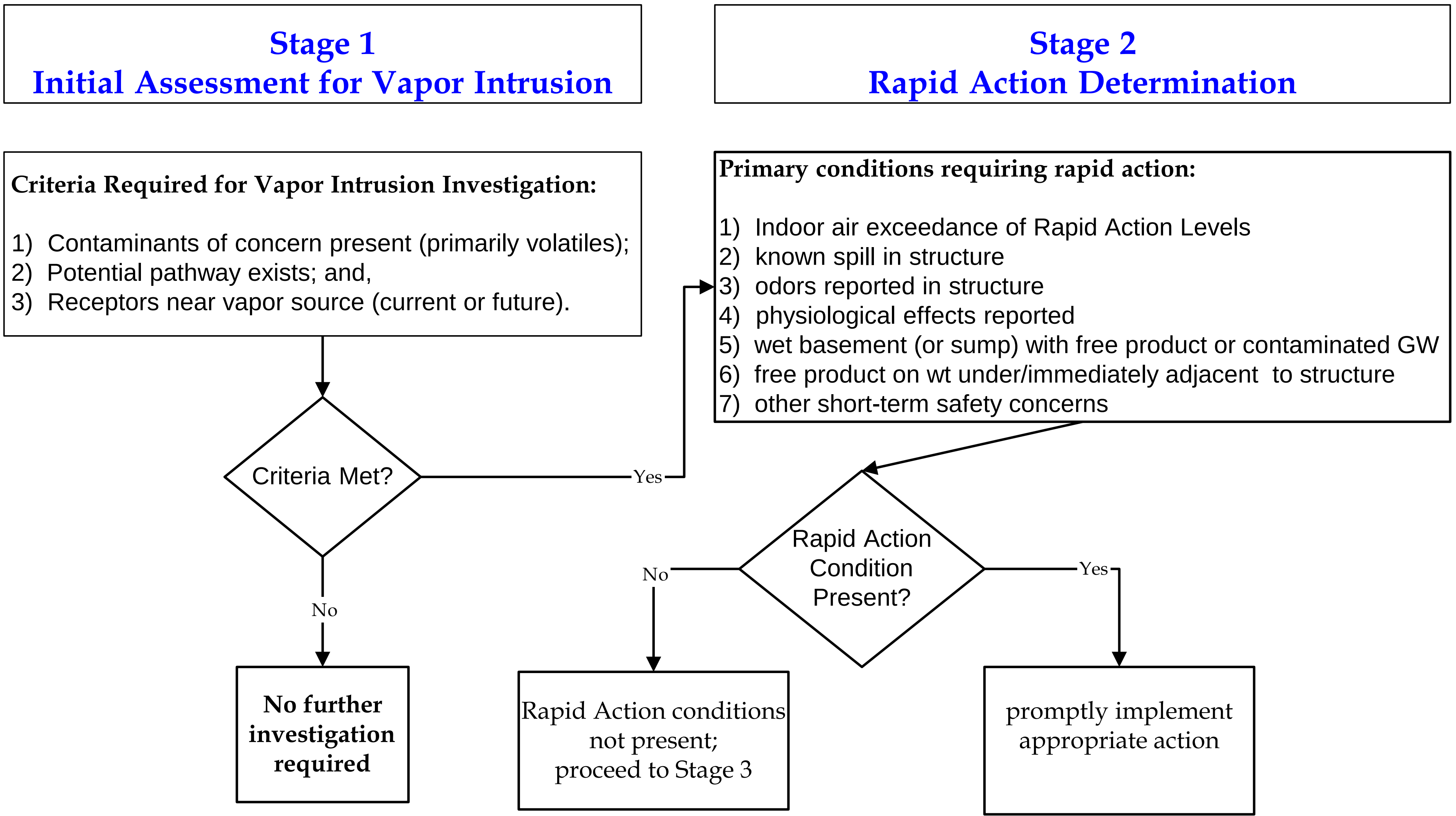
APPENDIX A

Decision Flow Chart

(Refer to Chapter 3 for additional guidance)

Decision Flow Chart for Vapor Intrusion Pathway

Preliminary Assessment and Site Investigation (PA / SI)



Stage 1
Initial Assessment for Vapor Intrusion

Stage 2
Rapid Action Determination

Criteria Required for Vapor Intrusion Investigation:

1) Contaminants of concern present (primarily volatiles);
2) Potential pathway exists; and,
3) Receptors near vapor source (current or future).

Criteria Met?

Yes

No

No further investigation required

Primary conditions requiring rapid action:

1) Indoor air exceedance of Rapid Action Levels
2) known spill in structure
3) odors reported in structure
4) physiological effects reported
5) wet basement (or sump) with free product or contaminated GW
6) free product on wt under/immediately adjacent to structure
7) other short-term safety concerns

Rapid Action Condition Present?

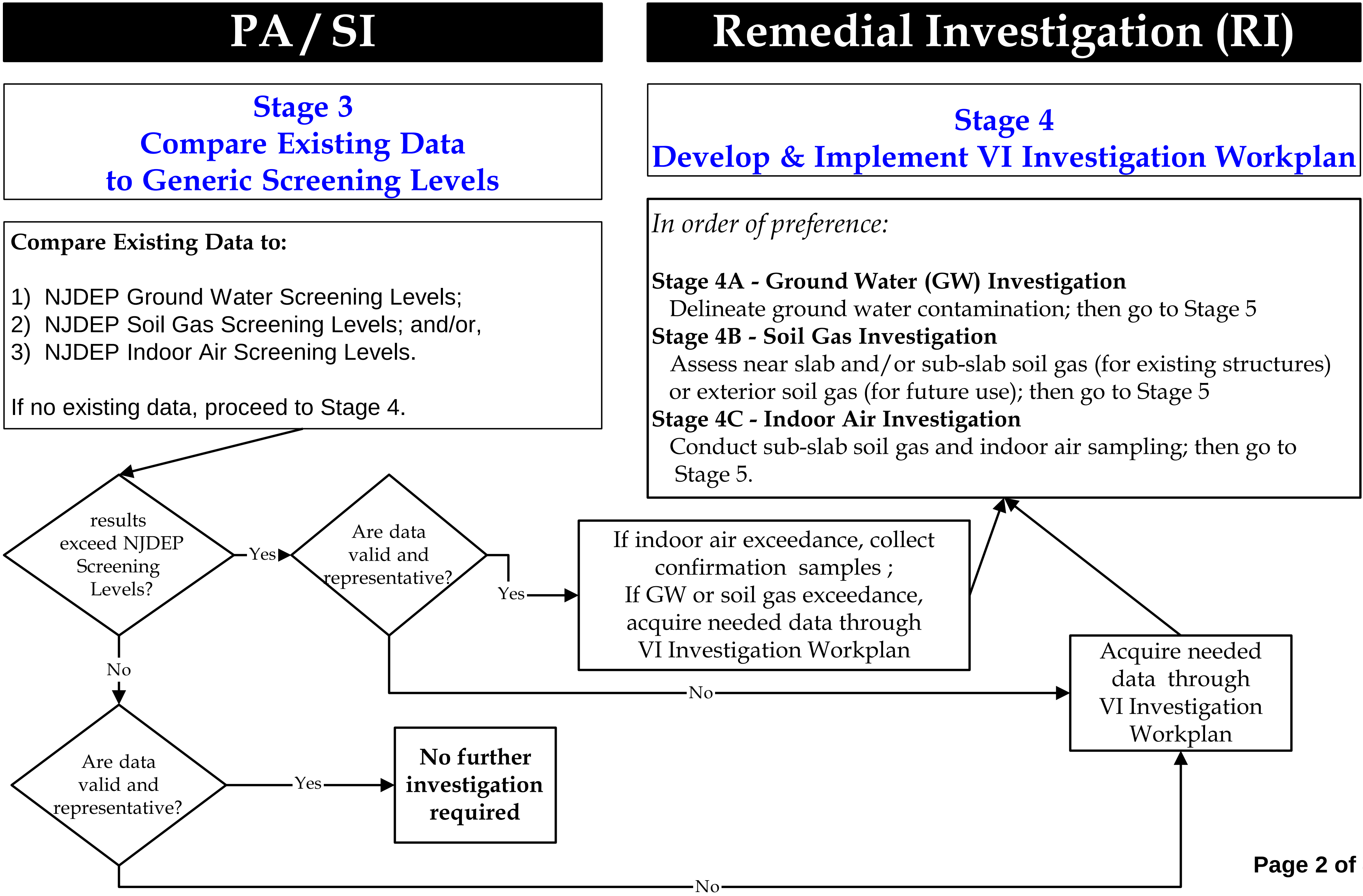
No

Yes

Rapid Action conditions not present; proceed to Stage 3

promptly implement appropriate action

Decision Flow Chart for Vapor Intrusion Pathway



PA / SI

Remedial Investigation (RI)

Stage 3
Compare Existing Data to Generic Screening Levels

Compare Existing Data to:

1) NJDEP Ground Water Screening Levels;
2) NJDEP Soil Gas Screening Levels; and/or,
3) NJDEP Indoor Air Screening Levels.

If no existing data, proceed to Stage 4.

Stage 4
Develop & Implement VI Investigation Workplan

In order of preference:

Stage 4A - Ground Water (GW) Investigation
Delineate ground water contamination; then go to Stage 5

Stage 4B - Soil Gas Investigation
Assess near slab and/or sub-slab soil gas (for existing structures) or exterior soil gas (for future use); then go to Stage 5

Stage 4C - Indoor Air Investigation
Conduct sub-slab soil gas and indoor air sampling; then go to Stage 5.

If indoor air exceedance, collect confirmation samples ;
If GW or soil gas exceedance, acquire needed data through VI Investigation Workplan

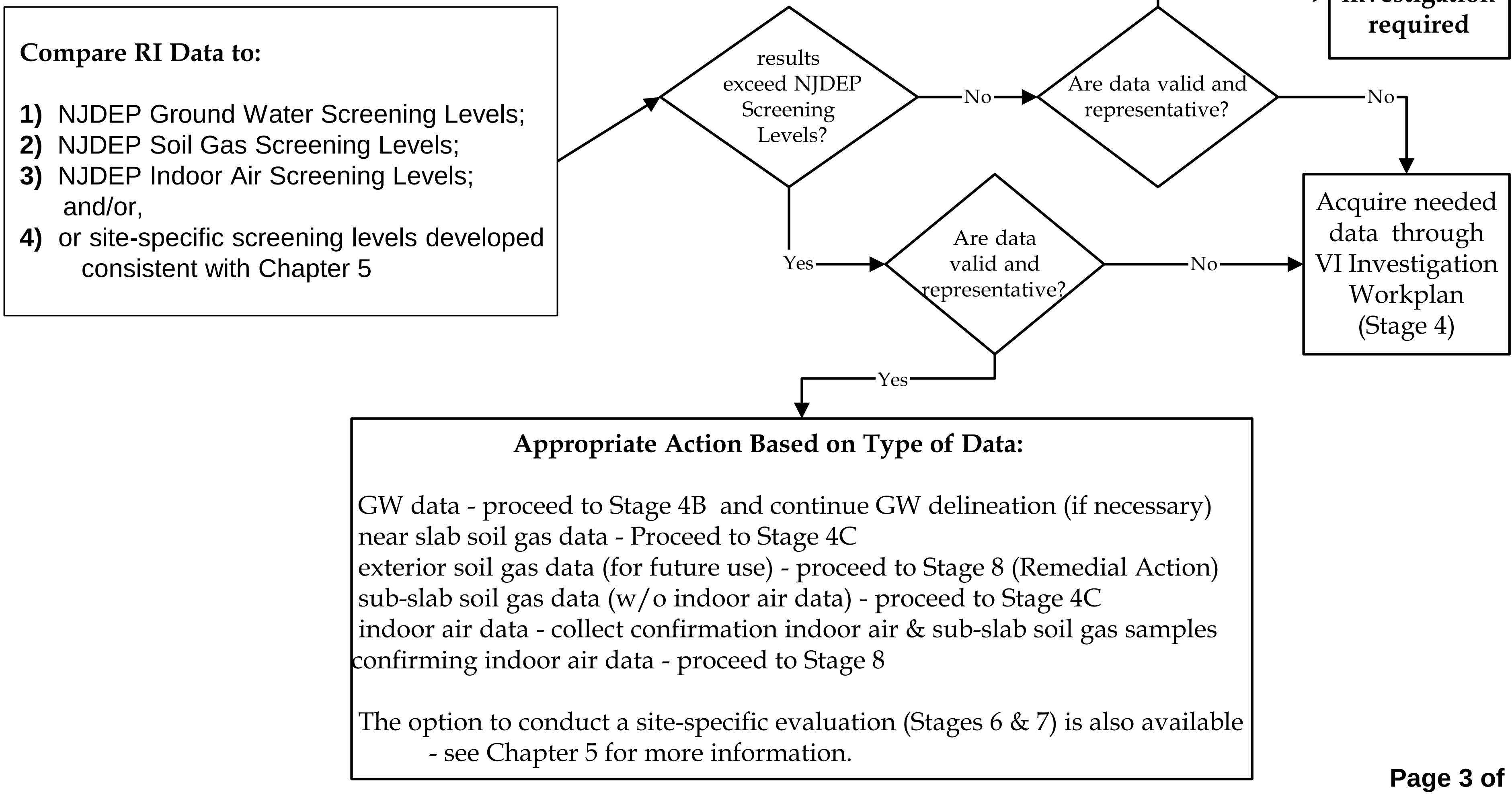
Acquire needed data through VI Investigation Workplan

No further investigation required

Decision Flow Chart for Vapor Intrusion Pathway

Remedial Investigation (RI)

Stage 5
Evaluate RI Data using NJDEP Generic Screening Levels



Compare RI Data to:

1) NJDEP Ground Water Screening Levels;
2) NJDEP Soil Gas Screening Levels;
3) NJDEP Indoor Air Screening Levels; and/or,
4) or site-specific screening levels developed consistent with Chapter 5

No further investigation required

Acquire needed data through VI Investigation Workplan (Stage 4)

Appropriate Action Based on Type of Data:

GW data - proceed to Stage 4B and continue GW delineation (if necessary)
near slab soil gas data - Proceed to Stage 4C
exterior soil gas data (for future use) - proceed to Stage 8 (Remedial Action)
sub-slab soil gas data (w/o indoor air data) - proceed to Stage 4C
indoor air data - collect confirmation indoor air & sub-slab soil gas samples
confirming indoor air data - proceed to Stage 8

The option to conduct a site-specific evaluation (Stages 6 & 7) is also available - see Chapter 5 for more information.

Decision Flow Chart for Vapor Intrusion Pathway

Remediation Decision Matrix - Stage 8

		Indoor Air Concentrations (for COCs)	
		< IASL	**>IASL**
Sub-Slab Soil Gas Concentrations (for COCs)	**<SGSL**	**No Action**	**No Action *** (if no other subsurface source)
	>SGSL to 10X SGSL	**No Action or Monitor**	**Investigate further or Mitigate**
	>10X SGSL	**Monitor or Mitigate**	**Mitigate**

Notes:

* Investigator should consider the potential for vadose zone (soil) contamination and/or preferential pathways as part of the assessment of vapor intrusion before concluding "no further action"

Red Decision Points - investigators should use professional judgement when determining which action is appropriate. Factors to consider include the relative exceedance of the screening level, the ratio of the sub-slab soil gas and indoor air results, building construction, and possible affects of background sources of contamination and sampling errors. (Refer to Chapter 7, *Evaluation of Analytical Results* , for more guidance and information.)

APPENDIX B

Indoor Air Building Survey and Sampling Form

New Jersey Department of Environmental Protection

INDOOR AIR BUILDING SURVEY
and SAMPLING FORM

Preparer's name: ___________________________________ Date: __________________________

Preparer's affiliation: ________________________________ Phone #: _______________________

Site Name: ____ Case #: ________________________

Part I - Occupants

Building Address: ____

Property Contact: ________________________ Owner / Renter / other: _______________________

Contact's Phone: home ( )__________ work ( )______________ cell ( )____________

# of Building occupants: Children under age 13 _____ Children age 13-18 ______ Adults _____

Part II – Building Characteristics

Building type: residential / multi-family residential / office / strip mall / commercial / industrial

Describe building: ____ Year constructed: _________

Sensitive population: day care / nursing home / hospital / school / other (specify): _______________

Number of floors below grade: ______ (full basement / crawl space / slab on grade)

Number of floors at or above grade: ______

Depth of basement below grade surface: ______ ft. Basement size: _______ ft^2

Basement floor construction: concrete / dirt / floating / stone / other (specify): ________________

Foundation walls: poured concrete / cinder blocks / stone / other (specify) ________________

Basement sump present? *Yes / No* Sump pump? *Yes / No* Water in sump? *Yes / No*

Type of heating system (circle all that apply):

- hot air circulation
- heat pump
- hot air radiation
- hot water radiation
- wood
- kerosene heater
- steam radiation
- electric baseboard
- other (specify): ________________________

Type of ventilation system (circle all that apply):

- central air conditioning
- individual air conditioning units
- mechanical fans
- kitchen range hood fan
- bathroom ventilation fans
- outside air intake
- other (specify): ___________________

Type of fuel utilized (circle all that apply):

Natural gas / electric / fuel oil / wood / coal / solar / kerosene

Are the basement walls or floor sealed with waterproof paint or epoxy coatings? *Yes / No*

Is there a whole house fan? *Yes / No*

Septic system? *Yes / Yes (but not used) / No*

Irrigation/private well? *Yes / Yes (but not used) / No*

Type of ground cover outside of building: grass / concrete / asphalt / other (specify) _____________

Existing subsurface depressurization (radon) system in place? *Yes / No* *active / passive*

Sub-slab vapor/moisture barrier in place? *Yes / No*
Type of barrier: ____________________________

Part III - Outside Contaminant Sources

NJDEP contaminated site (1000-ft. radius): ____

Other stationary sources nearby (gas stations, emission stacks, etc.): _____________________________

Heavy vehicular traffic nearby (or other mobile sources): ______________________________________

Part IV – Indoor Contaminant Sources

Identify all potential indoor sources found in the building (including attached garages), the location of the source (floor and room), and whether the item was removed from the building 48 hours prior to indoor air sampling event. Any ventilation implemented after removal of the items should be completed at least 24 hours prior to the commencement of the indoor air sampling event.

