VAPOR INTRUSION MITIGATION SYSTEM CURTAILMENT AND SHUTDOWN FACT SHEET

A key concept throughout the process of designing, implementing, and operating a vapor intrusion mitigation system (VIMS) is using monitoring data to optimize system operation over time and evaluating whether the monitoring data and vapor intrusion (VI) conceptual site model (CSM) potentially support a reduction in monitoring scope and/or monitoring termination. It is recognized that in some cases the continued operation of an active or passive VIMS may be required indefinitely. In other instances, multiple lines of evidence (MLE) may support elimination of ongoing system operation and monitoring requirements entirely. See the **Multiple Lines of Evidence Fact Sheet** for more information.

This fact sheet presents a framework to consider for optimizing the monitoring and operation of a VIMS based upon long-term site management objectives while prioritizing effective management of the VI pathway. The objectives in this document may not be appropriate to consider for every site. Further, state and local regulatory requirements may preclude implementation of some of the strategies and processes discussed herein.

This fact sheet discusses three common site management objectives and conceptual approaches that can be considered to achieve the following objectives:

- Objective 1: Reduce ongoing system monitoring requirements.
  - After multiple rounds of VIMS performance monitoring, there may be increased confidence in the operation of the VIMS and understanding of the VI CSM, which collectively may support a reduced monitoring scope of work.
- Objective 2: Transition from active to passive system operation.
  - MLE may support the transition of an active mitigation system to passive operation, or in the case of a large building, the transition of a targeted portion of a building from active to passive operation.
- Objective 3: Develop a shutdown strategy to terminate ongoing VIMS monitoring and/or operation.
  - MLE may indicate that ongoing monitoring of a mitigation system is no longer warranted because, for example, the source of vapors from vapor-forming chemicals (VFCs) may be remediated or may biodegrade within the life cycle of a mitigation strategy and therefore, in some cases, render the system (or targeted areas of the system footprint) unnecessary.

One or each of these scenarios could exist for a given building. For example, there are often cases where VIMS are installed and operated out of an abundance of caution because of uncertainties associated with spatial and temporal variability in the sampling and analysis of data, background sources, and/or conservative regulatory guidance. In this situation, the performance monitoring data could support an initial reduction of the scope of ongoing monitoring, then lead to transitioning the system from active to passive operation, and eventually to terminating future monitoring and/or VIMS shutdown because MLE indicate the potential for a complete VI pathway does not exist.

Alternatively, MLE may be sufficient to support an immediate transition from active operation to terminating system operation and monitoring (i.e., progressing through the three objectives presented above in a step-by-step, sequential sequence may not be necessary). Regardless of the exact scenario, VIMS management decisions should be considered only when MLE support system modifications and/or scope reductions and in accordance with applicable regulatory requirements.

The primary VIMS monitoring approaches presented in this fact sheet focus on sub-slab vapor chemical data, sub-slab-to-indoor air differential pressure monitoring, and indoor air sampling because these metrics are more commonly applied and are also most referenced in regulatory VI guidance(s). Research into additional and alternative approaches for VI assessment and mitigation design and performance monitoring has been demonstrated and validated through Environmental Security Technology Certification Program (ESTCP) projects. These methods can also be used to assess the continued need for a mitigation system or whether the system may be considered for decommissioning. For example, the goal of ESTCP (McAlary et al. 2018) was to demonstrate and validate a more rigorous and cost-effective process for design and optimization of VIMS to reduce the capital and long-term operating costs. The mass-loading and mass-flux assessment methodologies applied in ESTCP (McAlary et al. 2018; 2020) can also be used to understand whether the rate of mass removal from a system has resulted in decreased concentrations of VFCs to levels below the risk-based screening level for mass loading and therefore no longer pose a risk for VI (McAlary et al. 2018; 2020).

Vapor Intrusion Mitigation System Curtailment Framework

The purpose of the VIMS curtailment framework (the Framework) is to present common VIMS site management objectives and conceptual approaches that can be considered to achieve those objectives. The underpinning concept of this fact sheet is the use of MLE to demonstrate system performance and the protection of building occupants from VI over time, which thereby can be used to support VIMS management decision-making.

The concepts behind the Framework are an expansion of existing VI regulatory guidance documents on the subject. In general, existing VI regulatory guidance on the topic of VIMS curtailment and shutdown focuses either solely on curtailment strategies or does not discuss the concept. In a review of existing VI regulatory guidance documents Eklund et al. (2018) included an evaluation of various state provisions for curtailment strategies. States such as Massachusetts (MADEP 2016), New York (NYSDOH 2006), New Jersey (NJDEP 2021), and Wisconsin (WDNR 2018) include recommendations for certain data collection efforts to support a curtailment strategy decision, such as the following:

- Verification sampling and analysis of sub-slab vapors and/or indoor air and outdoor air and comparison to protective screening levels
- Temporary shutdown of system operation prior to the verification sampling to allow vapor concentrations to rebound to potential levels that might be expected after system shutdown
- Multiple verification monitoring events to account for temporal variability
- Operation of the system between verification monitoring events or indoor air monitoring to maintain protectiveness

This Framework follows the above principles established in some VI regulatory guidance documents and expands the concepts beyond the sole focus of curtailment strategies to broader VIMS management decision-making, such as potential scope reductions over time and/or transitions from active to passive system operation.