Potential Sources	**Location(s)**	**Removed** **(Yes / No / NA)**
Gasoline storage cans		
Gas-powered equipment		
Kerosene storage cans		
Paints / thinners / strippers		
Cleaning solvents		
Oven cleaners		
Carpet / upholstery cleaners		
Other house cleaning products		
Moth balls		
Polishes / waxes		
Insecticides		
Furniture / floor polish		
Nail polish / polish remover		
Hairspray		
Cologne / perfume		
Air fresheners		
Fuel tank (inside building)		NA
Wood stove or fireplace		NA
New furniture / upholstery		
New carpeting / flooring		NA
Hobbies - glues, paints, etc.		

Part V – Miscellaneous Items

Do any occupants of the building smoke? *Yes / No* How often? ______________

Last time someone smoked in the building? ____________ hours */ days ago*

Does the building have an attached garage directly connected to living space? *Yes / No*

If so, is a car usually parked in the garage? *Yes / No*

Are gas-powered equipment or cans of gasoline/fuels stored in the garage? *Yes / No*

Do the occupants of the building have their clothes dry cleaned? *Yes / No*

If yes, how often? weekly / monthly / 3-4 times a year

Do any of the occupants use solvents in work? *Yes / No*

If yes, what types of solvents are used? ____

If yes, are their clothes washed at work? *Yes / No*

Have any pesticides/herbicides been applied around the building or in the yard? *Yes* / No

If so, when and which chemicals? ____

Has there ever been a fire in the building? *Yes / No* If yes, when? _____________

Has painting or staining been done in the building in the last 6 months? *Yes / No*

If yes, when __________________ and where? ____________________________

Part VI – Sampling Information

Sample Technician: ____________________________ Phone number: (   ) _______ - ___________

Sample Source: Indoor Air / Sub-Slab / Near Slab Soil Gas / Exterior Soil Gas

Sampler Type: Tedlar bag / Sorbent / Stainless Steel Canister / Other (specify): _________________

Analytical Method: TO-15 / TO-17 / other: _________ Cert. Laboratory: _________________

Sample locations (floor, room):

Field ID # _____ - _________________________ Field ID # _____ - ___________________________

Field ID # _____ - _________________________ Field ID # _____ - ___________________________

Were "Instructions for Occupants" followed? Y*es / No*

If not, describe modifications: ____

Provide Drawing of Sample Location(s) in Building

Part VII - Meteorological Conditions

Was there significant precipitation within 12 hours prior to (or during) the sampling event? *Yes / No*

Describe the general weather conditions: ____

____

Part VIII – General Observations

Provide any information that may be pertinent to the sampling event and may assist in the data interpretation process.

____

____

____

(NJDEP 1997; NHDES 1998; VDOH 1993; MassDEP 2002; NYSDOH 2005; CalEPA 2005)

APPENDIX C

Instructions for Occupants - Indoor Air Sampling Events (English and Spanish)

Instructions for Occupants
Indoor Air Sampling Events

Representatives of the New Jersey Department of Environmental Protection (NJDEP) or an environmental consulting firm will be collecting one or more indoor air samples from your building in the near future. In order to collect an indoor air sample in your structure that is both representative of indoor conditions and avoids the common sources of background air contamination associated with household activities and consumer products, the NJDEP requests your assistance.

Please follow the instructions below starting at least 48 hours prior to and during the indoor air sampling event:

- Operate your furnace and whole house air conditioner as appropriate for the current weather conditions
- Do not use wood stoves, fireplaces or auxiliary heating equipment
- Do not open windows or keep doors open.
- Avoid using window air conditioners, fans or vents
- Do not smoke in the building
- Do not use air fresheners or odor eliminators
- Do not use paints or varnishes (up to a week in advance, if possible)
- Do not use cleaning products (e.g., bathroom cleaners, furniture polish, appliance cleaners, all-purpose cleaners, floor cleaners)
- Do not use cosmetics, including hair spray, nail polish remover, perfume, etc.
- Avoid bringing freshly dry cleaned clothes into the building
- Do not partake in hobbies indoors that use solvents
- Do not apply pesticides
- Do not store containers of gasoline, oil or petroleum based or other solvents within the building or attached garages (except for fuel oil tanks)
- Do not operate or store automobiles in an attached garage
- Do not operate gasoline powered equipment within the building, attached garage or around the immediate perimeter of the building

You will be asked a series of questions about the structure, consumer products you store in your building, and household activities typically occurring in the building. These questions are designed to identify “background” sources of indoor air contamination. While this investigation is looking for a select number of chemicals related to the subsurface contamination, the laboratory will be analyzing the indoor air samples for a wide variety of chemicals. Thus, tetrachloroethene used in dry cleaning or acetone found in nail polish remover might be found in your sample results.


Typical air sampling

Your cooperation is greatly appreciated.

If you have any questions about these instructions, please feel free to contact the NJDEP at ________________________________.

Instrucciones Para Ocupantes
Eventos de Muestreo de Aire de Interiores

En un futuro cercano, representantes del Departamento de Protección Ambiental de Nueva Jersey (NJDEP) o una firma de consultoria ambiental estaran colectando una o mas muestras de aire del interior de su edificio. NJDEP requiere de su ayuda para colectar una muestra del interior en su estructura que a la vez es representativa de las condiciones del interior y el evitar las fuentes comunes de antecedentes de contaminación de aire asociado con actividades de la casa y productos de consumo.

Por favor siga las instrucciones abajo mencionadas comenzando por lo menos 48 horas antes de y durante el evento de muestreo:

- Opere su horno y el aire acondicionado de toda la casa apropiadamente a las actuales condiciones del tiempo
- No use estufas de leña, chimeneas o equipos auxiliares de calefacción.
- No abrir las ventanas o mantener las puertas abiertas.
- Evite usar aires acondicionados, abanicos o ventiladores de ventanas
- No fume dentro del edificio
- No use refrescantes de aire o eliminadores de olor
- No use pinturas o barniz (hasta una semana por adelantado, si es posible)
- No use productos de limpieza (ej. Limpiadores de baño, cera para muebles, limpiadores de aparatos electrodomésticos, limpiadores para “todo propósito”, limpiadores del piso)
- No use cosméticos, incluyendo fijador del cabello, removedor de esmalte de uñas, perfume
- Evite traer ropa recientemente limpiada en seco (de la tintorería) al edificio
- No participe en pasatiempos en el interior del edificio que usen solventes
- No aplique pesticidas
- No almacene envases de gasolina, aceite o derivados de petróleo u otros solventes dentro del edificio o garajes adjuntos (con exepción de tanques de aceite de combustible -“fuel oil”)
- No opere o almacene automoviles en un garaje adjunto
- No opere equipos impulsados por gasolina dentro del edificio, garaje adjunto o alrededor de los perímetros inmediatos del edificio

Se le hara una serie de preguntas acerca de la estructura, productos de consumo que usted almacena en su edificio, y actividades de la casa típicamente ocurriendo dentro del edificio. Esas preguntas son diseñadas para identificar “antecedentes” de fuentes de contaminación de aire dentro del edificio. Mientras esta investigación esta buscando por un selecto número de químicos relacionados a la contaminación de la sub superficie, el laboratorio estará analizando las muestras de aire del interior por una variedad de químicos. Así, “tetrachloroethene” usado en tintorerías o acetona encontrada en el removedor de esmalte de uñas podria ser encontrado en los resultados de su muestra.

Su cooperación es grandemente apreciada. Si usted tiene alguna pregunta acerca de estas instrucciones, por favor sienta la libertad de contactar a NJDEP al ______________________

APPENDIX D

Evaluating Indoor Air Near VOC Contaminated Sites Fact Sheet

APPENDIX E

Subsurface Depressurization Systems Fact Sheet

APPENDIX F

Background Volatile Levels in homes: Literature Review

BACKGROUND VOLATILE LEVELS IN HOMES: LITERATURE REVIEW

Introduction

A literature review was conducted in June 2002 to determine available information regarding background levels of volatile compounds in homes and other structures. Over the last twenty years, several studies have been conducted to determine personal exposures to these chemicals. Most of them used personal air monitors that added up exposures from all locations visited by the subjects. However, many of these studies also included dedicated indoor air sampling where measurements were taken in an indoor fixed location. Most of these studies were done in urban areas throughout the United States, but some studies were conducted in other countries. In total, over 1000 homes were sampled. While small contributions from outdoor air concentrations of volatiles can occur, indoor levels are frequently much higher due to indoor sources of these chemicals. Therefore, the results from these various studies indicate the range of expected volatile concentrations resulting from the use of consumer products, the presence of home furnishings, building materials, and activities such as smoking and cooking. While it is possible that some of these studies may have inadvertently included a few homes that were located above soil or groundwater contaminated with volatiles, the likelihood of this is small. For this literature survey, median and 90th percentile, and maximum levels of measured concentrations were compiled, the first two of which would largely eliminate the effect of outlier concentrations from homes located above contaminated soil or groundwater.

Because most of these studies were designed as personal air monitoring studies, they employed compact sampling devices that could be worn by the subject. Either adsorbent cartridges or passive adsorption badges were typically used. The adsorbent cartridge technique requires a small pump to pass air through the cartridge, while passive adsorption badges rely on a concentration-dependant mass flux of chemical through a stagnant air layer. Both of these techniques require extraction of the adsorptive medium and analysis of the subsequent extract. These techniques are different from the typical air sampling technique (SUMMA® canister). However, all three have been useful for determining indoor air concentrations. Studies included in this review were those for which median, 90th percentile, or maximum volatile concentrations were reported.

TEAM (Total Exposure Assessment Methodology)

The Total Exposure Assessment Methodology study (TEAM) was conducted in the 1980s (USEPA 1987; Wallace 1987; Wallace, et al. 1985). The study included sampling of 347 homes in New Jersey (Bayonne and Elizabeth), 183 homes in California (Los Angeles, Antioch, and Pittsburgh), 24 homes in Greensboro, North Carolina, and 23 homes from Devils Lake, North Dakota. Many of the New Jersey and California homes were sampled two or more times. The study employed personal air monitors using Tenax cartridges, and samples taken from 6 pm-6 am were taken as indoor air samples, since most subjects (85% of New Jersey subjects) remained indoors during this time.

NHEXAS (National Human Exposure Assessment Survey)

The National Human Exposure Assessment Survey (NHEXAS) study was conducted in the 1990s (Clayton et al. 1999; Gordon et al. 1999; Bonanno 2000). The study included sampling of 248 homes in the Midwest (Illinois, Indiana, Michigan, Minnesota, Ohio and Wisconsin) and 185 homes in Arizona. Several of the Midwest homes were sampled twice. The study employed passive vapor monitors (3M Organic Vapor Monitors) that were left indoors at a fixed location for 6 days.

RIOPA (Relationship of Indoor, Outdoor and Personal Air

A study entitled Relationship of Indoor, Outdoor and Personal Air (RIOPA) is currently in progress (Weisel et al. 2001; Zhang et al. 2001). The project design entails twice sampling 100 homes in each of three urban centers. Preliminary results from one of these centers (Elizabeth, New Jersey) are currently available. This study also employs passive vapor monitors (3M Organic Vapor Monitors) that were left in place for a 48-hour period. Houses with smokers were excluded.

EXPOLIS (Air Pollution Exposure Distributions of Adult Urban Populations in Europe)

Assessment of the recently concluded EXPOLIS study (Air Pollution Exposure Distributions of Adult Urban Populations in Europe) is currently in progress (Jantunen et al. draft final report; Edwards et al. 2001). Indoor air samples were collected in homes from several European cities. The cities included Athens, Greece; Basel, Switzerland (47 samples); Helsinki, Finland (177 samples) and Prague, Czech Republic. Either Tenax or active charcoal tubes were used to collect samples over a 48-hour period, but only during nonworking hours, when the residents were normally at home. Results available for this study to date are preliminary.

BASE (Building Assessment Survey and Evaluation)

The Building Assessment Survery and Evaluation (BASE) study sampled 56 public and commercial buildings for volatile organic chemicals (Girman 2000). Samples were collected using multisorbent active tubes. Only preliminary data are available at this time. This is the only study in this review where volatiles from buildings other than residential dwellings are reported.

Hong Kong study

Six homes were sampled in Hong Kong using pre-cleaned SUMMA® canisters (Lee et al. 2002). All residences except one were located in multi-story buildings. Samples were taken in both the living room and kitchen, and each home was sampled two or three times. Eight-hour samples were taken.

Korean study

In a study conducted in Korea, 12 homes were sampled using active Carbotrap tubes (Baek et al. 1997). Six residences were in the city of Seoul and six were in Korea’s third largest city, Taegu. Each residence was sampled during the summer and winter, and in each case, two-hour samples were taken from 14:00-16:00 and 10:00-12:00.

Finland Study

Fifty “normal” homes were sampled in a study in Finland using active Tenax samplers (Kostianen 1995). (Results from thirty-eight additional homes that were suspected to have indoor air problems are not reported here.) Samples were analyzed for over 200 volatiles, forty-eight of which were selected for quantitative analysis.

Summary of Indoor Background Levels

The fifty-two volatiles subject to NJDEP guidance for the groundwater to indoor exposure pathway were taken from the larger list of New Jersey regulated chemicals in groundwater. Tables F-1, F-2 and F-3 indicate median, 90th percentile, and maximum concentrations from the various studies, and a summary of these results is given in Table F-4. A significant fraction of the samples were taken from urban areas of New Jersey; and concentrations from those samples were usually qualitatively similar to those from other parts of the United States. Concentrations from studies in other parts of the world sometimes varied more widely than those from the United States (Table F-3). But overall, they were usually qualitatively similar to United States concentrations.

Benzene, carbon tetrachloride, chloroform, p-dichlorobenzene, ethylbenzene, styrene, tetrachlorethene (PCE), 1,1,1-trichloroethane, trichloroethene, toluene, and xylene were commonly found in homes at $\mu g/m^3$ concentrations. Chemicals less frequently found were bromodichloromethane, chlorobenzene, 1,2-dibromoethane, o-and m-dichlorobenzene, 1,2-dichloroethane and 1,1,2,2-tetrachloroethane. 1,1-dichloroethene was also sometimes reported in the New Jersey TEAM studies but these results are questionable since this compound has been reported to be seldom found indoors for reasons other than subsurface contamination. Chemicals only rarely found were bromoform and dibromochloromethane. Methylene chloride, acrolein and MTBE were only determined in the RIOPA study, but median values for these were above the detection limit and this suggests that they may commonly occur. Likewise, acetone was only determined in the BASE study, but significant levels were frequently found. Further investigation of levels of these latter four chemicals in homes would be desirable. Three of the remaining chemicals, 1,1,2-trichloroethane, MIBK and vinyl chloride have minimal data provided in the EPA Guidance document (USEPA 2002b). The remaining chemicals (nineteen of the forty-six chemicals) appear to have little or no available information. Some of these chemicals may not have been determined in the past because there are no known sources for them and they may not occur indoors. However, the RIOPA and BASE studies did find a few chemicals normally not measured in these indoor air studies. Therefore, the possibility exists that some of the other unstudied chemicals may occur as well. A NJDEP research study will provide occurrence information for the entire list of chemicals of concern.

Additional Recent Studies

Although not included in Tables F-1 through F-4, the recent studies of Sexton et al. (2004) and Zhu et al. (2005) may also be considered when reviewing indoor air results. The data from these studies are generally similar to the summary tables, but show a possible tendency towards lower concentrations than the earlier studies.

Recommendations

When measuring indoor air levels of volatiles, the resulting concentrations can be compared to the range of concentrations commonly observed due to indoor sources (Tables F-1 through F-4). This step is part of the overall multiple lines of evidence approach when assessing indoor air results and the potential impact from background sources of air contamination.

This comparison will be possible for commonly occurring volatiles that were frequently studied in the background air studies, particularly benzene, carbon tetrachloride, chloroform, p-dichlorobenzene, ethylbenzene, styrene, tetrachloroethene (PCE), 1,1,1-trichloroethane, trichloroethene, toluene, and xylene. The approach is less practical at this time for most of the other chemicals where background data is scarce.

APPENDIX G

Derivation of the Generic Screening Levels

DERIVATION OF THE GENERIC SCREENING LEVELS

The basis for the development of the Ground Water Screening Levels (GWSL), Indoor Air Screening Levels (IASL), and Soil Gas Screening Levels (SGSL) listed in Table 1 is presented below. As discussed in Chapter 4, the screening levels are to be used in the evaluation of a site for the vapor intrusion (VI) pathway.

1.0 DETERMINATION OF THE LIST OF VOLATILE ORGANIC CHEMICALS

VI is a potential concern when soil, soil gas or ground water is contaminated with volatile organic compounds (VOC) since volatile vapors may readily migrate through the subsurface into building basements and living areas. The USEPA Draft Vapor Intrusion Guidance (USEPA 2002b) defines VOC as chemicals with a Henry's Law constant greater than or equal to 1 x 10^{-5} atm m^{-3} mol^{-1} at room temperature. A chemical's Henry's Law constant is approximately equal to the ratio of the chemical's vapor pressure divided by its water solubility. Thus, the Henry's Law constant takes into account a chemical's most fundamental measure of volatility (vapor pressure) and its tendency to volatilize from water. Chemicals with high Henry's Law constants are those with relatively high vapor pressures and relatively low water solubilities.

The use of Henry's Law criteria alone in the evaluation of potential VI can lead to anomalous results. For example, the USEPA Draft Vapor Intrusion Guidance lists p,p-dichlorodiphenyldichloroethylene (DDE), dieldrin and di-n-octyl phthalate as VOC. These chemicals are not identified as VOC by the Department since they have low vapor pressures and are highly adsorbed to soil. In contrast, chemicals commonly viewed as VOC (benzene, trichloroethylene, etc.) typically are liquids, have vapor pressures of several hundred to several thousand mm Hg at room temperature, and are weakly adsorbed to soil (K_{oc} values of 10-1000 ml/g). Borderline volatile chemicals, such as dichlorobenzene and trimethylbenzenes, may have vapor pressures between 1 and 10 mm Hg. Since the vapor pressure of a chemical is the most fundamental measure of volatility, the Department is applying vapor pressure as a secondary parameter in the definition of a VOC. Consideration of the vapor pressure in the definition is also compatible with current VOC analytical methods, which do not include low vapor pressure chemicals, such as those discussed above. The Department is therefore considering a chemical to be volatile if its Henry's law constant is greater than 10^{-5} atm m^{-3} mol^{-1} and its vapor pressure is greater than 1 mm Hg at room temperature.