The time frame for remedial actions to address VI can vary. Although active or passive mitigation may be ongoing for some time, site managers should develop a plan for stepping down and/or terminating mitigation systems in advance. Regulatory programs may direct responsible parties to continue mitigation until VI sources are sufficiently reduced to demonstrate a clear plan for ending remedial activities. This plan should outline specific criteria for determining when the site no longer poses an unacceptable VI risk. Factors such as mitigation techniques, performance criteria, cleanup goals, source area remediation/removal, exposure points, and current and future building use should be considered. The curtailment strategy should be documented in a decision document with well-defined, achievable outcomes.

Creating a VIMS management and curtailment strategy framework is challenging because every site and VI CSM is unique; regulations and guidance varies by site location; mitigation design, operation and performance monitoring data, and approaches and requirements vary; and the state of the VI practice is constantly evolving, which means the approaches to assess, mitigate, and evaluate the performance of a VIMS advances over time. This Framework is therefore intended to be general so that the readers can apply the concepts to a broad range of scenarios and conditions while simultaneously being detailed enough to be usable and practical. For example, many of the approaches discussed herein involve the collection and analysis of sub-slab vapor chemical data, sub-slab-to-indoor air differential pressure data, and/or indoor air sampling data to evaluate the performance of a VIMS. This is largely because these three approaches are currently the most commonly applied metrics in the VI industry to evaluate the performance of a VIMS.

This Framework is not intended to imply that one, or each, of the three commonly used metrics are the only MLE that can be used to support VIMS management decision-making. The more important concept to follow is that MLE should be used to support decision-making, and a single line of evidence (LOE) may be more appropriate or applicable than others depending upon the site and regulatory conditions. For these reasons, the reader is encouraged to refer to the **Multiple Lines of Evidence Fact Sheet** to supplement this fact sheet.

The Framework focuses on three common objectives that stakeholders may have related to the long-term management of a VIMS. For each of the objectives, a hypothetical general scenario and flow chart or table is presented to consider whether MLE are supportive of achieving the target objective and to aid in regulatory decision-making.

Flow Charts

This Framework consists of three common VIMS management objectives, as follows:

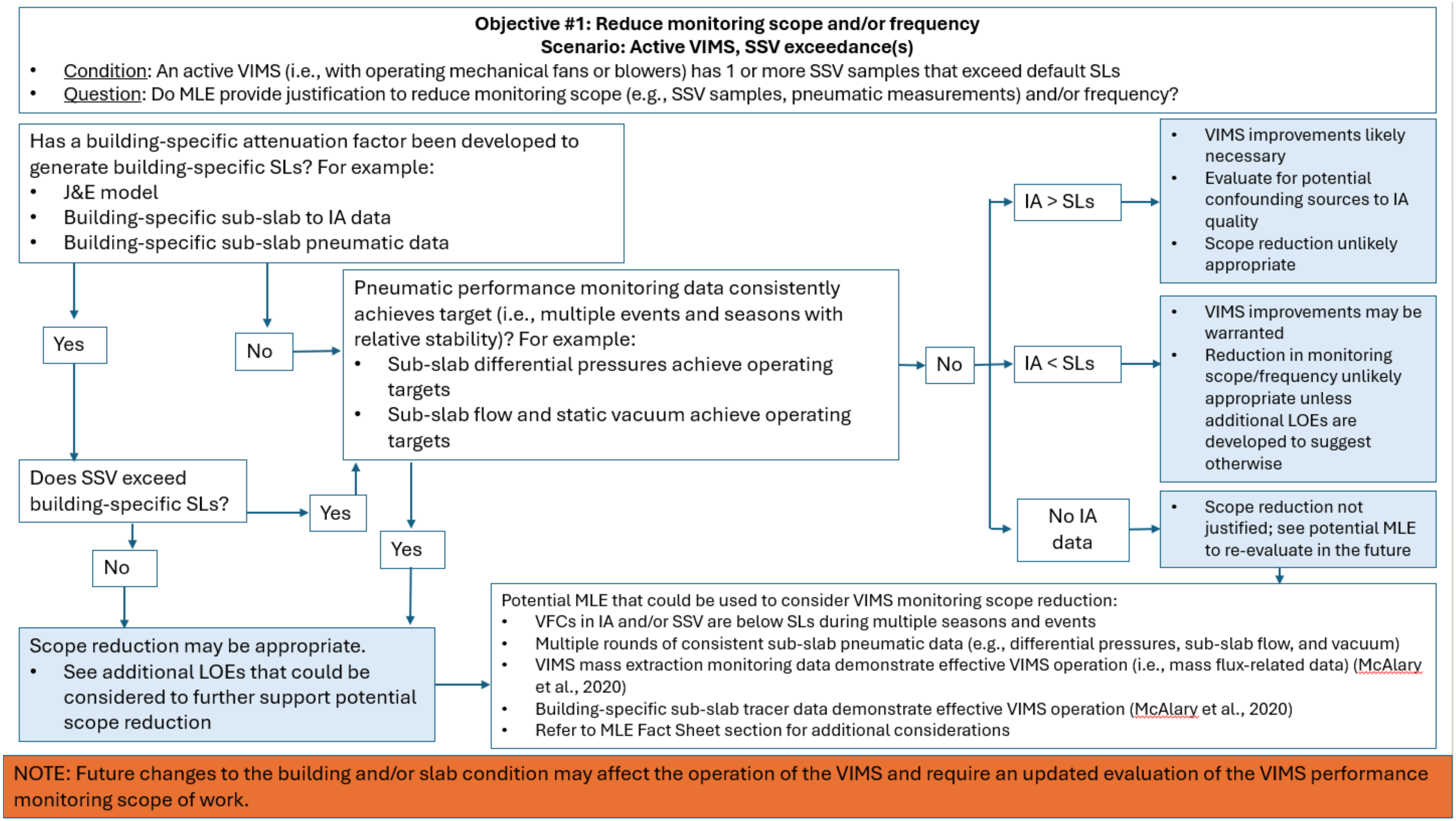
Objective 1: Reduction of ongoing system monitoring requirements (**Figure 1**)