The VOC with screening levels listed in this document are based on the chemicals included in the Department's state contract for USEPA Method TO-15 (NJDEP 2003b; NJDEP 2003c). Consideration of those chemicals listed in the USEPA TO-15 analytical method in the evaluation of the VI pathway is necessary since some chemicals considered VOC are not readily analyzed using currently available and standard analytical methods. The above definition used to determine the VOC chemicals of concern for the pathway resulted in the removal of the anomalous chemicals discussed previously that are included in the USEPA Draft Vapor Intrusion Guidance. Tert-butyl alcohol (TBA) is the only chemical on New Jersey's TO-15 list that fails the Henry's law constant criteria, with a value of 9.0E-06 atm m^{-3} mol^{-1}. However, this value is very close to the 10^{-5} cutoff and its vapor pressure (40 mm Hg) meets the vapor pressure cutoff. TBA is also an important gasoline additive associated with leaking underground storage tanks. TBA has, therefore, been included in the list of chemicals and is considered a VOC.

Two other USEPA Method TO-15 chemicals (hexachlorobutadiene and 1,2,4-trichlorobenzene) meet the Henry's Law constant criteria but do not meet the vapor pressure criteria, with vapor pressures of 0.22 mm Hg and 0.46 mm Hg, respectively. These values, however, are close to the 1 mm Hg cutoff criteria, and are sufficiently volatile to be analyzed by USEPA Method TO-15. The chemicals have, therefore, been included on the list of chemicals in this guidance. Additional volatile compounds will be added to the list in future updates to the document based on new information and modifications pertaining to the VOC analytical methods.

1.1 Rounding of the Screening Level Values

The screening level values have been rounded to 2 significant figures for a value greater than or equal to 10, and to 1 significant figure for a value less than 10, including those less than 1. This approach is used by the USEPA Office of Solid Waste and Emergency Response and is described in the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, (USEPA 2001a). The rounding rules specified below are contained in Hurlbert (1994).

The screening levels and analytical reporting limits were rounded as follows:

- If the first number beyond the last significant digit is less than 5, the last significant number remains the same; and the remaining numbers are dropped. For example, 4.438 is rounded to one significant figure, 4; and 44.38 is rounded to 2 significant figures, 44.

- If the first number beyond the last significant digit is more than 5, the last significant number increases by one and the remaining numbers are dropped. For example, 4.638 is rounded to one significant figure, 5; and 46.68 is rounded to 2 significant figures, 47.

- If the first number beyond the last significant digit is exactly 5, then the last digit is rounded to the closest even number. For example, 4.5 is rounded to one significant figure, 4; and 45.5 is rounded to two significant figures, 46.

2.0 GROUND WATER SCREENING LEVELS

To develop the screening levels, the Department evaluated the USEPA Draft Vapor Intrusion Guidance (USEPA 2002b). The USEPA Draft Vapor Intrusion Guidance calculates screening levels using indoor air criteria, the Henry's law constant for the chemical, and an assumed dilution attenuation factor of 1 x 10^{-3} between the ground water and indoor air (USEPA 2002b). This approach was found to be protective of 95% of the residences studied where paired ground water and indoor air measurements were available.

An alternate approach is to use the J&E model to calculate ground water screening levels (Johnson and Ettinger 1991; USEPA 2002b). This approach is somewhat more rigorous, in that it calculates chemical specific dilution attenuation factors, which vary according to chemical properties such as diffusivity and the Henry's law constant. Additionally, a series of spreadsheets for evaluating the J&E model has recently been released by the USEPA that allows adjustment of the Henry's law constant for the ground water temperature (USEPA 2004d). The simpler method described in the USEPA Draft Vapor Intrusion Guidance uses Henry's law constants at a temperature of 25°C, which is considerably higher than ground water temperatures in New Jersey. New Jersey ground water temperatures typically range from 10-15°C (United States Geological Survey, 2003). A lower ground water temperature reduces the Henry's law constant. This reduces the source vapor concentration and moderately raises the ground water screening level. Screening levels calculated using the J&E model compare favorably with the simpler USEPA approach (USEPA 2002b), and it has been used successfully by several other states for calculation of screening levels for the VI pathway (Connecticut, Massachusetts, Michigan). Therefore, this model was utilized by the Department with New Jersey specific factors (where appropriate) instead of the simple USEPA approach for calculation of the GWSL.

The J&E model assumes contaminants volatilize from the surface of the water table in accordance with Henry's law. Contaminants then diffuse through the capillary zone of the soil column and the unsaturated soil zone, as controlled by air and water diffusion coefficients, the Henry's law constant, and soil properties (soil texture, soil moisture content, soil porosity). Upon nearing a building foundation, contaminants enter a zone of influence where soil gas advection and/or convection may occur, which may then transport the contaminant into a structure of concern via bulk soil gas flow. The magnitude of this transport is dependent on the magnitude of building depressurization, if any, and the extent of openings in the building foundation (e.g. cracks in the foundation slab and the magnitude of the crack size between the foundation slab and the foundation wall). In some cases, building depressurization may be minimal or absent, and contaminants will diffuse through these openings via diffusion. The J&E model calculates the relative contribution of each of these transport mechanisms. Contaminants entering the building are assumed to immediately mix with building interior air. The amount of contaminant dilution that occurs upon entry into the building depends on the soil gas entry rate, the building air exchange rate and the building size.

USEPA discusses the various input parameters that are used in the J&E model and provides recommended quantitative values for them based on the most current information available in the USEPA Draft Vapor Intrusion Guidance (USEPA 2002b). In 2003, the USEPA released several

EXCEL spreadsheets incorporating various versions of the J&E Model (USEPA 2004d). These spreadsheets incorporate the current recommended parameter values. The screening spreadsheet (GW-SCREEN) was used by the Department to calculate ground water screening levels for the VI pathway.

In accordance with departmental policy, when calculated health-based screening values are below the current New Jersey Ground Water Quality Standards (GWQS), the screening levels are set at the higher GWQS instead of the calculated values. Table G-1 presents the calculated health-based screening values and the applicable GWQS. Table 1 presents the GWSL after consideration of the calculated values and the GWQS.

2.1 Input Parameters for the Johnson and Ettinger (J&E) Model

Input parameter values used in the development of the ground water screening levels presented in Table G-1 were largely adopted as per USEPA recommendation, with the exception of ground water temperature. For the sensitivity analyses discussed below, all parameters except the one under study were held at the base value.

2.1.1 Soil Texture

Soil texture should be specified in the J&E spreadsheet and has a large effect on contaminant diffusion rates through the capillary zone and the unsaturated soil zone. The calculated Ground Water Screening Levels (GWSL) are therefore quite sensitive to this parameter. Sandy soil is common in much of the southern half of New Jersey (Tedrow 1986). This soil texture results in the most conservative estimates of ground water screening levels for the VI pathway, since heavier soil types (sandy loam, loam, etc.) provide more resistance to contaminant diffusion through the soil column. Additionally, the USEPA generic ground water screening levels use an attenuation factor of 1×10^{-3}, which corresponds to the approximate attenuation factor calculated using the J&E model with sand soil. Therefore, this soil texture was selected for development of GWSL, and was used in all locations in the spreadsheet where a soil texture was required (soil texture just above water table, soil texture in vadose zone for estimation of soil physicochemical properties, and soil texture to estimate soil permeability).

Sensitivity of Tetrachloroethene Screening Level to Soil Texture

Soil Texture	*Screening Level (ug/L)*
Sand	0.755
Loamy sand	1.8
Sandy loam	4.7
Loam	7.3

2.1.2 Soil Chemical and Physical Properties

These parameters are pre-set in the spreadsheet according to the soil texture. Since sand was used for the calculations, the following values were incorporated: Vadose zone dry soil bulk density, 1.66 gm/cm^3; vadose zone soil total porosity, 0.375, vadose zone soil water-filled porosity, 0.054; vadose zone soil effective permeability, 9.96E-08 cm^2. The soil organic carbon fraction is fixed at 0.002 in the GW-SCREEN spreadsheet, but does not affect results when the source of the contamination is the ground water. Dry soil bulk densities typically range from 1.2 to 1.8 g/cm^3 (USEPA 2004d). The screening level is unaffected by the value of this parameter.

Total soil porosity generally varies from 0.3 to 0.5. At a given soil moisture level, sensitivity of the screening level to this parameter is non-linear, and becomes more pronounced at low porosity due to the lack of air space for contaminant diffusion:

Sensitivity of Tetrachloroethene Screening Level to Total Soil Porosity

Total Soil Porosity	*Screening Level (ug/L)*
0.3	6.2
0.375	0.755
0.4	0.589
0.5	0.376

Vadose zone water-filled porosity may vary from 0.02 to 0.43 and has a large non-linear effect on screening levels. The high screening levels at high soil moisture levels are due to the lack of available soil airspace for contaminant diffusion.

Sensitivity of Tetrachloroethene Screening Level to Water-Filled Porosity

Water-Filled Soil Porosity	*Screening Level (ug/L)*
0.02	0.722
0.054	0.755
0.2	1.6
0.3	161
0.375	262

Soil permeabilities range from 10^{-6} to 10^{-12} cm^2 (USEPA 2004d). This parameter may be used to calculate the soil gas entry rate from the zone of influence into the building. However, as recommended by USEPA, the soil gas entry rate is fixed at 5 L/min (see below). Thus, the soil permeability is not used in the calculation of the Department's screening levels.

2.1.3 Chemical Properties

Sources for chemical properties are consistent across the USEPA Soil Screening Guidance Document (USEPA 1996a), the USEPA Draft Vapor Intrusion Guidance (USEPA 2002b) and the chemical database built into the J&E spreadsheet (USEPA 2004d). Therefore, chemical properties contained in the J&E spreadsheet were used whenever possible. As discussed above, the chemicals currently investigated by the Department for this exposure pathway are the chemicals listed under the state contract for USEPA Method TO-15 (NJDEP 2003b). Not all of these chemicals are included in the J&E spreadsheet. For these chemicals, the data sources used in the above USEPA documents were first consulted to obtain chemical properties if possible. If unavailable, alternate data sources were used, and are noted in Table G-2. The chemical properties used in the J&E spreadsheet are the organic carbon partition coefficient, the diffusivity in air, the diffusivity in water, the water solubility, the Henry's law constant, the boiling point, the critical temperature, and the enthalpy of vaporization.

Organic carbon partition coefficients for the compounds regulated vary from about 0.5 to 5 x 10^4 cm^3/g. Under the assumed scenario, the value of this parameter had no effect on calculated screening levels, since it is only used to calculate source vapor concentrations when the soil is the source of contamination. Air diffusivities for the chemicals regulated range from about 1.5E-02 cm^2/sec to 2.7E-1 cm^2/sec and have a moderate effect on the calculated screening level:

Sensitivity of Tetrachloroethene Screening Level to the Air Diffusivity

Diffusivity in air (cm^2/sec)	*Screening Level (ug/L)*
1.40E-02	2.9
4.00E-02	1.2
7.20E-02	0.755
1.00E-01	0.611
2.70E-01	0.374

Water diffusivities range only from about 7.8E-06 cm^2/sec to 1.2E-05 cm^2/sec and had no effect on the screening level. Water solubilities are not used in the model calculations; rather, they are used as an upper limit for the allowed soil water concentration. If a calculated screening level is above the water solubility, it means the indoor air criteria cannot be exceeded at any ground water concentration. This did not occur with any of the calculated screening levels.

Henry’s law constants for the regulated compounds vary over several orders of magnitude and the sensitivity of the screening level to this parameter varies over an equally wide range:

Sensitivity of Tetrachloroethene Screening Level to the Henry’s Law Constant

Henry’s Law Constant at 25ºC (dimensionless)	*Screening Level (ug/L)*
3.71E-04	836
3.20E-02	17.2
7.53E-01	0.755
3.01E+00	0.189
6.80E+01	0.0084

Most Henry’s law constants for VOC, however, lie within the range of 10^{-1} and 10^{-2}. Within this range, screening levels vary by approximately an order of magnitude.

The boiling point, critical temperature and enthalpy of vaporization are used to adjust the Henry’s law constant for ground water temperature, and are not directly used in the model. The values used for these fundamental parameters are relatively accurate.

2.1.4 Chemical Toxicological Properties

USEPA Region III toxicological parameters and assumptions were used to derive ground water screening numbers (USEPA 2005). The J&E model back-calculates screening values from allowed inhalation exposures. The required parameters are the unit risk factor (URF) for carcinogens and the reference concentration (RfC) for noncarcinogens (Table G-3). For a few parameters, Region III values were not available, and other sources were used. Four chemicals listed under the Department's Method TO-15 contract do not have toxicological information (1,2-dichlorotetrafluoroethane, 4-ethyltoluene, n-heptane, and 2,2,4-trimethylpentane). GWSL were not calculated for these chemicals.

The screening level is inversely related to the URF (i.e., doubling the URF will cause the screening level to drop by one-half when the carcinogenic endpoint controls the screening level). The RfC is linearly related to the screening level (i.e. doubling the RfC doubles the screening level when the noncarcinogenic endpoint controls the screening level).

2.1.5 Exposure Parameters

USEPA Region III exposure assumptions were used. This includes a target risk level of 10^{-6} for carcinogens and a target hazard quotient of 1 for noncarcinogens. These values are also in accordance with departmental policy. Other exposure assumptions, with one exception, were consistent across USEPA Region III, the USEPA Soil Screening Guidance and the USEPA Draft Vapor Intrusion Guidance. These parameter values were: averaging time for carcinogens, 70 years; averaging time for noncarcinogens, 30 years; exposure duration, 30 years; exposure frequency, 350 days/year. The exception pertains to body weight and inhalation rates during the exposure period. USEPA Region III includes an exposure adjustment for carcinogens when determining acceptable air concentrations that factor in the different contact rates of children to chemical vapors. This adjustment results in a 26% reduction in the GWSL calculated assuming adult only exposure. Since the J&E spreadsheet cannot make this adjustment, the screening levels obtained from the spreadsheet were multiplied by 74% to obtain the ground water screening level when the value was controlled by a carcinogenic endpoint.

The 74% child exposure adjustment factor, discussed above, used in the development of the carcinogenic effects based GWSL is not appropriate for vinyl chloride because the risk assessment approach for this chemical differs from that used for the other chemicals. Region III uses a non-prorated early lifetime exposure segment in the development of their risk based air concentration to account for early exposure to vinyl chloride.

To develop an appropriate child exposure adjustment factor for vinyl chloride, the Department compared the target vinyl chloride air concentration (0.28 ug/m^3) generated using the USEPA Draft Vapor Intrusion Guidance (USEPA 2002b) approach, that does not include an age adjustment factor, to the Region III risk based air concentration (0.072 ug/m^3) that incorporates an exposure adjustment for children. Based on this comparison, the appropriate carcinogenic effects child exposure adjustment factor is 26% for vinyl chloride, rather than the 74% adjustment factor used for other chemicals. This factor is reflected in the GWSL for vinyl chloride presented in Tables G-1, 1 and 3.

Screening levels are linearly related to the target risk level for carcinogens, and the target hazard quotient for noncarcinogens (i.e. doubling either of these factors will double the screening level in ground water). The averaging time for carcinogens should be set at the average lifetime (70 years) and is nonadjustable. The averaging time for noncarcinogens should be set equal to the exposure duration. Modification of the exposure duration is only relevant for carcinogens. This factor is inversely related to the screening level for carcinogens (i.e. doubling the exposure duration will halve the allowed screening level for carcinogens).

2.1.6 Building Parameters

As recommended and discussed in the USEPA Draft Vapor Intrusion Guidance, the soil gas entry rate (Qsoil) was set at 5 L/min. The building air exchange rate is fixed in GW-SCREEN at 0.25/hr according to USEPA recommendations. The building type used for generation of screening numbers was the generic size recommended for buildings with basements – a floor area of 10 m by 10 m and a height of 3.66 m. Contaminants entering the building are assumed to immediately mix into this volume.

Qsoil values generally vary from 1 to 10 L/min for typical residences (USEPA 2004d). Within this range, the screening level varies by about a factor of three:

Sensitivity of Tetrachloroethene Screening Level
to the Air Infiltration Rate, Q_{soil}

Q_{soil} (L/min)	***Screening Level (ug/L)***
1.00E+00	1.69
3.00E+00	0.918
5.00E+00	0.755
7.00E+00	0.691
1.00E+01	0.642

The building air exchange rate and building size (volume) are fixed in GW-SCREEN. However, if they were adjustable, the GWSL would show a linear dependence on the exchange rate and the building size (doubling either parameter would double the screening level).

2.1.7 Other Parameters

The depth to ground water was fixed at 352.5 cm below ground surface. This is equivalent to 5 feet below the building foundation (which extends to a depth of 200 cm, or 6.5 feet) and is the minimum separation between the building and the ground water recommended for using the J&E model (USEPA 2002b). The depth to ground water has a relatively small effect on the ground water screening level. The building foundation depth is only significant in that it affects the depth interval between the foundation and the water table.

Sensitivity of Tetrachloroethene Screening Level to the Ground Water Depth (building foundation fixed at 6.5 feet)

Depth to Ground Water (ft)	*Screening Level (ug/L)*
7.5	0.644
9.8	0.71
11.6	0.755
13.1	0.799
16.4	0.895
19.7	0.992
23.0	1.1
26.2	1.2
29.5	1.3

The ground water temperature for the Department's screening criteria was set at 13°C. This is equivalent to the average temperature of two shallow ground water monitoring wells in the Kirkwood-Cohansey aquifer that had installed temperature monitors at depth (United States Geological Survey 2003). The ground water temperature has a moderate effect on the Henry's law constant and therefore the GWSL. However, shallow ground water temperatures in New Jersey generally fluctuate between 10 and 15°C. This is significantly lower than the 25°C assumed generically in the USEPA Draft Vapor Intrusion Guidance, and it frequently results in a near doubling of the screening level.

Sensitivity of Tetrachloroethene Screening Level to the Ground Water Temperature

Ground Water Temperature (ºC)	*Henry's Law Constant (dimensionless)*	*Screening Level (ug/L)*
5	0.251	1.21
10	0.336	0.895
13	0.398	0.755
15	0.445	0.679
20	0.581	0.520
25	0.750	0.403

2.1.8 Summary of Sensitivity Analysis of the J&E Model

As noted in the table below, the parameters with the largest effects on the GWSL are the soil texture and the water-filled porosity. Parameters with significant, but more moderate effects are soil total porosity, the air diffusivity, the Henry's law constant, the unit risk factor, reference concentration, the risk level, the target hazard quotient, the exposure duration, the soil gas entry rate, building air exchange rate, building size, and ground water temperature. The depth to ground water had only a small effect on the screening level for sand soil. Several parameters (soil organic carbon content, soil effective permeability, organic carbon partition coefficient, and diffusivity in water) had no effect on the ground water screening level.

Parameter	***GWSL Sensitivity***
Soil Texture	High
Soil Bulk Density	None
Soil Porosity	Moderate
Soil Water-Filled Porosity	High
Soil Effective Permeability	None
Soil Organic Carbon Fraction	None
Organic Carbon Partition Coefficient	None
Diffusivity in Air	Moderate (non-linear)
Diffusivity in Water	None
Henry's Law Constant	Moderate (non-linear)
Unit Risk Factor	Moderate (inverse linear)
Reference Concentration	Moderate (linear)
Target Risk Level	Moderate (linear)
Hazard Quotient	Moderate (linear)
Exposure Duration	Moderate (inverse linear)
Soil Gas Entry Rate	Moderate (non-linear)
Building Air Exchange Rate	Moderate (linear)
Building Size	Moderate (linear)
Depth to Ground Water	Low
Ground Water Temperature	Moderate (non-linear)

2.2 Calculated Ground Water Screening Values

The chemical specific dilution attenuation factors for the calculated health-based ground water screening values varied slightly above and below 1×10^{-3}, with a maximum of 2.13×10^{-3}, a minimum of 3.05×10^{-4}, and a mean of 1.12×10^{-3}. These factors are close to the generic USEPA factor of 1 x 10^{-3}. The USEPA factor was selected to be protective of nearly worst case conditions and was found to be adequately conservative for 95% of residences in which empirical ground water and indoor air data were available. The scenario assumed by the Department for the J&E model was also nearly worst case (sand soil, 5 feet to water table from building foundation). The similarity in the J&E model predicted worst case attenuation factors and the conservative empirical USEPA attenuation factor was noted by the USEPA and gives support to the use of the model (USEPA 2002b). The lower ground water temperature assumed for the Department's scenario (13°C versus 25°C for the USEPA approach) results in a lower source vapor concentration just above the water table (typically about a factor of 0.5 lower). This results in ground water screening levels that are in most cases slightly higher than those calculated using the USEPA approach.

3.0 INDOOR AIR SCREENING LEVELS

3.1 Comparison of Risk Based Approaches

The Department considered the methodologies used by USEPA in the Draft Vapor Intrusion Guidance (USEPA 2002b) and the *Region III Risk Based Concentration (RBC) Table* (USEPA 2005) in the development of the health-based indoor air screening values. The Department is adopting the USEPA Region III approach since the Region III risk based air concentrations have historically been used by the Department in the evaluation of indoor air data and the approach has been approved by the New Jersey Department of Health and Senior Services (NJDHSS). The Region III approach also incorporates a combined childhood and adult exposure scenario when evaluating carcinogenic effects. Incorporation of childhood exposure parameters in the carcinogenic effects equation results in lower (approximately 26%), more protective health-based indoor air screening values when compared with the USEPA Draft Vapor Intrusion Guidance values.

3.2 USEPA Draft Vapor Intrusion Guidance

The USEPA Draft Vapor Intrusion Guidance includes target risk based indoor air concentrations under a residential exposure scenario using a chemical's noncancer based RfC or cancer based URF. The RfC is a "provisional estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime (USEPA 1997). The inhalation RfC is expressed as a concentration in ug/m^3 or mg/m^3 units. The URF value is the quantitative estimate of cancer risk from inhalation exposure per ug/m^3 of air breathed (USEPA IRIS).

The USEPA guidance uses the RfC value as the target noncancer based indoor air concentration and does not include modification of the RfC value based on the typical residential exposure duration of 30 years and exposure frequency of 350 days per year. The cancer based indoor air concentration is calculated using the URF with the residential exposure assumptions noted above, as outlined in the USEPA Supplemental Guidance for Developing Soil Screening Levels (USEPA 2001a). The USEPA guidance does not incorporate the analytical reporting limit in the development of the indoor air concentrations.

3.3 NJDEP Residential Health-Based Indoor Air Screening Values

The USEPA Region III (USEPA 2005) risk based concentration equations (Equations 1, 2 and 3 included below) have been used in the development of the residential health-based indoor air screening values presented in Table G-4. The USEPA Region III risk based approach differs from the USEPA Draft Vapor Intrusion Guidance in that the Region III approach includes conversion of the RfC/URF values to reference dose inhalation (RfDi) and cancer potency slope inhalation (CPSi) values. This conversion allows risks to be evaluated under various exposure scenarios. The Region III approach includes the use of an age adjusted factor (Equation 2) in the residential carcinogenic effects equation. The age adjusted factor allows consideration of the child in the calculations by integrating the different exposures that occur from birth through age 30. The adjustment factor combines contact rates, body weights, and exposure durations for small children and adults.

Due to special considerations for vinyl chloride, the residential health-based indoor air screening value for vinyl chloride presented in Table G-4 is not based on the carcinogenic effects Equation 1 and 2 below but includes consideration of a non-prorated early lifetime exposure in the development of the screening level. Details on the development of the residential health-based indoor air screening value for vinyl chloride is presented in the USEPA Region III May 6, 2001 *Derivation of Vinyl Chloride RBCs* memorandum that can be accessed at the Region III web site located at http://www.epa.gov/reg3hwmd/risk/human/info/vcrbc.pdf.

The Department, as mandated by the Brownfield Contaminated Site Remediation Act (NJSA 58:10B-1 et seq), has used an incremental lifetime cancer risk of 10^{-6} and a hazard quotient (HQ) of 1 in the development of the health-based indoor air screening values. Both cancer and noncancer endpoint indoor air concentrations were calculated with the health-based indoor air screening value determined as the more stringent of the cancer or noncancer based values. The USEPA Region III equations along with the residential exposure parameters used in the calculations are presented below.

Residential Health-Based Indoor Air Screening Value Equations

EQUATION 1- Carcinogenic Effect

$$RBC \quad \frac{\mu g}{m^3} \quad = \quad \frac{TR * ATc * 1000 \,\frac{\mu g}{mg}}{EFr * IFAadj * CPSi}$$

EQUATION 2-Carcinogenic Effect Age-Adjusted Factor

$$IFAadj \quad \frac{m^3 * y}{kg * d} \quad = \quad \frac{EDc * IRAc}{BWc} + \frac{(EDtot - EDc) * IRAa}{BWa}$$

EQUATION 3- Noncarcinogenic Effect

$$RBC\ \frac{\mu g}{m^3} = \frac{THQ * RfDi * BWa * ATn * 1000\ \frac{\mu g}{mg}}{EFr * EDtot * IRAa}$$

Parameter/Description	Default
CPSi/ carcinogenic potency slope inhaled	Chemical specific (risk per mg/kg/day)
RfDi/ reference dose inhaled	Chemical specific (mg/kg/day)
TR/ target cancer risk	1 x 10^{-6}
THQ/ target hazard quotient	1
BWa/ body weight, adult	70 kg
BWc/ body weight, child (age 1-6)	15 kg
ATc/ averaging time, carcinogenic effect	25550 days
ATn/ averaging time, non-carcinogenic effect	ED * 365 days
IRAa/ inhalation rate, adult	20 m^3/day
IRAc/ inhalation rate, child	12 m^3/day
IFAadj/ inhalation factor, age adjusted	11.66 m^3-y/kg-day
EFr/ exposure frequency	350 days/year
Edtot/ exposure duration, total	30 years
EDc/ exposure duration child, age 1-6	6 years

3.4 NJDEP Nonresidential Health-Based Indoor Air Screening Values

The USEPA Draft Vapor Intrusion Guidance does not present target indoor air concentrations under a nonresidential exposure scenario in the document. Since the Department has found that the evaluation of VI at sites under review frequently includes the collection of indoor air samples at nonresidential facilities, health-based nonresidential indoor air screening values have been developed and are included in Table G-4. The carcinogenic and noncarcinogenic effect equations and the exposure parameters used in the calculations are presented below. The nonresidential health-based indoor air concentration equations are based on the Region III equations with the child related exposure parameters removed from the carcinogenic effect equation. The typical indoor worker exposure frequency of 250 days per year and exposure duration of 25 years included in USEPA's Supplemental Guidance for Developing Soil Screening Levels (USEPA 2001a) has been used in the calculations.

The nonresidential health-based screening values are appropriate for the typical commercial/ industrial indoor use of a site and are based on the adult worker as the most sensitive receptor. Equations 4 and 5 used in the development of the nonresidential IASL are presented below.

Nonresidential Health-Based Indoor Air Screening Value Equations

EQUATION 4-Carcinogenic Effect

$$RBC \quad \frac{\mu g}{m^3} = \frac{TR * ATc * BWa * 1000 \ \frac{\mu g}{mg}}{EFo * EDo * IRAa * CPSi}$$

EQUATION 5-Noncarcinogenic Effect

$$RBC \ \frac{\mu g}{m^3} = \frac{THQ * RfDi * BWa * ATn * 1000 \ \frac{\mu g}{mg}}{EFo * EDo * IRAa}$$

PARAMETER/DESCRIPTION	DEFAULT
CPSi/ carcinogenic potency slope, inhaled	Chemical specific (risk per mg/kg/day)
RfDi/ reference dose, inhaled	Chemical specific (mg/kg/day)
TR/ target cancer risk	1 x 10^{-6}
THQ/ target hazard quotient	1
BWa/ body weight, adult	70 kg
ATc/ averaging time, carcinogenic effect	25550 days
ATn/ averaging time, non-carcinogenic effect	ED * 365 days
IRAa/ inhalation rate, adult	20 m^3/day
EFo/ exposure frequency, occupational	250 days/year
EDo/ exposure duration, occupational	25 years

3.5 Chemical Toxicity Factors

The Department has adopted the latest USEPA Region III RBC Table toxicity factors in the generation of the screening levels (USEPA 2005). Table G-5 lists toxicity factors and sources of the toxicity factors used in the calculations. As noted above, Region III converts the RfC/URF values to dose based RfDi and CPSi values. Equations 6 and 7 used to convert the RfC and URF toxicity factors to RfDi and CPSi dose base values are presented below (USEPA 2004c). Consistent with USEPA Region III, inhalation based toxicity factors have been used when available in the calculations. Oral based toxicity factors were used in the absence of available inhalation based values and are noted in Table G-5.

Inhalation Toxicity Factor Conversion Equations

EQUATION 6- Carcinogenic Effect- Carcinogenic Potency Slope Inhaled (CPSi)

$$CPSi \quad \frac{(kg - day)}{(mg)} = URF\left(m^3/ug\right) * \frac{day}{20m^3} * 70kg * \frac{10^3\ ug}{mg}$$

EQUATION 7- Noncarcinogenic Effect-Reference Dose Inhaled (RfDi)

$$RfDi \quad \frac{mg}{(kg - day)} = RfC\left(mg/m^3\right) * \frac{20m^3}{day} * \frac{1}{70kg}$$

USEPA Region III toxicity factors were not available for 3-chloropropene and tertiary butyl alcohol (TBA). The toxicity factors used for 3-chloropropene were obtained from the USEPA Integrated Risk Information System (IRIS) and the California EPA. The 3-chloropropene RfDi and CPSi values, along with the sources of the values, are noted in Table G-5. The toxicity factor used for TBA is based on an oral RfD value developed by the Department’s Division of Science Research and Technology (DSRT). The oral RfD value is also the basis of the soil standard for TBA currently included in the Department’s soil standard development effort. The TBA toxicity factor is also presented in Table G-5.

Toxicity factors were not available for four of the fifty-six chemicals obtained from the Department’s state contract for USEPA Method TO-15 (NJDEP 2003b). The four chemicals include 1,2-dichlorotetrafluoroethane, 4-ethyltoluene, n-heptane and 2,2,4-trimethylpentane.

3.6 Analytical Reporting Limits

The analytical reporting limits for each of the Table G-4 chemicals are based on the method detection limit of 0.5 ppbv using USEPA Method TO-15. The reporting limit is the value at which an instrument can accurately measure an analyte at a specific concentration with a defined degree of confidence that can be applied to the reproducibility and reliability of the data. The reporting limit is above the statistical method detection limit and is set at the concentration of the lowest calibration standard. The reporting limit values will be updated to reflect advances in the analytical methods and their associated reporting limits.

3.7 IASL Table Values

The residential and nonresidential health-based indoor air screening values, along with the USEPA Method TO-15 reporting limit, are presented in Table G-4. The applicable IASL for the chemical of concern is based on the higher of the health-based screening value and the USEPA Method TO-15 reporting limit. As an example, the applicable residential IASL for tetrachloroethene (PCE) is 3 ug/m^3 since the reporting limit value of 3 ug/m^3 is greater than the residential health-based screening value of 0.3 ug/m^3. The nonresidential IASL for PCE also defaults to the reporting limit value of 3 ug/m^3 since the health-based nonresidential indoor air screening value of 0.7 ug/m^3 is lower than the analytical reporting limit. The Department bases the applicable IASL on the analytical reporting limit, when higher, due to questions regarding the ability to accurately measure levels detected below the reporting limit. The table values have been rounded to 2 significant figures for a value greater than or equal to 10, and to 1 significant figure for a value less than 10, including those less than 1.

4.0 SOIL GAS SCREENING LEVELS

Table G-6 presents the calculated health-based screening values and the USEPA TO-15 Method reporting limits used in the development of the screening levels. As presented in the USEPA Draft Vapor Intrusion Guidance (USEPA 2002b), the health-based soil gas screening values were calculated by dividing the health-based indoor air values, presented in Table G-4, by an appropriate attenuation factor (α). Equation 8, below, presents the calculations used to derive the screening levels.

Equation 8: Health-Based Soil Gas Screening Value

$$Health-based\ Screening\ Value\left(\frac{\mu g}{m^3}\right)=Health-based\ Indoor\ Air\ Value\left(\frac{\mu g}{m^3}\right)\Big/\alpha$$

USEPA defines the attenuation factor as the factor by which subsurface vapor concentrations migrating into indoor air spaces are reduced due to diffusive, advective and/or other attenuating mechanisms (USEPA 2002b). The attenuation factor is noted to be the ratio of the indoor air concentration measured in a residence to the vapor concentration measured in the subsurface materials underlying or adjacent to the residence (USEPA 2002b). The attenuation factor is represented in Equation 9 below.

Equation 9: Attenuation Factor (α)

$$\alpha=\frac{C_{indoor}}{C_{subslab}}$$

The USEPA Draft Vapor Intrusion Guidance uses an attenuation factor of 0.1 in the development of the document's target shallow soil gas concentrations based on the information included in the USEPA Vapor Intrusion Database that was available when the 2002 USEPA guidance was drafted. USEPA's current reevaluation of the database, that includes additional empirical data, suggests that a reduced attenuation factor may be more appropriate in the development of sub-slab SGSL. Discussions at two recent USEPA VI attenuation factor workshops suggest that an attenuation factor between sub-slab soil vapor and indoor air in the range of 0.01 to 0.05 may be adequately protective (USEPA 2004a; USEPA 2004b).

Based on this information, the Department has selected an attenuation factor of 0.02 in the development of the health-based soil gas screening values. The resulting health-based soil gas screening values are presented in Table G-6. The attenuation factor and health-based soil gas screening values will be updated as the state of the science advances and as new information becomes available. Site-specific attenuation factors and SGSL may be developed as a part of the remedial investigation (see Chapter 5).

Consistent with the development of the IASL, the SGSL default to the analytical reporting limit, when higher than the health-based values. The soil gas analytical reporting limits presented in Table G-6 are generally 5.0 ppbv or a factor of 10 higher than the indoor air analytical reporting limits for several reasons. These reasons include:

1) the use of 1 liter canisters that limit the amount of available sample volume and result in an automatic dilution of 10 to the sample results,
2) the required sample dilutions due to the presence of high contaminant concentrations exceeding the calibration range in undiluted samples; and,
3) the potential presence of methane and carbon dioxide in the soil gas sample that can shut down the instrument system and result in the need to dilute the sample to eliminate the interference of these two compounds.

The reporting limits for acetone and tert-butyl alcohol (TBA) have been elevated to 90 ppbv and 100 ppbv respectively, to address concerns within the laboratory community.