- After multiple rounds of VIMS performance monitoring, there may be increased confidence in the operation of the VIMS and understanding of the VI CSM, which collectively may support a reduced monitoring scope of work.

For Objective 1, a scenario is presented involving an active VIMS with one or more sub-slab vapor concentration exceedances at sub-slab monitoring probes. It is important to note that this particular VIMS management objective could be sought for multiple different scenarios, not just the one presented in the flow chart. For example, there could be an objective to reduce the monitoring scope of work for a passive VIMS with or without sub-slab vapor concentration in excess of applicable screening levels. While the details of the approach for achieving the target objective in an alternative scenario may differ, the underpinning concept of the flow chart can still be applied, which is that MLE should be relied upon to demonstrate building protectiveness from VI and to support VIMS decision-making.

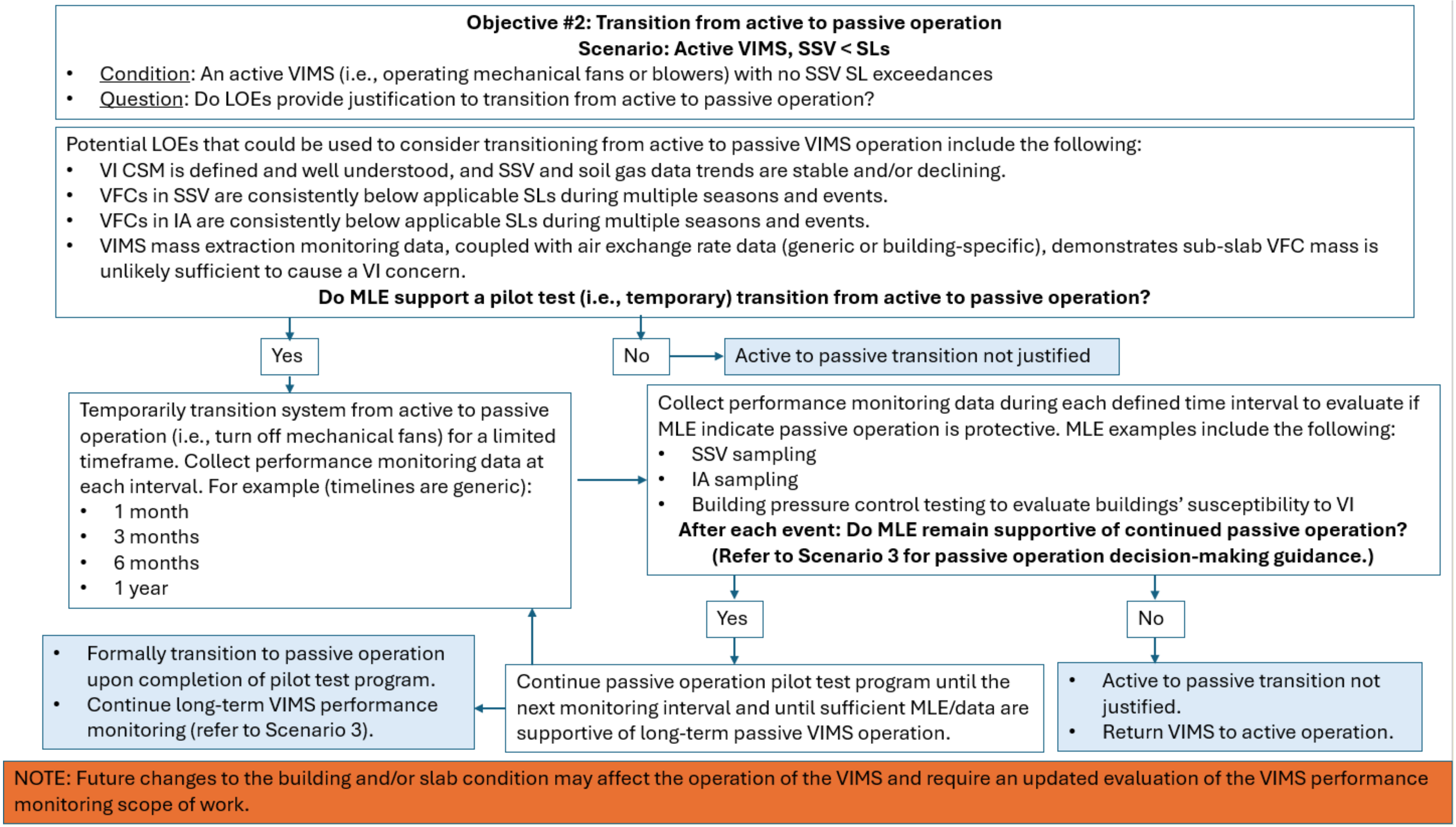
Objective 2: Transition from active to passive system operation (**Figure 2**)

- MLE may support the transition of an active mitigation system to operate passively, or in the case of a large building, the transition of a targeted portion of a building to transition from active to passive operation.