APPENDIX H

Common Household Sources of Background IA Contamination

Common Household Sources of Background Indoor Air Contamination

Acetone	rubber cement, cleaning fluids, nail polish remover
Benzene	automobile exhausts, gasoline, cigarette smoke, scatter rugs, carpet glue
Bromomethane	soil or space fumigant
2-Butanone (MEK)	printing inks, fragrance/flavoring agent in candy and perfume, cigarette smoke
Chlorobenzene	plastic foam insulation, paint related products
Chloroethane	refrigerant
Chloroform	generated from chlorinated water (showers)
Cyclohexane	paint thinner, paint and varnish remover
1,4-Dichlorobenzene	moth balls, general insecticide in farming, air deodorant, toilet disinfectant
Dichlorodifluoromethane	refrigerant (CFCs), cleaning solvent
1,1-Dichloroethane	Plastic products (food and other packaging material), flame retardant fabrics
1,3-Dichloropropene	fungicides
Ethylbenzene	paint thinners, insecticides, wood office furniture, gasoline
Formaldehyde	building materials (particle board), furniture, insulation, cigarette smoke
n-Heptane	nail polishes, wood office furniture, petroleum products
n- Hexane	gasoline, rubber cement, typing correction fluid, aerosols in perfumes
Methylene chloride	hairspray, paint stripper, rug cleaners, insecticides, furniture polish

Methyl isobutyl ketone	paints, varnishes, dry cleaning preparations, naturally found in oranges, grapes, and vinegar
Methyl *tert* butyl ether	gasoline (oxygenating agent)
Styrene	cigarette smoke, automobile exhaust, fiberglass, rubber and epoxy adhesives, occurs naturally in various fruits, vegetables, nuts, and meats
1,1,2,2-Tetrachloroethane	solvent, paint and rust removers, varnishes, lacquers
Tetrachloroethene (PCE)	dry cleaning, metal degreasing, adhesives and glues, insecticide, rug cleaner
Toluene	gasoline, automobile exhaust, polishes, nail polish, paint thinner, cigarette smoke
1,1,1-Trichloroethane	spot cleaners, glues, insecticides, drain cleaners, shoe polish
Trichloroethene (TCE)	scented candles, automotive cleaning and degreasing products
Xylenes, total	water sealer, gasoline, automobile exhaust, markers, floor polish, cigarette smoke

APPENDIX I

Quality Assurance Requirements

Quality Assurance Requirements for USEPA Methods TO-15 and TO-17

The majority of the air sampling conducted in New Jersey for the investigation of the vapor intrusion (VI) pathway is for volatile compounds. Thus, the focus of this section is on USEPA Method TO-15 and USEPA Method TO-17.

USEPA Method TO-15 uses specially prepared leak free stainless steel canisters (canisters) for the collection of air samples in the field (USEPA 1999). The samples are collected using the subatmospheric pressure technique. The sample from the canister is directed through a cryogenic concentrator on to a multisorbent trap and then on to a cryogenic focusing unit designed to reduce the water content of the sample prior to introduction in the gas chromatogram/mass spectrometer instrument system.

USEPA Method TO-17 uses sorbent tubes for the collection of air samples in the field. The tubes are thermally desorbed into a gas chromatogram/mass spectrometer instrument system. The method requires specific collection procedures and states that after desorption on to the column the samples are to be analyzed in accordance with USEPA Method TO-15.

Both of the methods were published or updated in January 1999 and instrument technology has advanced significantly since that time. There are sections in this guidance that reflect technology advances that are not specified in the method.

NJDEP is adding requirements and clarifications to the methods based on the previous sampling events carried out by NJDEP personnel.

I. CERTIFICATION REQUIREMENTS

All laboratories analyzing samples for submittal to the NJDEP must hold all the required NJDEP Environmental Laboratory Certifications. NJDEP offers certification for USEPA Methods TO-15 and TO-17. Laboratories may satisfy the NJDEP Environmental Laboratory Certification requirements by holding NJDEP Environmental Laboratory Certification, NJDEP Primary NELAP Accreditation, NJDEP Secondary NELAP Accreditation or a combination of certifications and accreditation. Laboratories must meet and maintain the analytical protocol requirements stipulated in the New Jersey Regulations Governing the Certification of Laboratories and Environmental Measurements (N.J.A.C. 7:18) and the certified method.

Information regarding certification can be obtained by contacting the NJDEP Office of Quality Assurance, PO Box 424, Trenton, New Jersey, 08625-0424, Phone (609) 292-3950.

The field determination of oxygen content in soil gas using any methodology beyond draeger tubes (e.g., field GC instrument) will require the investigator to obtain certification for the procedure from the NJDEP Office of Quality Assurance (OQA) prior to initiating field work. If an off-site laboratory is utilized for the determination of oxygen content in soil gas, the laboratory must be currently certified by OQA for USEPA Method 3C.

The certification issued by the NJDEP OQA for Method TO-15 was initiated using a 6-Liter specially prepared leak free stainless steel canister as per the method. However, due to the possibility of higher concentrations of contaminants in soil gas and the need to collect samples over a shorter time period, 1-Liter specially prepared leak free stainless steel canisters can be analyzed using TO-15. Approval must be obtained from the Office of Quality Assurance.

Laboratories that are using 1-Liter canisters for the analysis of soil gas must address their use in the Standard Operating Procedure (SOP) that they have on file with the NJDEP Office of Quality Assurance for Method TO-15. The SOP must address the canister preparation and sample handling procedures, as well as the analytical procedures that are specific to the use of 1-Liter canisters. The laboratories must follow all of the procedural requirements of Method TO-15 regardless of the volume of the canister that is being used. If the laboratory uses exactly the same analytical procedures in analyzing samples from a 1-Liter canister as it does from a 6-Liter canister, then the laboratory’s Method Detection Limit Study for TO-15 will apply to the analysis of samples from either size canister. In analyzing samples, it is appropriate for the laboratory to use smaller sample volumes, consistent with the reporting limit objectives, however this must be addressed in the laboratory's SOP. If the laboratory adds air to a sample, the air source must be the same as the air source that is used for the preparation of the method blanks, that being humidified, ultra-pure zero air.

1. Mobile Laboratories Used for Field Investigation

Mobile laboratories used for the field investigation of soil gas samples must be certified by the NJDEP Office of Quality Assurance prior to the initiation of any field analysis. This includes the collection of soil gas samples in Tedlar bags, 1-Liter canisters, or other approved sampling devices. The laboratory must contact the NJDEP Office of Quality Assurance for all certification requirements.

II. ANALYTICAL PROTOCOLS

The analytical methods required are from the Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air 2nd Edition, January 1999 issued by the Center for Environmental Research Information. These methods and other air toxic methods are available on the Internet from the USEPA website at http://www.epa.gov/ttn/amtic/airtox.html.

Method TO-15 is entitled "The Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially Prepared Canisters and Analyzed by Gas Chromatography/ Mass Spectrometry."

USEPA Method TO-15 (canisters) and Method TO-17 (sorbent tubes) are the accepted analytical methods for VOC in air collected from the interior and exterior of buildings. If Method TO-15 is being used for the analysis of samples from the interior of buildings, the 6-Liter canister is required. Any other method must be approved by NJDEP prior to sample collection.

USEPA Method TO-15 can be used for soil gas analysis. However, the minimum canister size that can be used is the 1-Liter canister. Method TO-17 is not appropriate for the collection of soil gas samples.

Method TO-17 is entitled "Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling Onto Sorbent Tubes."

USEPA Method TO-17 uses sorbent tubes as the method of sample collection. The method requires specific collection procedures that must be followed. Additionally, the type and frequency of the laboratory and field blanks type are mandated as per section 10.7.1 of the method. After the tubes are desorbed on to the trap, Method TO-17 requires that USEPA Method TO-15 be followed for the analysis of the samples.

Laboratories must meet and maintain the analytical protocol requirements stipulated in the New Jersey Regulations Governing the Certification of Laboratories and Environmental Measurements (N.J.A.C. 7:18) and USEPA Method TO-15. In addition, the laboratory must meet all QA/QC requirements as specified in N.J.A.C. 7:18-5-5 and Methods TO-15 and TO-17.

III. LOW LEVEL ANALYSIS AND REPORTING

NJDEP currently only accepts analytical data from laboratories for Method TO-15 with the lowest reporting limit of 0.2 ppbv. NJDEP is the process of standardizing requirements for the reporting of analytical data below 0.2 ppbv, which will be considered low level analysis. This information will be provided at a later date and will address both GC/MS Scan and GC/MS SIM requirements.

IV. REQUIREMENTS FOR BOTH METHODS

In accordance with the requirements of Method TO-17 Section 8.2 "Apparatus", thermal desorption of the tubes on to the trap is required. Following the desorption procedures, section 8.2.5 "GC/MS Analytical Components" states that the requirements of Method TO-15 are to be followed. Therefore, the following sections dealing with any analytical or quality assurance requirements pertain to both Method TO-15 and TO-17.

1. Gas Chromatography/Mass Spectrometry Tuning

The laboratory shall comply with all the GC/MS tuning requirements set forth in the instrument operator's manual, USEPA Method TO-15, and the approved Laboratory Standard Operating Procedure. Post acquisition manipulation of the ion abundances using computer software to achieve tuning criteria is unacceptable. Any sample analyzed in conjunction with a failed tune performance check requires a reanalysis. The laboratory shall comply with the requirements of N.J.A.C. 7:18-5.2(a) 8 through 5.2(a) 13.

2. General Instrumentation Requirements

The laboratory shall meet and maintain the minimum standards for laboratory instrumentation set forth in the “Regulations Governing the Certification Laboratories and Environmental Measurements.” General instrument requirements are specified within these regulations at N.J.A.C. 7:18-3.2 through 7:18-3.3 and N.J.A.C. 7:18-5.2(a)1 through 7:18-5.2(a)18. In addition, the equipment requirements specified in the analytical method shall be met and maintained.

The laboratory shall maintain a bound paginated laboratory notebook with the analyst’s and supervisor’s signature for archival storage of all data, except computerized data. The analyst and the supervisor must sign any computerized printout or chromatogram not maintained in a notebook on the first and last pages.

3. GC/MS Instrument Performance Tune Check Standard Requirements

The GC/MS Instrument Performance Tune Check Standard must contain BFB and cannot be combined with any calibration standard to create an injection consisting of a calibration standard and the tune solution. The BFB Tune Check Solution must be the first injection in any 24-hour sequence. The BFB tune must meet the requirements of Table 3 Required BFB Key Ions and Ion

Abundance Criteria of the Method TO-15 and Method Sections 10.4.3 and 10.4.4 to be considered acceptable.

4. Mass Spectral Library Requirements for GC/MS Analysis

The laboratory must maintain a gas chromatograph/mass spectrometer equipped with a computerized MS library search system capable of providing reverse searching for targeted analytes and forward searching for non-targeted analytes. The laboratory shall use the MOST recent NIST/EPA/MSDC (May 1992 release or later), or the most recent Wiley (May 1991 release or later) mass spectral library for searches of targeted analytes. The system shall also be capable of removing background signals from the suspect chemical pollutant spectrum (background subtraction capability). The laboratory must also comply with N.J.A.C. 7:18-5.2(a)9 and N.J.A.C. 7:18-5.2(a)13)(iii).

The laboratory will operate the GC/MS in the SCAN mode unless the NJDEP approved VI investigation workplan permits the samples to analyzed in the SIM Mode.

5. Electronic Media for Storage of Data

The laboratory shall store all raw data and processed electronic analytical data in the appropriate instrument manufacturer’s format, uncompressed and with no security codes. The electronically stored data shall include all data needed to completely reconstruct a hard copy and electronic deliverable. The electronic data files shall include, but are not limited to, blanks, spikes, tunes, calibrations, quality control samples, proficiency testing samples, and check samples. The electronic data files shall also include all laboratory generated spectral libraries and quantitation reports as well as the associated raw data files if those files contain data or instrument parameters related to analytical results. The electronic data files must be sent to the NJDEP Office of Quality Assurance within ten (10) days following a request for the files.

The laboratory must retain all raw and processed electronic data files for ten (10) years. The laboratory shall comply with N.J.A.C. 7:18-5-6(a).

6. Qualitative Identification of Targeted Compounds by GC/MS

The compounds listed as required for Method TO-15 on the Master QA Form for Air shall be identified by an analyst competent in the interpretation of mass spectra by comparison of the sample mass spectrum to the mass spectrum of a standard to the suspected compound. The Method TO-17 compounds must also meet this criterion, however, the compounds reported will be based on the sorbent material used. Two criteria must be satisfied to verify the identifications: (1) elution of the sample component at the same GC relative retention time as the standard component, and (2) correspondence of the sample component and standard component mass spectra.

If an investigator (i.e., person(s) responsible for evaluating the VI pathway) wants to use Method TO-17, they must follow the same requirements as those for Method TO-15, and as stated above and below. A Method TO-17 Master QA Form has been developed for the volatile organic compounds (USEPA Method TO-17 for Ambient Air: NJDEP Regulatory Reporting Format) and found on the NJDEP Vapor Intrusion website. Each compound under analysis must be reported on this form. This form can be modified for the reporting of compounds not listed on the form by changing the compound name, CAS number, and molecular weight. The embedded calculation will be operative.

For establishing correspondence of the GC relative retention time (RRT) the sample component RRT must compare within + 0.06 RRT units of the RRT of the standard component. For reference, the standard must be acquired in the same 24-hour time period as the sample. If samples are analyzed within the same 24-hour time period as the initial calibration standard, use the RRT values from the 10 ppbv standard (or the middle standard of the initial calibration). If co-elution of interfering compounds prohibits accurate assignment for the sample component RRT from the total ion chromatogram, the RRT should be assigned by using extracted ion current profiles for ions used to obtain reference RRTs.

For comparison of standard and sample component mass spectrum, mass spectra obtained on the laboratory's GC/MS are required. Once obtained, these standard spectra may be used for identification purposes only if the laboratory's GC/MS meets the daily instrument performance requirements for BFB. These standard spectra may be obtained from the run used to obtain reference RRT.

All ions present in the standard mass spectra at a relative intensity greater than 10 percent (most abundant ion in the spectrum equals 100.0 percent) must be present in the sample spectrum.

The relative intensities of ions specified above must agree within +\-20 percent between the standard and sample spectra.

Ions greater than 10 percent in the sample spectrum but not present in the standard spectrum must be considered and accounted for by the analyst making the comparison. The verification process should favor false positives. All compounds meeting the identification criteria must be reported with their spectra.

Structural isomers that produce very similar mass spectra can be explicitly identified only if they have sufficiently different GC retention times. Acceptable resolution is achieved if the height from the baseline to the valley between two peaks is less than 25% of the average height of the two peaks. Otherwise, structural isomers are identified as isomeric pairs.

If a compound cannot be verified by all the criteria above, but in the technical judgment of the mass spectral interpretation specialist the identification is correct, then the laboratory shall report that identification with comment and proceed with quantitation. **NOTE: Non Target Compound identification is not required for air analysis.**

V. SPECIFIC METHOD TO-15 REQUIREMENTS

1. Method TO-15 Canister Requirements

<u>6-Liter Canisters for Building Interiors and Soil Gas Sampling</u> - For the sampling of building interiors and soil gas, the investigator can use leak-free stainless steel 6-Liter pressure vessel

canisters. These canisters must be equipped with a laboratory preset regulator, pressure gauge, critical orifice, stainless steel frit dust filter over the orifice, and specially prepared interior surfaces. Canisters are shipped to the investigator at subatmospheric pressure approximating negative 30 inches of mercury. Hard seat metal valves are required for the shutoff valves on the canisters. Soft-seated valves are not acceptable.

Building interior sampling and the accompanying background sample usually occurs over an 8 hour or a 24 hour period. The laboratory will preset the flow rate of the regulator to the sampling period requested by the investigator.

The maximum flow rate for the collection of soil gas using a canister is 200 milliliters per minute. A 6-Liter canister with a preset flow rate of 200 milliliters per minute and a critical orifice of 0.0060 inches, and not drawing against backpressure constraints, will fill in approximately 30 minutes.

The backpressure is primarily a factor of the length of the tubing from the sampling point to the canister, the interior diameter of the tubing, the construction of the sampling probe, and the soil type. If the backpressure constraint is greater than the vacuum in the canister, sample collection will not occur. When possible, the system backpressure should be evaluated prior to sampling.

<u>1-Liter Canisters for Soil Gas</u> - For the sampling of soil gas, the investigator can use leak-free stainless steel 1-Liter pressure vessel canisters equipped with a critical orifice, a stainless steel frit dust filter over the orifice, and specially prepared interior surfaces. The canisters are shipped to the investigator at a subatmospheric pressure approximating negative 30 inches of mercury. Hard seat metal valves are required for the shutoff valves on the canisters. Soft seated valves are not acceptable.

Installation of flow regulators on 1-Liter canisters used for the collection of soil gas samples may not be practical, or may actually hinder the collection of the samples. A major concern during the collection of soil gas samples is the backpressure that may be caused by the sampling train used in the field. Given the dimensions of some of the 1-Liter canister, it may not be possible to secure a pressure gauge directly to the canister. It is important that the investigator communicates their needs with the laboratory before the canisters and regulators are sent to the field. The investigator may need to be provided with a specially fitted pressure gauge from the laboratory with each set of canisters in order to provide for the vacuum checks before and after sample collection.

A regulator with a preset flow rate that does not match the flow rate of the sampling train will constrain sample collection, and for this reason the use of flow regulators is not recommended. The use of a critical orifice to moderate the flow is recommended for this type of sampling. A 1-Liter canister equipped with a 0.0060 inch critical orifice (provides a flow rate of 200 milliliters per minute), and not drawing against backpressure constraints, will fill in approximately 5 minutes.

Design changes by the canister manufacturer now allow pressure gauges to be added as part of the sampling train for the 1-Liter canisters. If the laboratory is able to supply pressure gauges in line with the canister, the investigator will not have to obtain a separate pressure gauge from the laboratory.

The investigator, at the completion of the estimated fill time, is required to assess the vacuum of the 1-liter canisters to determine if they have adequate sample volume. If a vacuum gauge is not attached directly to the regulator, the investigator will shut down the system, break the tubing connection to install the laboratory provided pressure gauge to check the vacuum of the canisters. Adequate sample volume has been achieved if the pressure gauge is under –5 inches of Mercury. If the canister is not below –5 inches of Mercury, the investigator should reconnect the canister and continue sample collection.

2. Canister Preparation

The laboratory shall prepare canisters for sample analysis in accordance with the procedures specified in the SOP approved by the NJDEP Office of Quality Assurance during the certification process and with the provisions of the method. The laboratory must record the current and actual temperature and barometric (atmospheric) pressure of the room at the time the canisters (with the regulators) are prepared for shipment. Regulators, while not recommended for 1-Liter canisters, are an option.