Notes: IA = indoor air, J&E = Johnson and Ettinger, LOE = line of evidence, MLE = multiple lines of evidence, SL = screening level, SSV = sub-slab vapor, VFC = vapor-forming chemical, and VIMS = vapor intrusion mitigation system.

Figure 1. Viability of reduction in ongoing system monitoring.



Notes: CSM = conceptual site model, IA= Indoor Air, LOE = line of evidence, MLE = multiple lines of evidence, SSV = sub-slab vapor, VFC = vapor-forming chemical, VI = vapor intrusion, and VIMS = vapor intrusion mitigation system.

Figure 2. Viability of transitioning a vapor intrusion mitigation system from active to passive.

Similar to Objective 1, a scenario is presented assuming an active VIMS with no sub-slab vapor concentrations above applicable screening levels. As with Objective 1, there could be other scenarios (e.g., active VIMS with sub-slab vapor exceedances) in which the objective is to transition the VIMS from active to passive operation. The scenario presented for Objective 2 is not meant to imply that a prerequisite for active to passive transition is demonstrating that all sub-slab vapor concentrations are below default screening levels. MLE could be presented to demonstrate that a building is protected from VI despite having sub-slab vapor concentrations above screening levels. Again, the flow chart provides a framework based upon the concept of using MLE to demonstrate system performance and support VIMS decision-making.

Objective 3: Shutdown strategy to terminate ongoing VIMS monitoring (Figure 3)

- MLE may indicate ongoing monitoring of a mitigation system is no longer warranted because, for example, the source of VFCs may be remediated or may biodegrade within the life cycle of a mitigation strategy and therefore, in some cases, render the system (or targeted areas of the system footprint) unnecessary.

Objective #3: Shutdown strategy to terminate ongoing VIMS monitoring
Scenario: Passive VIMS

- Condition: Passive VIMS (i.e., no operating mechanical fans or blowers)
- Question: Do LOEs provide justification to terminate VIMS performance monitoring or monitoring within a sub-portion of a building?

Potential MLE that could be used to consider transitioning from passive VIMS operation to no additional ongoing monitoring include the following:

- VI CSM is defined and well understood, and SSV and soil gas data trends are stable and/or declining.
- VFCs in SSV are consistently below applicable SLs during multiple seasons and events.
- VFCs in IA are consistently below applicable SLs during multiple seasons and events.
- Multiple rounds of consistent sub-slab pneumatic data (e.g., differential pressures, flow-based measurements) under a variety of environmental conditions.
- VIMS mass extraction monitoring data, coupled with air exchange rate data (generic or building specific), demonstrates sub-slab VFC mass is unlikely sufficient to cause a VI concern.
- Building pressure control demonstrates, under a range in likely environmental conditions, the building is not susceptible to VI as the building is currently constructed and operating.

Notes: CSM = conceptual site model, IA = Indoor Air, MLE = multiple lines of evidence, VFC = vapor-forming chemical, VI = vapor intrusion, and VIMS = vapor intrusion mitigation system.

Figure 3. Shutdown strategy to terminate ongoing vapor intrusion mitigation system monitoring.

Table 1 provides decision-making guidance for Objective 3 based upon sub-slab vapor and indoor air chemical data. As has been acknowledged previously, sub-slab vapor and indoor air data are not the only metrics that can be used to justify terminating ongoing system monitoring, but these performance monitoring approaches are common VI practices used in the industry. The scenario presented in the table is for a passive VIMS; however, there could be scenarios where MLE are supportive of terminating ongoing monitoring of active mitigation systems as well.

The reader should recognize that for each of the objectives and approaches presented in these figures, future changes to the building and/or slab condition may affect the operation of the VIMS (e.g., active versus passive) and require an updated evaluation of the VIMS operation and performance monitoring scope of work.

There are many instances in which a passive VIMS may be installed out of an abundance of caution, as a preventative measure, and/or as required by a state law or regulation. If the passive VIMS is installed only because it is a statutory or regulatory requirement and there is not a VI risk to the building necessitating a

VIMS, then an operation, maintenance, and monitoring (OM&M) plan and a VIMS curtailment plan may not be necessary.

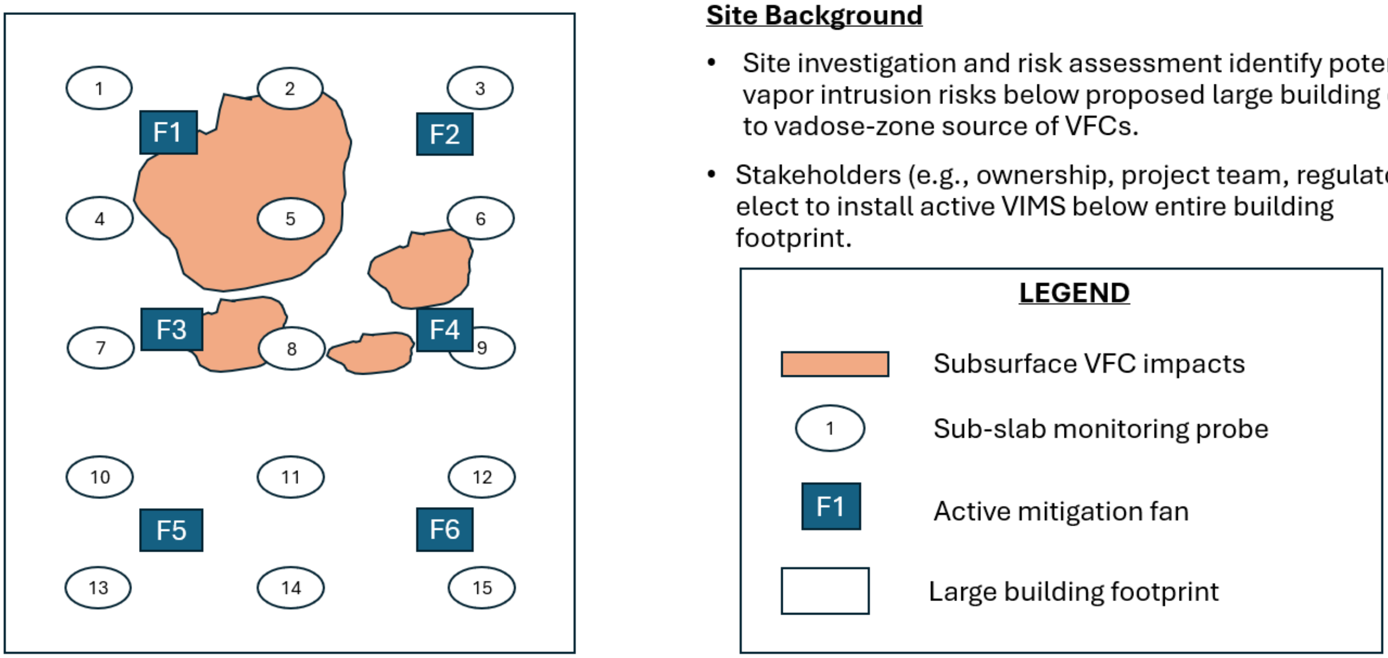
Table 1. Viability of reducing monitoring requirements of passive vapor intrusion mitigation systems.

Passive VIMS	SSV Below Screening Levels	SSV Above Screening Levels	No SSV Data
IA below screening levels	• This may warrant consideration for no additional monitoring. • Additional LOEs could be considered to provide supplemental support to terminate ongoing monitoring.	Terminating the ongoing monitoring requirements may be viable. Several additional LOEs are highly recommended to demonstrate the building will be protective over time given the SSV exceedances.	Terminating the ongoing monitoring requirements may be viable. Additional LOEs are highly recommended to demonstrate the building will be protective over time given the unknowns below the building.
IA above screening levels	• Ongoing monitoring should continue until the source of the IA exceedance(s) is identified. • Possible sources to evaluate include dead zones in the VIMS, preferential pathways (e.g., conduit VI), and confounding background sources unrelated to VI.	• Ongoing monitoring should continue. • This may warrant transitioning the VIMS operation to active mode.	Ongoing monitoring should continue to identify the source of the IA VFC exceedances.
No IA data	This may warrant consideration for no additional monitoring if additional LOEs provide supplemental support for decision-making.	• Ongoing monitoring should continue. • This warrants additional LOEs to demonstrate the VIMS is protective and could include transitioning the VIMS to active mode.	Performance monitoring data should be collected to evaluate the effectiveness of the VIMS.
Future changes to the building and/or slab condition may affect the operation of the VIMS and require an updated evaluation of the VIMS performance monitoring scope of work.			

Notes: Table assumes performance monitoring data have been collected over multiple sampling events in multiple seasons (unless an alternative metric, such as building pressure control, is implemented to demonstrate the protectiveness of the building under a variety of conditions). IA = indoor air, LOE = line of evidence, SSV = sub-slab vapor, VFC = vapor-forming chemical, VI = vapor intrusion, and VIMS = vapor intrusion mitigation system.

Conceptualized Scenarios to Support Vapor Intrusion Mitigation System Decision-Making

The flow charts are intentionally generic for the reasons mentioned previously. To provide more clarity in applying the principles of the flow charts, a hypothetical set of scenarios involving an active VIMS in a large building is presented (Figure 4). The scenario begins after VIMS construction (i.e., at the beginning of VIMS OM&M) and takes the reader through a hypothetical life cycle of VIMS management for the building. It begins with an initial objective to reduce VIMS OM&M at some time in the future (Objective 1), then presents an objective to transition the system from active to passive operation (Objective 2), and finally presents an objective to terminate ongoing monitoring (the curtailment strategy, Objective 3). The conceptualized scenario is intended to provide clarity in applying the concepts of the flow charts and should be reviewed in parallel with the flow charts. Not every site will progress through each step of these scenarios, and some may never exit the monitoring stage. These are just examples of how VIMS management decision-making may progress.