3. Limitations on the Number of Days Canisters can be out of the Laboratory

Both 6-Liter and 1-Liter canisters after evacuation to approximately –30 Inches of Mercury have a finite time frame before the level of the pressure loss that occurs naturally will inhibit the use of the canister in sample collection. Due to the lost of pressure that occurs naturally during the storage of canisters, NJDEP is establishing a fifteen (15) calendar day time limit that canisters can be out of the laboratory. The fifteen-day time limit begins with the shipment of the canisters to the investigator. The canisters must be returned to the laboratory after 15 calendar days whether they were used for sample collection or not.

4. Setting the Regulators

All 6-Liter canisters must be provided with sample collection regulators. Regulators are optional for 1-Liter canisters. The regulators must be flexible enough to collect samples over a variety of time frames. The maximum sampling time will be 24 hours for 6-Liter canisters and 4 hours for 1-Liter canisters. The investigator will direct the laboratory to preset the canister regulators to specific sample collection times. It will be the laboratory's responsibility to preset the regulators for the sample collection time frames specified and to clearly identify each canister's regulator preset sample collection time. The laboratory must record the current and actual temperature and barometric (atmospheric) pressure of the room at the time the canisters (with the regulators) are prepared for shipment.

5. Temperature Requirements for Sample Shipment

This method doesn’t have any temperature requirements for shipment since stainless steel canisters are used for sample collection.

6. Sample Delivery Group

A Sample Delivery Group (SDG) is a unit of no greater than twenty (20) canisters collected at a particular site. The SDG assignment is made upon receipt of the samples at the laboratory's facility. If less than twenty (20) samples are submitted for a particular site, it is considered a single SDG. If more than twenty samples are submitted from a particular site, then the laboratory is required to split those samples into separate SDGs of 20 or less and analyze each SDG with the appropriate number of QC samples.

A SDG is a group of 20 or fewer samples received over a period of up to seven (7) calendar days. Data from all samples in a Sample Delivery Group are due concurrently.

Samples from the sampling event may be assigned to a SDG at the discretion of the laboratory.

Laboratory Control Samples and Laboratory Control Sample Duplicates are considered QC samples and are not included in the sample count for a SDG.

The SDG assignment made by the laboratory is not related to the analytical sequence. The sample delivery group assignment is strictly used to track the movement of the samples in the laboratory, for defining the SDG and the production of the analytical data package.

7. Collection of Field Duplicates

NJDEP does not require the collection of Field Duplicates for Method TO-15. NJDEP has instituted the use of Laboratory Control Samples instead.

8. Trip Blank Canisters

NJDEP does not require the collection of trip blank canisters for any Method TO-15 sampling event. Trip blanks are defined as canisters that are prepared at the laboratory, shipped to investigator and shipped back to the laboratory unopened.

9. Ambient Temperature and Pressure Determinations during Sample Collection

For a sampling event, there are two ways to attain this information. The first way to obtain information is from the nearest weather reporting station. This information can be acquired directly from the station or from information posted on the Internet. Two websites that may be useful to the investigator are the National Oceanic and Atmospheric Administration, National Weather Service website at http://www.weather.gov or Weather Underground at http://www.wunderground.com/. The investigator can also bring portable instrumentation on site to obtain the information real time. The investigator must specify how the ambient pressure and temperature will be obtained in the workplan, including but not limited to the weather station from which the information will be obtained or the make and model of the portable instrument will be for the measurements. In the sampling report, the actual procedures used must be specified.

For interior samples, the collection of the ambient temperature cannot be obtained from a weather station or the Internet. This information must be obtained from portable instrumentation brought on site by the investigator to obtain the information real time. This information is sample location specific, because there can be temperature variations within a building. As part of the VI investigation workplan, the investigator must specify how this information is to be collected and the type of instrument that will be used in the interior of buildings. In the sampling report, the actual procedures used must be specified.

10. NJDEP TO-15 Field Test Data Sheets

The NJDEP TO-15 Field Test Data Sheets (FTDS), as provided at the end of this appendix, must be completed for each canister used in the sampling events. All information must be completed on the FTDS for each canister, and for both the fixed laboratory and a mobile laboratory. The FTDS will be initiated by the laboratory and will accompany the canisters to and from the field. The laboratory will fill out Canister Serial Number at the top of the form in the General Information Section and the Batch Certification Number or File Number (as applicable) and the

Date Shipped at the bottom section of the form in the Laboratory Information Section. The FTDS will be included in the analytical data package prepared by the laboratory. The FTDS must be located immediately behind the case narrative of the data package and prior to any sample data.

11. Pressure of Canisters

Laboratories must check and record the negative or subatmospheric pressure of all canisters prior to shipping and upon return receipt. This negative pressure information must be recorded in a laboratory notebook and reported in the Data Package. The use of "<" or ">" from the standard pressure of 30 inches is not acceptable; the actual numeric reading is required.

Recent advances in the concentrator units (for example, the Entech™ 7100A Concentrator) allows laboratories to remove samples from canisters with a negative pressure of –10 inches of mercury without having to add makeup air. There are older concentrators such as the NuTechs that only can pull from canisters that are less than –5 inches of Mercury. It is acceptable to use either the older type or the advanced concentrator units.

The laboratory cannot automatically add makeup air to every canister received. The amount of air that is added to each canister cannot be a standard amount because the determination of the amount of air that must be added is based on the pressure that is in the canister at the time it is received at the laboratory. The amount of air added to any canister cannot cause the total amount of air in the canister to exceed 6.5 Liters. Ideally, the total amount of air in a canister should not exceed 6 Liters. Additionally, if the canister is received at the laboratory at a pressure that does not require air to be added, the addition of makeup air is prohibited. The laboratory SOP must clearly describe how the pressure of the canister is determined and exactly how the amount of makeup air to be added to canisters is determined.

If a sample of air is received and the negative pressure in the canister is less than –10 (or-5 inches if an older concentrator is used) inches of mercury, the laboratory may proceed with the analysis of the sample as specified in Method TO-15. (Note: It is understood that a sample should never be received at zero negative pressure or a pressure equal to atmospheric pressure.

The laboratory should consult the investigator for guidance on analyzing the samples in these situations.) The humidified ultra pure zero air that is added to a canister for pressure adjustment must be from the same source as the method blank air.

Example: If a sample is received with a negative pressure of -5 inches of mercury, the laboratory may proceed with any pressure adjustment as needed for analysis. If pressure adjustment is required, the analyst must bring the canister pressure up to the method specified pressure using humidified, ultra-pure zero air. This is the same air as used for the method blank. The procedures to correct the negative pressure of the canister must be documented in the Case Narrative of the Data Package. Additionally, when the canister pressure is adjusted, a table entitled Canister Dilution Calculations must be provided in the Data Package. NJDEP Method TO-15 Ambient Air Regulatory Data Report (found on the NJDEP Vapor Intrusion website) specifies the documentation requirements for the table.

If the negative pressure in a sample is greater than -10 inches of mercury, then the laboratory must contact the investigator immediately for permission to analyze the sample.

Example: If a sample is received with a negative pressure of -12 inches of mercury, the laboratory must contact the investigator for permission to analyze the sample. Contact NJDEP for guidance on whether this sample should even be analyzed due to the incomplete sample collection.

12. Volume of Sample Used for Analysis

The undiluted volume of sample drawn from the canister for analysis will vary from laboratory to laboratory based on the procedures established by the laboratory and by the instrumentation employed.   There are two acceptable procedures for sample dilution.

The first procedure is the use of smaller volumes of air drawn from the canister and injected on the column. Certain mass flow controllers on the instruments allow smaller volumes to be drawn from the canister, thus creating a dilution without the addition of makeup air.

The second procedure is to draw a known volume from the canister and injecting the volume into another certified clean canister. A known volume of ultra pure humidified zero air is then added to the second canister. The dilution factor is determined based on the initial volume of air and the makeup air. A volume of air is then drawn from the second canister and injected onto the instrument.

Both procedures must be documented on the instrument logbook page. If the second canister is used, the clean canister certificate documentation must be provided.

13. Specific Requirements for Method Detection Limits, Clean Canister Certification and Reporting Limits for 6-Liter Canisters used in Building Interiors

Method Detection Limits for 6-Liter Canisters for Building Interior Sampling - The laboratory shall calculate all Method Detection Limits (MDLs) in accordance Method TO-15. Section 11.2 requires the use of the procedures stated in Appendix B of 40 CFR 136 for performing the MDL study. There are specific criteria that the laboratory must meet regarding the MDL. The MDL is a statistical determination based on the requirements of the Method. Method Detection Limit Studies must be conducted yearly.

The MDL determination is the same concentration as used for the low calibration standard (for example 0.5 ppbv) in the initial calibration.

The recommended spiking level for the MDL determination is the same concentration as used for the low calibration standard (for example 0.5 ppbv) in the initial calibration.

Required MDL Levels - The maximum MDL reported for each target analyte must be less than or equal to the clean canister certification specified in Method TO-15. The clean canister certification level is established in Method TO-15, Section 8.4.1.6.

The maximum MDL for acetone (2-propanone) and *tert*-butyl alcohol have been elevated to address various concerns within the laboratory community. The MDL for acetone is 1.0 ppbv and for *tert*-butyl alcohol to 3.0 ppbv. Laboratories may use lower MDLs for these compounds.

The submittal requirements for the Method Detection Limit Study is located in Method TO-15 Regulatory Reporting Format found on the NJDEP Vapor Intrusion website. This information must be reported in each Analytical Data Package generated for a sampling event.

Clean Canister Certification for 6-Liter Canisters for Building Interior Sampling - The laboratory is required to follow the requirements of Method TO-15, Section 8.3 and their approved NJDEP-OQA SOP regarding cleaning and certifying canisters.

The canisters must be batch cleaned and certified with all Method TO-15 target analytes <0.2 ppbv. The laboratory must document which canisters are associated with each batch certification. The actual level to which the canisters are certified to must be provided on the reporting form for the clean canister certification. If the canister used for batch certification exceeds these levels, the entire batch must be recleaned and recertified.

The clean canister certification level for acetone (2-propanone) and *tert*-butyl alcohol has been elevated to address various concerns within the laboratory community. The contamination levels for these two compounds cannot exceed the new specified levels. The clean canister certification for acetone is 3.0 ppbv, and for *tert*-butyl alcohol is 6.0 ppbv. Laboratories may use lower clean canister certification levels for these compounds.

The GC/MS documentation for clean canister certification is to be included in the Data Package (found on the NJDEP Vapor Intrusion website).

Reporting Limits 6-Liter Canisters for Building Interior Sampling - The reporting limit is the value at which an instrument can accurately measure an analyte at a specific concentration with a defined degree of confidence that can be applied to the reproducibility and reliability of the data.

This value is above the statistical method detection limit and is set at the concentration of the lowest calibration standard.

The maximum Reporting Limit (RL) for each target analyte must be less than or equal to 0.5 ppbv as required by Method TO-15, Section 11.1.1.

The maximum RL for acetone (2-propanone) and *tert*-butyl alcohol has been elevated to address various concerns within the laboratory community. The RL for acetone is 9.0 ppbv and that for *tert*-butyl alcohol to10.0 ppbv. Laboratories can use lower RLs for these compounds.

14. Specific Requirements for Method Detection Limits, Clean Canister Certification and Reporting Limits for 1 Liter and 6-Liter Canisters used for Soil Gas Sampling

Method Detection Limits for 1-Liter and 6-Liter Canisters for Soil Gas Sampling - The laboratory shall calculate all Method Detection Limits (MDLs) in accordance Method TO-15. Section 11.2 requires the use of the procedures stated in Appendix B of 40 CFR 136 for performing the MDL study. There are specific criteria that the laboratory must meet regarding the MDL. The MDL is a statistical determination based on the requirements of the Method. The laboratory determines a level, above the statistical MDL, at which a defined degree of confidence can be applied to the reproducibility and reliability of the data. This value is commonly referred to as the Reporting Limit. Method Detection Limit Studies must be conducted yearly.

The MDL determination is the same concentration as used for the low calibration standard (for example 0.5 ppbv) in the initial calibration.

The recommended spiking level for the MDL determination is the same concentration as used for the low calibration standard (for example 0.5 ppbv) in the initial calibration.

Required MDL Levels - The maximum MDL reported for each target analyte must be less than or equal to the clean canister certification specified in Method TO-15. The clean canister certification level is established in Method TO-15, Section 8.4.1.6.

The maximum MDL for acetone (2-propanone) and tert-butyl alcohol have been elevated to address to address various concerns within the laboratory community. The MDL for acetone is 1.0 ppbv and for tert-butyl alcohol to 3.0 ppbv. Laboratories may use lower MDLs for these compounds.

The submittal requirements for the Method Detection Limit Study are located in Method TO-15 Regulatory Reporting Format (found on the NJDEP Vapor Intrusion website). This information must be reported in each Analytical Data Package generated for a sampling event.

Clean Canister Certification for 1- liter and 6-Liter Canisters for Soil Gas Sampling - The laboratory is required to follow the requirements of Method TO-15, Section 8.3 and their approved NJDEP- OQA SOP regarding cleaning and certifying canisters.

The clean canister certification level for the 1-liter canisters and 6-Liter canisters used for soil gas sampling must be down to 0.4 ppbv except for acetone and tert-butyl alcohol which have a maximum clean canister certification level of 6.0 ppbv. The laboratory has the option of using a lower reporting limit. The actual level to which the canisters are certified to must be provided for on the reporting form for clean canister certification. If the canister used for the batch certification exceeds these levels, the entire batch must be recleaned and recertified. The laboratory must document which canisters are associated with each batch certification.

The GC/MS documentation for clean canister certification is to be included in the Data Package.

Soil Gas Reporting Limits - NJDEP has elevated the Reporting Limits for the Near Slab and Sub Slab soil gas samples. The elevation of the Reporting Limits for this type of sampling is at the option of the laboratory conducting the analysis. For all compounds except for acetone and tert-butyl alcohol, the Reporting Limit has been increased from 0.5 ppbv to 5.0 ppbv. The Reporting Limit for acetone has been increased from 9.0 ppbv to 90.0 ppbv and for tert-butyl alcohol from 10 ppbv to 100 ppbv. The laboratory has the option of using a lower reporting limit.

15. Water Content in Canisters

The investigator must be aware of the height of the water table when collecting soil gas samples. The sample point must be above the capillary fringe of the water table to limit the amount of water that is collected in the canisters. Additionally, interior building samples and the associated background samples can also be affected by humidity. The analytical instrument manufacturers are acutely aware of this problem. The limitation of the laboratory’s analytical system is caused by the inability of the traps in the concentrator units to remove the water from the sample. If there is too much water in the canister, the laboratory will be unable to analyze the sample. In fact, the Entech Concentrator Model 7100 Manual states that 1.0 L of air at 70% RH and room temperature contains 18 μL of water. Therefore, if a 500 ml sample size from the canister is used the system is designed to handle up to 9 μL of water present in the injected volume. The investigator should discuss the water content limitations with the laboratory analyzing the samples.

16. Replicate Samples

The laboratory has the option to analyze a replicate sample from one of the canisters from the sampling event. A replicate analysis defined as a second volume drawn from a canister that is treated the same as the original sample in order to determine the precision of the method. The frequency of the replicate cannot exceed one sample for every twenty samples submitted for a particular sampling event. The laboratory cannot automatically add additional humidified zero air to the canister that they have chosen of the replicate analysis prior to the analysis of the parent sample and the replicate sample.

17. Tracer Compounds for Soil Gas

Tracer compounds are required to determine if the soil gas collection system is free of leaks. NJDEP is recommending the use of two tracer compounds, isopropyl alcohol or n-butane. Prior to the initiation of sampling, the investigator must contact the laboratory to determine which tracer compound the laboratory is currently including in its calibration. Laboratories are not required to provide tracer gas to the investigator. In most commercially prepared gas standard cylinders, isopropyl alcohol is in the mixture, while n-butane may not be in the standard mixture. If the investigator wants to use n-butane as the tracer compound, the laboratory will be required to obtain commercially prepared gas standards that contain n-butane.

18. Holding Times

Samples collected in stainless steel canisters must be analyzed within thirty (30) calendar days of sample collection.

19. Standards Preparations

The laboratory must use gaseous standards (not water standards) for any analysis conducted using USEPA Method TO-15. The laboratory must purchase commercially prepared gaseous standards from one of the standard suppliers. The laboratory must use standard mixtures of target gases in high pressure cylinders certified traceable to a NIST Standard Reference Materials (SRM) or NIST/USEPA approved Certified Reference Material (CRM). The use of water standards is prohibited. The laboratory must certify in the case narrative of each data package that gaseous standards have been used. The laboratory must specify their suppliers in the Standard Operating Procedure submitted to the Office of Quality Assurance for certification. The use of laboratory generated standards using static bottle dilution technique, permeation tubes, water standards or dynamic dilution using neat liquids is not acceptable.

20. Second Source for Standards

All laboratories are required to use a gaseous standard purchased from a commercial gas standard supplier for all Laboratory Control Samples. This does not preclude purchasing of other standards from a second outside source. The second source must be a commercially prepared gas standard purchased from a standard supplier. The Standards prepared by laboratory personnel from neat standards do not meet the requirements of a gas standard second source. The standard must contain all the compounds of interest. NJDEP recognizes the fact that currently there are a limited number of gas standards suppliers in the country and purchasing gas standards from different suppliers usually will involve the handling and storage of numerous gas cylinders. The second source can be from a different supplier or from an independent lot (different from the lot used for the calibration standards) certified from their current gas standard supplier. The laboratory must document in their Standard Operating Procedures how they handle the second source for standards and document it in the standards logbooks. The second source supplier and which standard uses a second source must be listed in the case narrative.

21. Method Blanks

The laboratory is required to follow the requirements of Method TO-15 Section 10.7 regarding method blanks. Any method blank that deviates from the preparation and technical acceptance requirements specified in the method is not acceptable and will be rejected. Any analysis that is related to a failed method blank will also be rejected.

22. Instrument Blanks

If the laboratory determines during the analytical sequence that an instrument blank needs to be analyzed for any reason within an analytical sequence, the instrument is to meet the requirements of Method TO-15 Section 10.7 to be acceptable. The samples must be labeled as an instrument blank and the reason for analyzing the blank documented in the case narrative and the instrument run log.

23. Laboratory Control Samples

The laboratory is required to analyze two Laboratory Control Samples (LCS) each time a method blank is analyzed.