Notes: VFC = vapor-forming chemical and VIMS = vapor intrusion mitigation system.

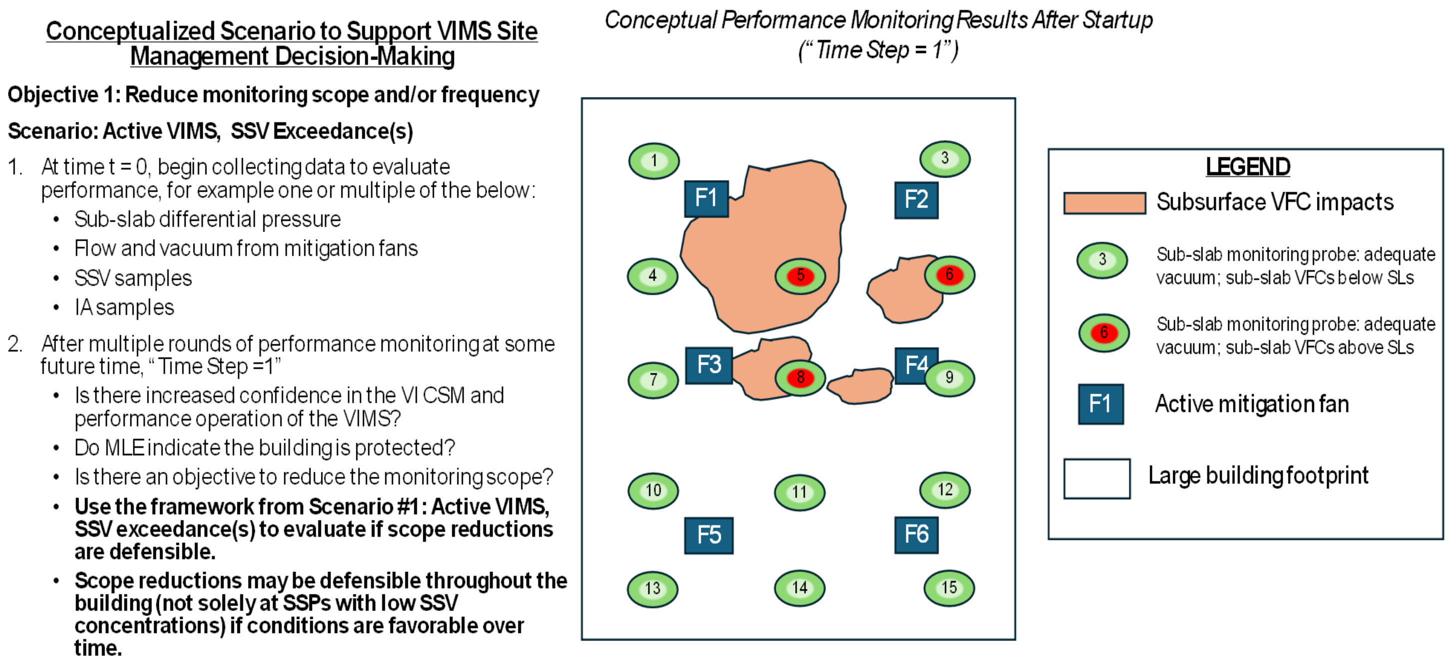
Figure 4. Conceptualized scenario to support vapor intrusion mitigation system site management decision-making—introduction.

The conceptual scenario assumes the following:

- The VI CSM is reasonably understood prior to design. There is a known mass of VFCs in the vadose zone covering a fraction of a large new construction building footprint.
- The risk screening process indicates there is a potential VI risk for the building.
- Although the predesign site data indicates the source of VFCs is located below only a fraction of the building, the VIMS is designed to encompass the full building slab and initially operate actively based on the soil-vapor data and risk screening results obtained during the predesign investigation.
- The VIMS design team recognizes during the design phase that an active VIMS for the entire building footprint may be overly conservative but elected to proceed accordingly because some unknowns remained with respect to the VI CSM and ownership risk tolerances preferred a proactive approach.

The conceptual scenario is analogous to the way in which many newly constructed large building designs progress, and it should also be clear from the onset that there could be opportunities to modify system operation over time and potentially terminate ongoing monitoring at some point in the future if MLE are supportive.

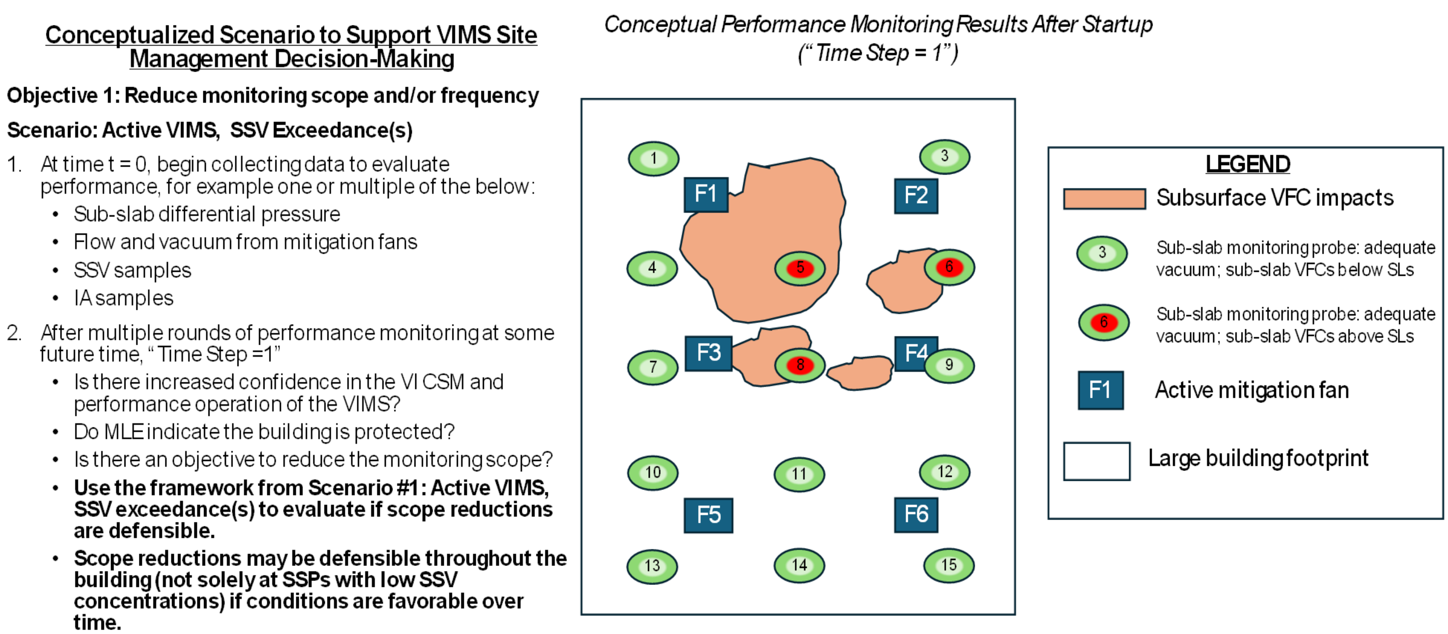
After the VIMS is constructed, VIMS OM&M should be performed to confirm the building is protected from VI. Over time, there should be an increased understanding of the VI CSM and operation and performance of the VIMS. The primary performance monitoring metrics shown in the conceptual scenario are sub-slab-to-indoor-air differential pressure measurements and sub-slab vapor chemical data. As has been mentioned previously, other metrics can also be used to monitor VIMS performance; differential pressure and sub-slab vapor data were selected as they are the most common metrics for evaluating VIMS performance. At some future time after startup (referred to as Time Step = 1 in the scenario), the project stakeholders may want to consider evaluating Objective 1 and the associated flow chart, which is a reduction in monitoring scope and/or frequency over time (Figure 5).



Notes: CSM = conceptual site model, IA= Indoor Air, LOE = line of evidence, SL = screening level, SSP = sub-slab pressurization, SSV = sub-slab vapor, VIMS = vapor intrusion mitigation system, and VFC = vapor-forming chemical.

Figure 5. Conceptualized scenario to support vapor intrusion mitigation system site management decision-making—Objective 1.

As VIMS monitoring continues over time, there could be opportunity to transition a portion of the active mitigation system to passive operation (Objective 2), then eventually a termination of ongoing VIMS performance monitoring (Objective 3). In each case, the reader is referred to the corresponding flow charts from the Framework to support VIMS management decision-making (Figure 6 and Figure 7).



Notes: IA= Indoor Air, LOE = line of evidence, SL = screening level, SSV = sub-slab vapor, VIMS = vapor intrusion mitigation system, and VFC = vapor-forming chemical.

Figure 6. Conceptualized scenario to support vapor intrusion mitigation system site management decision-making—Objective 2.

For the conceptual scenario presented, each of the three objectives are followed sequentially to support the understanding of the corresponding flow charts. It should not be inferred that for every condition sequential progression through each objective is required. It does highlight, however, an overarching concept that VIMS curtailment and eventual shutdown strategies should be based upon more than a single event or LOE and should be viewed as a process.