The LCS must be prepared in the same manner as the method blank (USEPA Method TO-15 Section 10.7) with the only difference being that the canister is spiked with all compounds at a concentration of 10 ppbv or at the same concentration as the midpoint calibration standard. The LCS is required to meet the same technical requirements as a method blank as provided for in USEPA Method TO-15 Section 10.7.5.

The LCS recovery must be within 70-130 % of the spiked value for 90 % of the compounds for the LCS to be considered acceptable. In addition, the LCS must be analyzed immediately after the calibration standard and prior to the method blank analysis for each 24-hour window following the daily calibration standard.

In a calibration sequence that is used to certify a canister as clean as per the method, only one LCS sample is required to be analyzed in the sequence.

24. Internal Standards

During the course of sample analysis, the laboratory may determine that the internal standard area response is outside the control limits as established by Method TO-15, Section 10.8.6. When this occurs, the laboratory must comply with the corrective action procedures specified in the method and reanalyze the sample as required. The laboratory must report data for both the initial analysis and the reanalysis. The laboratory may not submit more than two sets of data. If upon reanalysis of the sample after corrective action, the internal standard area responses are within the control limits established by the method, the problem is determined to be within the control of the laboratory and the laboratory will submit only the compliant analysis. If upon reanalysis of the samples, the internal standard area responses are outside of the control limits established by the method, a matrix effect is occurring. This matrix effect is outside the control of the laboratory. Therefore, the laboratory will submit both analyses.

25. Analytical Sequence for Sample Analysis

Method TO-15 specifies the analytical sequence for the analysis of samples. The only addition to this sequence is the analysis of the two (2) Laboratory Control Samples prior to the analysis of the method blank and after the completion of the initial calibration sequence or daily calibration.

Method TO-15 Sections 10.4 -10.8 reference the analytical sequence required for the initial and daily calibration requirements. The laboratory must meet both the method and guide requirements for the initial and daily calibrations.

26. Dilutions Due to Calibration Range Exceedence

The laboratory in their NJDEP OQA approved Standard Operating Procedure (SOP) must establish screening procedures and procedures specifying limitation's analyte concentration above the upper point of calibration that will require dilution analysis. If the laboratory has not established these procedures, they must revise their SOP accordingly and submit the documents to the NJDEP OQA for approval.

Unless screening results determine otherwise, the laboratory must analyze the sample as undiluted. The criteria for determining when a dilution is required is when the peak response of any target analyte in the sample exceeds the peak response in the highest standard in the initial calibration. At that point, a new volume of air must be drawn from the canister, diluted and reanalyzed.

When the screening results indicate that the peak response of a target analyte will exceed the peak response in the highest standard in the initial calibration (as per the approved SOP), the laboratory is not required to analyze the sample as undiluted. Instead, the laboratory will be required to analyze the sample at a most concentrated dilution and one further dilution to demonstrate the dilution level is correct.

In both procedures, the dilution factor must keep the concentration of the target analyte that required dilution in the upper half of the initial calibration range.

If the laboratory must add air to the sample that is being diluted, the source must be humidified ultra pure zero air. This source is the same air that is used for method and instrument blanks.

All dilutions must be documented in the case narrative of the analytical data package. For samples that are initially analyzed as undiluted, and if a dilution is then required, the laboratory must report data for both analytical runs. For samples that are initially analyzed as diluted, the laboratory must report data from the most concentrated dilution and one further dilution.

Both sets of data must be submitted as individual sample results. Merging of the results on the data summary page or in electronic format is not acceptable.

Tracer Gas Dilutions - The laboratory is not required to dilute samples that have peak response of any tracer gas in a sample that exceeds the peak response in the highest standard in the initial calibration. The presence of the tracer gas in the sample must be documented in the Case Narrative of the analytical data package and the concentration reported on the data summary sheet for each sample.

Isopropanol and Ethanol - Laboratories reporting ambient air data by Method TO-15 are not required to dilute samples to bring the concentration for isopropanol and ethanol within the calibration range of the instrument (see Section VII of this appendix for additional information). The laboratory must report the sample concentrations for these two compounds in the case narrative. The laboratory should not report the isopropanol and ethanol results on any sample data summary forms within the data package, nor on any electronic data format submitted to the state.

27. Pressure and Temperature Issues

In preparing the canisters for sample collection, the laboratory establishes the flow rate of the regulators based on the barometric (atmospheric) pressure and temperature inside the laboratory. The laboratory must record the actual temperature and barometric (atmospheric) pressure of the room at the time the canisters (with the regulators) are prepared for shipment. Canister pressure for shipment from the laboratory must be set at –30 inches of mercury. The required flow control regulators will stop the sample collection at a preset level that will maintain the interiors of the canisters at a subatmospheric pressure as required by the method.

Once in the field, depending on the sampling location, the temperature and atmospheric pressure changes that will occur over the sample collection time can affect the rate of sample collection. Air samples are considered composite samples since they are collected over a set period, and the variations can be expected. Additionally, since the regulators that control the flow of the samples into the canister are preset at the laboratory, the actual flow rate into the canisters in the field may differ. Temperature changes during the time of collection can decrease or increase the rate of airflow into the canister. It will not affect the amount of sample being collected unless the temperature increase is sufficiently high enough to slow the rate of collection. Research on the effects of temperature indicates that a sharp decrease in the temperature (from the temperature at which the regulators are set in the laboratory) during the period of sample collection will increase the flow rate into the canister, while an increase in temperature will slow the flow rate. Therefore, it is important that the changes in atmospheric pressure and temperature throughout the sampling period be recorded by the investigator on the FTDS. The laboratory must record the temperature and pressure in the laboratory when they perform the pressure check of the canisters after equilibration to laboratory conditions.

Concerns have been raised regarding canisters that have been received at the laboratory at lower or higher residual pressures that expected. The flow controllers are preset at the laboratory based on the pressure inside the laboratory. Additionally, the laboratory evacuates the canisters to –30 inches of mercury based on the pressure within the laboratory. Atmospheric pressure differs from the laboratory location to sampling location. Pressure changes due to fluctuating weather conditions are a major cause of the pressure changes associated with the canisters. These changes are inherent with any type of air sampling.

Examples: If the atmospheric pressure in the field during sample collection is lower than the atmospheric pressure when the canister is received at the laboratory, the canister pressure will be more negative at the laboratory than the final pressure recorded in the field.

If the atmospheric pressure in the field during sample collection is higher than the atmospheric pressure when the canister is received at the laboratory, the canister pressure will be more positive at the laboratory than the final pressure recorded in the field.

The critical issue is that the canister valves must be closed properly by the investigator so the hard seated metal valves are not stripped by over tightening, which will cause leakage into the canisters. The investigator should consult with laboratory on the proper closing procedures for each canister type.

This guide now recommends the collection of ambient temperature and pressure readings during the collection of air samples. See the requirements of the method specific field test data sheets.

VI. Specific Method TO-17 Requirements

1. Sampling Issues

The investigator must be aware that sorbent tube sampling is more involved than just setting a stainless steel canister up in an area and coming back to pick it up. Sorbent tube sampling requires choosing the right sorbent material, pump and pump flow rate. In addition, Method TO-17 stipulates the collection of tubes in parallel at different rates. The sampling plan submitted to the department must address how the investigator intends to meet all the requirements in the guide, as well as those noted in Method TO-17. The investigator is advised to be familiar with the various sampling issues prior to initiating the sampling event.

For each sampling point, the investigator will be required to collect two sorbent tubes for each sampling point in parallel. The sorbent material in each tube must be same material. If additional tubes are required to collect analytical data for the different contaminants of concern, separate sampling units must be set up to collect the air samples.

The investigator must be aware of various issues under Method TO-17 that affect the establishment of pump flow rates, including safe sampling volumes, time weighted averaged monitoring requirements, and detection limit requirements. The pump rate must be set so that the final calculated reporting limit used by the laboratory shall be less than or equal to 0.5 ppbv.

Sampling Volume Constraints - Method TO-17 uses the direct method for determining the safe sampling volume constraints (SSVs). The direct method states the safe sampling volume is calculated by taking two-thirds of the breakthrough volume. The investigator must take into account the direct method in setting the pump flow rate

Time Weighted Average Monitoring Requirements - There are only two sampling times allowed for Method TO-17, eight (8) hour and twenty four (24) 24 hour. The investigator must adjust the pump flow rate to ensure SSVs are not exceeded during the collection period.

Detection Limit Requirements - Within the constraints of safe sampling volumes and pump flow rates limits, air volumes selected for trace level (ambient) air monitoring should be maximized. However, in all instances, the investigator must be aware that the Reporting limits cannot exceed 0.5 ppbv for any compound when reported by the laboratory.

The distributed volume pairs procedure as described in Method TO-17 Sections 10.7.2 and 14.4 is used to ensure high quality data in all initial investigations and for routine monitoring. The use of single tube sampling may be allowed only in instances where NJDEP has determined that acceptable data have been routinely obtained through use of distributed volume pairs and the ambient air is considered to be well characterized.

The minimum sample collection time for the sorbent tubes has been established by NJDEP as eight (8) hours. A twenty-four (24) hour sample collection time is the preferred sampling time, since it provides a longer time weighted average for exposure.

The sorbent tubes collected in parallel must be collected at different rates. The ratio between the two rates must be maintained at a proportion of 1:4. The investigator can adjust the flow rate to accommodate low safe sampling volumes by proportionally reducing both rates. However, the lower flow rate result cannot result in a sample volume less than 300 mL total volume. The 300 mL sample gives adequate detection limits (<0.5ppb per analyte) using a full scan GC/MS.

The choice of TO-17 sampling apparatus is left to the investigator. However, the apparatus must conform to USEPA Method TO-17 Section 6.3.1, which requires accommodations for two sampling tubes with the capability of independent control for sampling rate at a settable value in the range of 10 to 200 ml/min.

2. Ambient Pressure and Temperature Requirements during Sample Collection

Method TO-17 requires the collection of the ambient temperature and pressure during the sample collection time in order to calculate the concentrations reported for each sample.

For a sampling event there are two ways to attain this information. The first way is to obtain the information from the nearest weather reporting station. This information can be acquired directly from the station or this information from the Internet. Two websites that may be useful to the investigator are the National Oceanic and Atmospheric Administration, National Weather Service website at http://www.weather.gov or Weather Underground at http://www.wunderground.com/. The investigator can also bring portable instrumentation on site to obtain the information real time. The investigator must specify how the ambient pressure and temperature was obtained in the sampling plan, including but not limited to the weather station from which the information will be obtained or the make and model of the portable instrument to utilized. In the sampling report, the actual procedures used must be specified.

For interior samples, the collection of ambient temperature cannot be obtained from a weather station or the Internet. This information must be obtained from portable instrumentation brought on site by the investigator to obtain the information real time. This information is sample location specific, because there can be temperature variations with a building. So as part of the sampling plan that uses Sorbent tubes, the investigator must specify how this information is to be collected and the type of instrument that will be used in the interior of buildings. In the sampling report, the actual procedures used must be specified.

3. Field Test Data Sheets

The Field Test Data Sheets (FTDS), as provided on Page 17-37 of the Method TO-17 and reproduced at the end of this appendix as part of the Method TO-17 Regulatory Reporting Format, must be completed to record all the required information regarding the sampling event. At the end of the sampling period and PRIOR to switching off the each pump, the investigator is required to recheck all sampling flow rates and record this information on the FTDS.

The FTDS or a copy must accompany the tubes to the laboratory for inclusion with the analytical data package and for the laboratory to properly report the data. The FTDS must be located immediately behind the case narrative of the data package and prior to any sample data.

4. Method TO-17 Sorbent Tubes

The laboratory shall prepare sorbent tubes and the blank tubes in accordance with the procedures specified in the SOP approved by the NJDEP Office of Quality Assurance during the certification process and with the provisions of the method.

5. Temperature Requirements for Sample Shipment

The cartridges must be chilled after sample collection with artificial ice to <4^o Centigrade and stored in refrigeration at the laboratory at less than 4^o Centigrade unless the samples are analyzed on the same day they are collected. The samples must be stored in an organic solvent free environment. For shipment to and from the field, small packages of activated charcoal/ silica gel must accompany each shipment container of multiple tubes.

6. Temperature Indicators for Sample Shipment

The laboratory may include a temperature indicator bottle in every shipping container containing sorbent tubes. The temperature indicator bottle shall contain an appropriate liquid for monitoring the temperature of the shipment case and the samples on arrival at the laboratory. The laboratory is to place the temperature indicator bottle in an appropriate position in the shipping container with the sample bottles. On receipt, sample custody personnel shall determine the temperature of the shipping container and contents as cited below:

Locate temperature indicator bottle, remove screw cap and insert a calibrated thermometer (-50 to 50^{o} Centigrade). Permit the thermometer to equilibrate for 3 - 5 minutes. The Sample Custodian must record the temperature on the appropriate chain of custody and other appropriate documents.

As an alternative to using a thermometer, the laboratory may check the temperature of a sample bottle by using an infrared thermometer. Use of an infrared thermometer must comply with NJDEP's laboratory certification code at N.J.A.C. 7:18-3-3(a) 5 specifically, the verification and accuracy requirements set forth in N.J.A.C. 7:18-3-3(a) 5v. Infrared temperature measuring devices must be verified quarterly and the data entered into a logbook signed by the analyst.

7. Sample Delivery Group

A Sample Delivery Group (SDG) is a unit of no greater than ten sorbent tube samples collected at a particular site. The SDG assignment is made upon receipt of the samples at the laboratory's facility. If less than ten (10) samples are submitted for a particular site, it is considered a single Sample Delivery Group. If more than ten samples are submitted from a particular site, then the laboratory is required to split those samples into separate Sample Delivery Groups of 10 or less and analyze each sample delivery with the appropriate number of QC samples for each group.

A SDG is a group of 10 or fewer samples received over a period of up to seven (7) calendar days, excluding Sundays and government holidays. In addition, samples from the sampling event may be assigned to Sample Delivery Groups at the discretion of the laboratory.

The SDG assignment made by the laboratory is not related to the analytical sequence. The sample delivery group assignment is strictly used to track the movement of the samples in the laboratory and the production of the analytical data package.

8. Method Detection Limits

The laboratory shall calculate all Method Detection Limits (MDLs) in accordance Method TO-17, Section 14.2 that requires the procedures, as stated in Appendix B of 40 CFR 136. The maximum MDL for each Method TO-17 target analyte must be less than or equal to 0.5ppb as required by Method TO-17 Section 14.1. The data must be reported in ppb.

There are specific criteria that the laboratory must meet. The MDL is a statistical determination based on the requirements of the Method. The laboratory establishes a level above the Statistical MDL at which they determine, with a certain degree of confidence, the reproducibility and reliability of the data. In such instances, the laboratory states this value as the Reporting Limit.

According to Method TO-17 Section 7.4, “Detection Limits and Maximum Quantifiable Concentrations of Air Pollutants,” detection limits for atmospheric monitoring vary depending on several key factors. These factors are:

- Minimum artifact levels
- GC detector selection
- Volume of air sampled

The volume of air sampled is in turn dependent upon a series of variables including SSVs, pump flow rate limitations, and time weighted average monitoring time constraints.

Generally speaking, detection limits range from sub-part-per-trillion (sub-ppt) for halogenated species, such as CCl_4, and the freons using an electron capture detector (ECD) to sub-ppb for volatile hydrocarbons in 1 Liter air samples using the GC/MS operated in the full SCAN mode.

Detection limits are greatly dependent upon the proper management of water for GC capillary analysis of VOC in air using sorbent technology.

The submittal requirements for the Method Detection Limit Study are located in Method TO-17 Regulatory Reporting Format (found on the NJDEP Vapor Intrusion website). This information must be reported in each Analytical Data Package generated for a sampling event.

9. Reporting Limits

The reporting limit for Method TO-17 is based upon the amount of air that is drawn through the tube during sample collection. The investigator must provide the actual amount of air pulled through the tube. The FTDS found on page 17-37 of the method and in the Method TO-17 Regulatory Reporting Format should be used to record all of the field information. The reporting limit will vary from sample to sample based on the volume of air drawn through the tube. The reporting limit for any compound may vary from sample to sample. However, the reporting limit for any compound cannot <u>exceed 0.5 ppb</u>.

10. Holding Times

Cartridges must be analyzed within 30 calendar days, except for when limonene, carene, bis-chloromethyl ether and labile sulfur or nitrogen containing volatiles are present. If these compounds are expected to be present, the holding time is 7 calendar days from sample collection.

11. General Analytical Requirements

In accordance with the requirements of Method TO-17 Section 8.2 “Apparatus”, thermal desorption of the tubes into the trap is required. Following the desorption procedures, section 8.2.5 “GC/MS Analytical Components” states that the requirements of Method TO-15 are to be followed. Therefore, the laboratory must meet any analytical or quality assurance requirements pertaining to Method TO-15 following desorption into the trap. The laboratory must meet all QA/QC requirements as specified in N.J.A.C. 7:18-5-5 and Methods TO-15 and TO-17.

12. Standard Preparations

The laboratory is allowed to use both gas phase standards (Method Section 9.2) and liquid phase standards (Method Section 9.3) for Method TO-17.

Gas Standard Requirements - The laboratory must use standard mixtures of target gases in high-pressure cylinders certified traceable to a NIST Standard Reference Materials (SRM) or NIST/EPA approved Certified Reference Material (CRM). The use of water standards is prohibited. The laboratory must certify in the case narrative of each data package that gaseous standards have been used. The laboratory must purchase gaseous standards from a standard supplier. The laboratory must specify their suppliers in the Standard Operating Procedure submitted to the Office of Quality Assurance for certification.

Liquid Standard Requirements - The laboratory must use liquid standards that are certified traceable to a NIST Standard Reference Materials (SRM) or NIST/EPA approved Certified Reference Material (CRM). The laboratory must certify in the case narrative of each data package when liquid standards are used. The laboratory must purchase liquid standards from a standard supplier. The laboratory must specify their suppliers in the Standard Operating Procedure submitted to the Office of Quality Assurance for certification.