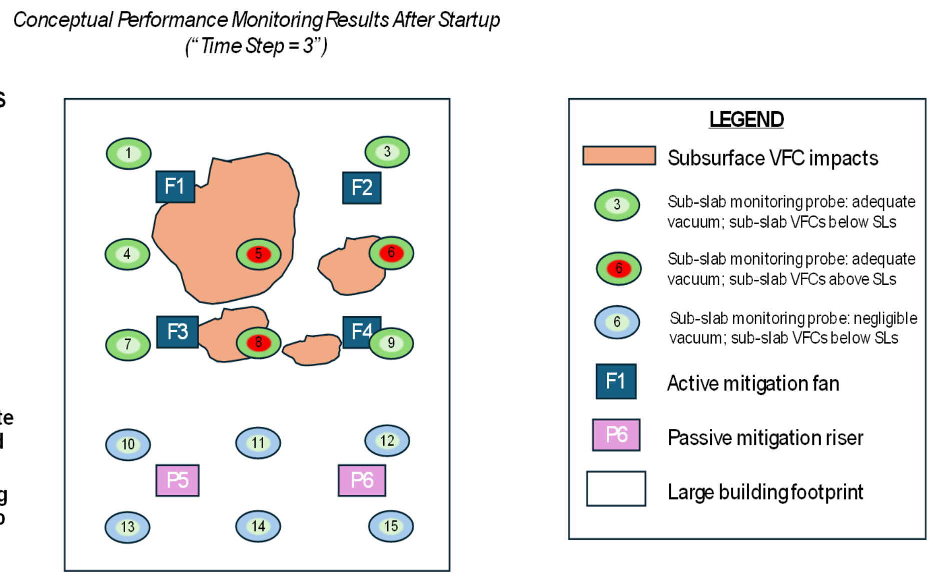
Additionally, the end result for the conceptual scenario presented herein was that the VIMS transitioned from a fully active mitigation system to a targeted active mitigation system, and a portion of the building no longer required ongoing VIMS monitoring. The concepts shown in the Framework and this scenario can be applied to broader situations—for example, to develop a VIMS curtailment plan for an entire building, rather than a targeted portion of a building.

Conceptualized Scenario to Support VIMS Site Management Decision-Making

Objective 3: Shutdown strategy to terminate ongoing VIMS monitoring

Scenario: Passive VIMS

1. After Time Step = 2, continue collecting data to evaluate performance, for example one or multiple of the below:
   - SSV samples
   - IA samples
2. At Time Step = 3, do MLE suggest eliminating ongoing performance monitoring for some or all of the building?
   - **Use the framework from Objective #3: VIMS shutdown, to evaluate.**
   - **For this example, Scenario #3 is unlikely appropriate for evaluating the portions of the building mitigated by F1-F4 (unless additional LOEs are developed).**
   - **For this example, elimination of ongoing monitoring of the portions of the building surrounding sub-slab probes 10-15 may be defensible.**



Notes: IA= Indoor Air, LOE = line of evidence, SL = screening level, VIMS = vapor intrusion mitigation system, and VFC = vapor-forming chemical.

Figure 7. Conceptualized scenario to support vapor intrusion mitigation system site management decision-making—Objective 3.

Summary

This fact sheet presents a framework to consider for optimizing the monitoring and operation of a VIMS based upon long-term site management objectives. The underpinning concept of this fact sheet is the use of MLE to demonstrate system performance and the protection of building occupants from VI over time.

Three common VIMS management objectives were presented alongside a conceptual scenario to help contextualize the concepts from the flow charts. The hypothetical scenario presents the three objective statements in sequential order, though it is important to recognize that a linear progression through each objective statement (i.e., initial scope reduction, then transition from active to passive operation, then termination of ongoing performance monitoring) may not be appropriate or warranted for each site. Regardless of the exact scenario, modification of system operation or the selection of a curtailment strategy will depend on site-specific conditions and should be approached as a process, rather than as an event. The process should be based upon the use of MLE to evaluate and demonstrate effective operation of the VIMS and/or to provide justification that ongoing VIMS operation and monitoring is no longer warranted.

Occupant, Community, and Stakeholder Considerations

Any changes to or discontinuation of the VIMS will need to be communicated with stakeholders. If community engagement has been started early, stakeholders should be aware that VIMS operation may not be required in perpetuity. Further, if ownership or occupancy has changed, new stakeholders should be informed of VIMS status and operation. See **Section 3.6: Long-Term Stewardship Best Practices** for more information.

REFERENCES

Eklund, Bart, Lila Beckley, and Rich Rago. 2018. "Overview of State Approaches to Vapor Intrusion: 2018." *Remediation Journal* 28 (4): 23–35.

MADEP. 2016. "MassDEP Vapor Intrusion Guidance: Site Assessment, Mitigation and Closure." Massachusetts Department of Environmental Protection. **https://www.mass.gov/doc/wsc-16-435-vapor-intrusion-guidance-site-assessment-mitigation-and-closure/download**.

McAlary, T. A., W. Wertz, and D. Mali. 2018. *Demonstration/Validation of More Cost-Effective Methods for Mitigating Radon and VOC Subsurface Vapor Intrusion to Indoor Air*. U.S. Department of Defense: ESTCP. **https://clu-in.org/download/issues/vi/ER-201322-Final-Report.pdf**.

McAlary, T. A., W. Wertz, D. Mali, and P. Nicholson. 2020. "Mathematical Analysis and Flux-Based Radius of Influence for Radon/VOC Vapor Intrusion Mitigation Systems." *Science of the Total Environment* 740 (139988).

NJDEP. 2021. *Vapor Intrusion Technical Guidance. Version 5.0*. New Jersey Department of Environmental Protection Site Remediation and Waste Management Program. **https://www.nj.gov/dep/srp/guidance/vaporintrusion/vit_main.pdf**.

NYSDOH. 2006. "Guidance for Evaluating Soil Vapor Intrusion in the State of New York." New York State Department of Health, October. **https://www.health.ny.gov/environmental/indoors/vapor_intrusion/docs/2006_guidance.pdf**.

WDNR. 2018. *Addressing Vapor Intrusion at Remediation & Redevelopment Sites in Wisconsin*. Wisconsin Department of Natural Resources, Remediation and Redevelopment Program.