13. Laboratory Blanks

The laboratory is required to follow the requirements of Method TO-17 Sections 10.7.1.1 and 13.1.1 regarding the type and frequency of analysis of laboratory blanks. Laboratory blanks are sorbent tubes with identical packing as the tubes used for sample collection and are from the same batch. They are stored in the laboratory at <4^{o} Centigrade in a cleaned, controlled condition during the time the environmental samples are out being collected. In addition, the laboratory blanks are analyzed at the same time as the environmental samples, one at the beginning and one at the end of the sequence of runs. Laboratory blanks, as defined in Method TO-17, is equivalent to method blanks, as utilized in Method TO-15.

14. Field Blanks - Method TO-17

Field blanks are required when samples are collected for Method TO-17 analysis. The investigator and the laboratory are required to follow the requirements of Method Sections 10.7.1.2 and 13.1.1.

15. Laboratory Control Samples

The laboratory is required to analyze one laboratory control sample (LCS) each time a method blank is analyzed. They are stored in the laboratory at <4^{o} Centigrade in a cleaned, controlled condition during the time the environmental samples are out being collected.

The LCS must be prepared in the same manner as the laboratory blank (Method Section 10.7) with the only difference being the tube is spiked with all compounds at a concentration of 20 ngs. In addition, the LCS recovery must be within 70-130 % of the spiked value for 90 % of the compounds of the LCS to be considered acceptable.

The LCS must be analyzed immediately after the calibration standard and prior to the laboratory blank analysis for each 24-hour window following the daily calibration standard.

16. Analytical Sequence for Sample Analysis

Once the GC/MS run has been initiated by desorption of the focusing trap, Method TO-17 Section 11.3.2.1 requires that the chromatographic procedure continue as described in Method TO-15. The only deviations are that the laboratory blanks must be run as required by Method TO-17 Sections 10.7.1.1 and 13.1.1 and the laboratory control sample must be analyzed after the analysis of the first laboratory blank.

17. GC/MS Instrument Performance Tune Check Standard Requirements

The GC/MS Instrument Performance Tune Check Standard must contain BFB and cannot be combined with any calibration standard to create an injection consisting of a calibration standard and the tune solution. The BFB Tune Check Solution is the first injection in any 24-hour sequence. The BFB tune must meet the requirements of Method Sections 10.4.3 and 10.4.4 to be considered acceptable.

VII. Isopropanol and Ethanol

Isopropanol and Ethanol are components of many products used within residences and businesses in New Jersey. The concentrations of these two compounds in the indoor air samples are causing laboratories analyzing indoor air samples to conduct dilutions of samples because the concentrations exceed the calibration range of the instrument. These two compounds are routinely added to the gas cylinders supplied by the commercial standard suppliers. According to the standard manufacturers, ethanol is not stable within the standard mixtures. Additionally, laboratories cannot meet the reporting limit requirements of Method TO-15 for these compounds.

If these compounds are of concern at site, Method TO-17 must be used for the analysis of these compounds. Appendix 1 of Method TO-17 provides recommended sorbent material for the collection of alcohols. The investigator should also contact commercial suppliers of the sorbent tubes for the new advances in tubes.

Therefore, laboratories reporting ambient air data analyzed by Method TO-15 are required to report the concentrations of ethanol and isopropanol in the case narrative of the analytical data package. The laboratory is not required to dilute the sample to bring the concentration of these two compounds within the calibration range of the instrument. The laboratory should not report this data on any Sample Data Summary Forms within the data package, nor on any electronic data format submitted to the state.

VIII. Chain of Custody Requirements for Both Methods

Chain of custody commences with the preparation of the canisters or the sorbent tubes at the laboratory for shipment to the investigator. The laboratory will initiate the chain of custody on the forms and then transfer the canister and/or tubes under strict chain of custody to the investigator. Copies of the forms used by NJDEP are found on the NJDEP Vapor Intrusion website. The laboratory providing empty shipping containers to any investigator must seal empty shipping containers with custody seals.

Upon receipt of the canisters/tubes from the laboratory, the investigator should open the shipping containers to determine if the correct number of canisters/tubes was received from the laboratory. For a sorbent tube sampling, the investigator must determine that the shipping container contains artificial ice, a temperature bottle (if used) and the small packages of activated charcoal/silica. The investigator should document the condition of the shipping containers and its contents for both methods. If the sorbent tubes are not properly shipped, the integrity of the samples is compromised. An artificial ice exchange should be planned by the investigator prior to initiation of the sampling event to ensure that the sorbent tubes after sample collection are stored at less than 4^{o} Centigrade. The investigator must check the temperature of the shipping container upon receipt either through the temperature bottle or the infrared thermometer instrument.

The investigator must record the appropriate information on the chain of custody document for each sampling point as well as the Field Test Data Sheets that are provided for each method (found on the NJDEP Vapor Intrusion website). The investigator then ships the samples back to the laboratory where an authorized representative from the laboratory accepts custody and annotates such on each chain of custody document.

The laboratory has responsibility for storage and internal distribution of the sample. Each time responsibility for the sample changes from one individual to another, the laboratory shall record the changes on the laboratories own internal chain of custody form and sign it. On completion of sample analysis, attach all chain of custody documents to the data report and forward to the investigator. The laboratory must ensure that chain of custody forms are maintained in the laboratory and the forms travel with the samples throughout the laboratory. The form must bear the name of the person assuming responsibility of the samples and the date. The chain of custody is only acceptable if there is no lapse in the custody.

Real copies of the laboratories Internal and External chain of custody forms must be provided for review and approval in the sampling plan.

IX. Raw Data Storage for both Methods

The laboratory is responsible for storing the raw data collected during the analysis of all samples. Raw data consist of both electronic files and bound laboratory notebooks.

1. Bound Laboratory Notebook

The laboratory must maintain bound notebooks to record all raw data. The analyst must sign all entries in this laboratory notebook. The analyst's supervisor MUST also sign entries in this notebook. This information includes but is not limited to instrument run logs, canister certification batch assignments, canister preparation and receipt information, and the addition of air to bring up to volume documentation.

2. Electronic Data Storage and Retrieval System

The laboratory shall store GC/MS and other electronic data in a format retrievable on line to the data system for ten (10) years. The laboratory shall store the data storage medium under secure and appropriate environmental conditions to preclude the loss of data.

X. Data Package Reporting Deliverable Formats

NJDEP will not accept a reduced data package deliverables for any TO Method. This includes methods for which NJDEP has not developed a specific deliverable format. If the proposed method doesn’t specified deliverable format, the investigator should contact the Department and a deliverable format will be specified based on the analytical requirements of the method. Once the format is specified, a defined deliverable format will be developed.

NJDEP has developed deliverable formats for the two methods that will be used most frequently in New Jersey. The deliverable format for USEPA Method TO-15 was developed for the Professional Laboratory Services Contract entitled “ Laboratory Analysis of Air Samples Collected at Hazardous Waste Sites.” This format is governed by the requirements of this contract and will be updated as the contract is revised. The deliverable format for USEPA Method T0-17 was developed specifically to address the needs of the sampling guide, since a contract has not been issued for this method.

As part of the deliverable format developed for these two methods, three electronic deliverables have been incorporated in the requirements. These electronic formats described below are required for each and every sampling event. If a proposed method does not have an established deliverable format and it has to be specified by the department, it will automatically include the three electronic deliverables.

For all methods, the laboratory must at a minimum deliver to the investigator an original final data report and original data package summary, with one copy of the final data report and two copies of the summary data package to the investigator. The investigator is required to forward the original data report and the original summary data package to NJDEP for review along with the electronic deliverables to the NJDEP. Submittal of copied (or double-sided) data packages is not acceptable.

The analytical data packages shall be submitted to NJDEP in the format specified and must contain all the required documentation as set forth in the Deliverable format. The data package must be organized and formatted as per the requirements of the Deliverable format.

The analytical data generated by the instrumentation used to analyze the canisters and report the Method TO-15 data must be submitted in ppbv units. Submittal of instrumentation data in nanograms, ng/L, μg/m^3 or any other format is not acceptable for validation. The Method Detection Limit Study must also be submitted in ppbv.

The analytical data generated by the instrumentation used to analyze the sorbent tubes and report the Method TO-17 data must be submitted in nanograms. Submittal of instrumentation data in any other unit is not acceptable for validation. The Method Detection Limit Study must be submitted in ppb.

All data must be securely bound along the left margin. Once properly prepared by the laboratory, the data package shall not be reorganized.

1. Electronic Deliverables

The investigator is required to deliver three types of Electronic Deliverables to the Department. Each electronic deliverable requires a separate diskette with the information formatted as specified below.

The first electronic deliverable is entitled "Electronic Data Deliverable Format" and is used to document general information regarding the sampling event and analysis of the samples.

The second electronic deliverable consists of two tables. The first table is the "Method TO-15 Units Conversion Table" and is used to provide the analytical data in both ppbv and μg/m^3. The second table is the "Method TO-17 Units Conversion Table" and is used to provide the analytical data in nanograms and μg/m^3.

The third electronic deliverable is the Hazsites Electronic Data Submission.

<u>Electronic Data Deliverable Format</u> - The laboratory shall use the following format to document general information regarding the sampling event and analysis of samples. This information is to be delivered on a separate diskette.

ELECTRONIC DATA DELIVERABLES FORMAT TABLE			
Field Name	***Type***	***Length***	***Comment***
Site ID	Character	12	DEP site name.
Site Name	Character	40	DEP site name.
Initial Date Sampled	Date	10	Format: mm/dd/yyyy
Received at Lab Date	Date	10	Format: mm/dd/yyyy
Analysis Complete Date	Date	10	Format: mm/dd/yyyy
Laboratory	Character	30	Lab Name.
Number of Samples	Integer	3	
Contract	Character	6	None (include word none)
Report Format	Character	10	Regulatory
Field ID (for each sample)	Character	15	Unique ID from chain of custody form.
Laboratory ID (for each sample)	Character	15	Unique ID established by the lab.
Date Sampled (for each sample)	Date	10	Format: mm/dd/yyyy
Matrix (for each sample)	Character	10	AIR

Notes: Character fields must present all alphabetic characters in the upper case. Submit this information on double density or high density 3.5" diskettes. Contain the data fields in a Word Pad Text Document MS-DOS Format in a file named SAMPLE.TXT." Enter each data field on a separate line concluded by a carriage return line feed combination (ASCII characters 13 and 10). The file must appear as the following with values in place of the field names and ellipses where “n” equals the number of samples:

Site ID
Site Name
Initial Date Sampled
Received at Lab Date
Analysis Complete Date
Laboratory
Number of Samples
None
Report Format
Sample 1 Field ID
Sample 1 Laboratory ID

Sample 1 Date Sampled
Sample 1 Matrix
Sample 2 Field ID
Sample 2 Laboratory ID
Sample 2 Date Sampled
Sample 2 Matrix
Sample n Field ID
Sample n Laboratory ID
Sample n Date Sampled
Sample n Matrix

Method TO-15 Units Conversion Table - This table is in a Microsoft Excel spreadsheet and provides an imbedded calculation to convert the ppbv results obtained by the laboratory to μg/m^3. A separate excel work sheet within one Microsoft Excel™ file must be provided for each field sample. The name for each work sheet inserted at the bottom must be the Laboratory File Identification number not the Field Sample Identification Number. Additionally, a separate printed worksheet must be provided for each field sample directly behind the case narrative for each sample. The order of the compounds on the table can be revised to the order of elution of the compounds from the GC/MS. The files must be named with the SRP Identification Number and end with ".xls". Electronic copies of the Conversion Table are posted on at http://www.nj.gov/dep/srp/guidance/vaporintrusion.

Method TO-17 Units Conversion Table - This table is in a Microsoft Excel spreadsheet and provides an imbedded calculation to convert the nanograms results obtained by the laboratory to μg/m^3. A separate excel work sheet within one Microsoft Excel™ file must be provided for each field sample. The name for each work sheet inserted at the bottom must be the Laboratory File Identification number not the Field Sample Identification Number. Additionally a separate printed worksheet must be provided for each field sample directly behind the case narrative for each sample. The order of the compounds on the table can be revised to the order of elution of the compounds from the GC/MS. The files must be named with the SPR Identification Number and end with ".xls". Electronic copies of the Conversion Table are posted at http://www.nj.gov/dep/srp/guidance/vaporintrusion.

For compounds that are not listed in the tables, the laboratory is to add these compounds at the end of the current list of compounds.

Hazsites Electronic Data Submission of Results

A) Acceptable Format

The investigator shall use the following format to electronically deliver the analytical results. This information shall be delivered on a separate diskette. Results of laboratory analysis are to be electronically submitted in one of the following ways.

The HAZSITE Database is a stand-alone data collection application that contains all the required fields, help screens, and built-in checks to ensure data meets the required format. If the laboratory uses this option, it must first create DATASET and SAMPLE records from information provided by NJDEP and then create the RESULTS records. A diskette copy of this application, identified as HazSite4 LATEST VERSION, may be requested from NJDEP by calling (609) 292-9418 or the document can be downloaded from the DEP Home Page at http://www.state.nj.us/dep/srp/hazsite.

The Electronic Data Submission Application (EDSA) contains built-in checks to ensure data meets the required format. If the laboratory uses this option, it must first create DATASET and SAMPLE records from information provided by DEP, and then create the RESULTS records. A CD containing this application and other support tools of this application, may be requested from DEP by calling (609) 292-9418, or the hazsite materials can be downloaded from the DEP Home Page at http://www.state.nj.us/dep/srp/hazsite.

B) Analytes/Parameters

The analytes and parameters for which results are being submitted must appear exactly as they appear in the DEP internal system. If using the HazSite4 LATEST VERSION option, the analytes/parameters are included in the HazSite4 LATEST VERSION as a "pick list". If using the .wk1 or .dbf file format option for submission of results, the analytes/parameters list can be obtained from the NJDEP in hard copy and must be used by the laboratory. This file may be obtained from NJDEP in a hard copy format and or as an ELECTRONIC file on diskette by calling 609-292-9418.

C) Additional Data provided by the investigator

The investigator will provide to the laboratory the first three fields required for the electronic submission of results. These fields are SRP ID, Sample Date, and Sample Number.

D) Data Transmission

All physical media sent to the department must be in an IBM-Compatible format. Files are to be transmitted on 3.5" 1.44 IBM formatted diskettes.

The laboratory should transmit the diskette to the investigator for that sample batch along with the other documents submitted as part of the required deliverables. A transmittal letter indicating the facts of the electronic data submittal must accompany the official hard copy submission of the Data Report. The memo should specify exactly what data is being submitted. The diskette should be labeled on its exterior as "Analytical Results" and include the Site Name and Data of Submittal.

E) Discussion of Fields

For clarification on the definition of fields, please see the SRP-Electronic Data Interchange (EDI) manual, at http://www.nj.gov/dep/srp/hazsite/docs/.

F) Additional Field Requirements

The last column in the Hazsites results file format is labeled "QAQC". The laboratory will populate this field with the Sample Delivery Group Number that is assigned to particular group of samples. The field must be populated for every compound. The field length is currently a maximum of 15 characters in length.

Two additional fields are added following the field labeled "QAQC". These fields are to be used to report the analytical data as it comes off the instrument. The laboratory will populate both fields for every compound. The field lengths for both columns are currently a maximum of 15 characters in length.

The first field is named "UNCCONC" and will used for reporting the "uncorrected" result value. This is a numeric field only with a decimal point as needed. This is the concentration that is reported off the instrument prior to conversion to $\mu g/m^3$.

The second field is named "UNCUNIT" and will be used for the "uncorrected" results unit value. This is also used for the detection limit units. The field will be populated with "ppbv” (Method TO-15) and “ngs” (Method TO-17) as the uncorrected result concentration unit.

METHOD TO-15 CANISTER SAMPLING FIELD TEST DATA SHEET

A. GENERAL INFORMATION

Site Location:____

Site Address:____

Field ID No:_________________________ Size of Canister:_________________________

Sampling Date(s):____________________ Canister Serial No:________________________

Shipping Date:_______________________ Flow Controller No:_______________________

B. SAMPLING INFORMATION

TEMPERATURE (Fahrenheit)

	Interior	**Ambient**	**Maximum**	**Minimum**
Start				
Stop				

PRESSURE (inches of Hg)

	Ambient	**Maximum**	**Minimum**
Start			
Stop			

CANISTER PRESSURE (inches of Hg) FROM GAUGE

Start		
Stop		

SAMPLING TIMES (24 hour clock)

	Local Times	**Elapsed Time Meter Reading**
Start		
Stop		

____

Signature/Title of Investigator

C. LABORATORY INFORMATION

FLOW RATES (ml/min)

	Flow Controller Readout	
Shipping out from Lab		required (from lab record log) after return
Receiving in Lab		(if applicable)

CANISTER PRESSURE

	Inches of Hg	
Initial Pressure (to field)		required (from lab record log) after return
Final Pressure (from field)		required (from lab record log) after return

Data Shipped: ________________________

Date Received: ________________________

Individual Canister Certification (provide File #): ______________________

Batch Certification (provide Batch ID#): ______________________

____

Signature/Title

GC/MS Analyst for TO-15

COMPENDIUM METHOD TO-17
FIELD TEST DATA SHEET

A. GENERAL INFORMATION

Project________________________________ Date(s) Sampled:______________
Site:_________________________________ Time Period Sampled:___________
Location:____________________________ Operator:_________________________
Instrument Model No:__________________ Calibrated By:______________________
Pump Serial No:___________________________ Rain:_______Yes________No

ADSORBENT CARTRIDGE INFORMATION:

	Tube 1	Tube 2
Type:	______________	______________
Adsorbent:	______________	______________
Serial No:	______________	______________
Sample No:	______________	______________

B. SAMPLING DATA

Tube Id	Sampling Location	Ambient Temp, °F	Ambient Pressure, in Hg	Flow Rate (Q), mL/min		Sampling Period		Total Sampling Time, min	Total Sample Volume, L
				Tube 1	Tube 2	Start	Stop		

C. FIELD AUDIT

	Tube 1	Tube 2
Audit Flow Check Within 10% of Set Point (Y/N)?	pre-______________	pre-______________
	post-	post-

CHECKED BY:__________________________________
DATE:______________________________________