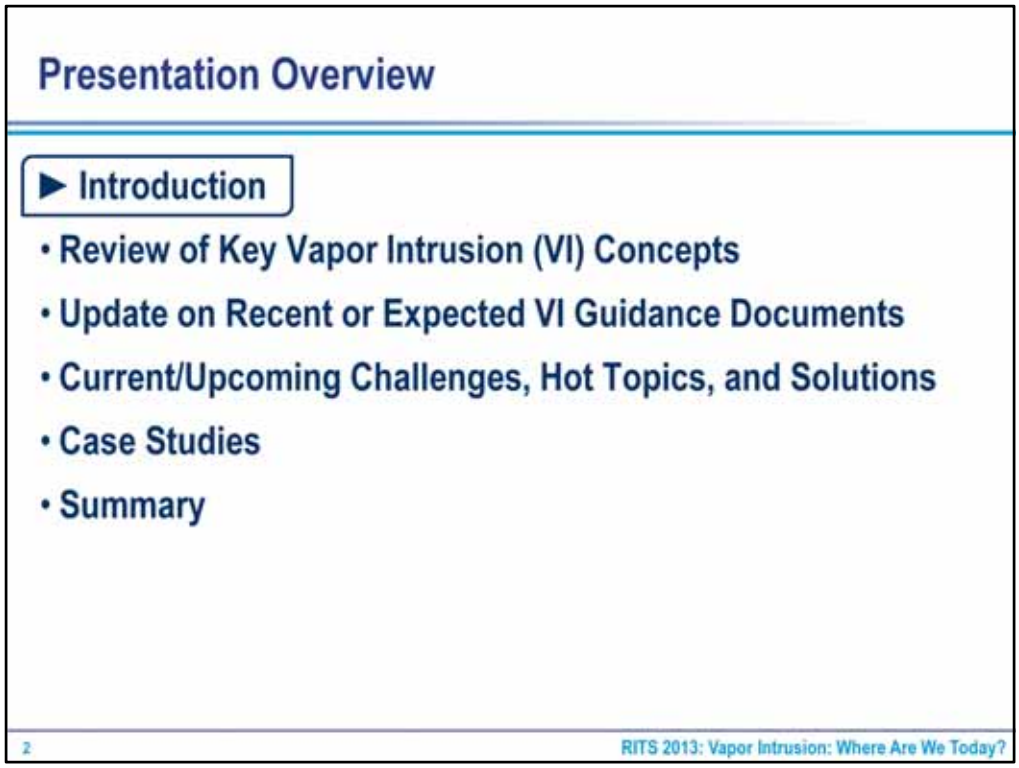
Vapor Intrusion: Where Are We Today?

RITS 2013

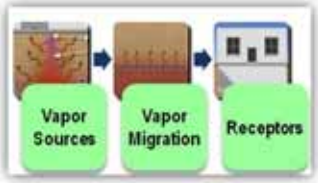


This presentation will provide a brief introduction, followed by a review of some key VI concepts. I will then provide an update on VI-related guidance documents. Most of today's presentation will focus on VI challenges, hot topics, and solutions, along with three case studies.

What is Vapor Intrusion?

"Migration of volatile chemicals from subsurface into indoor air" (EPA, 2002)

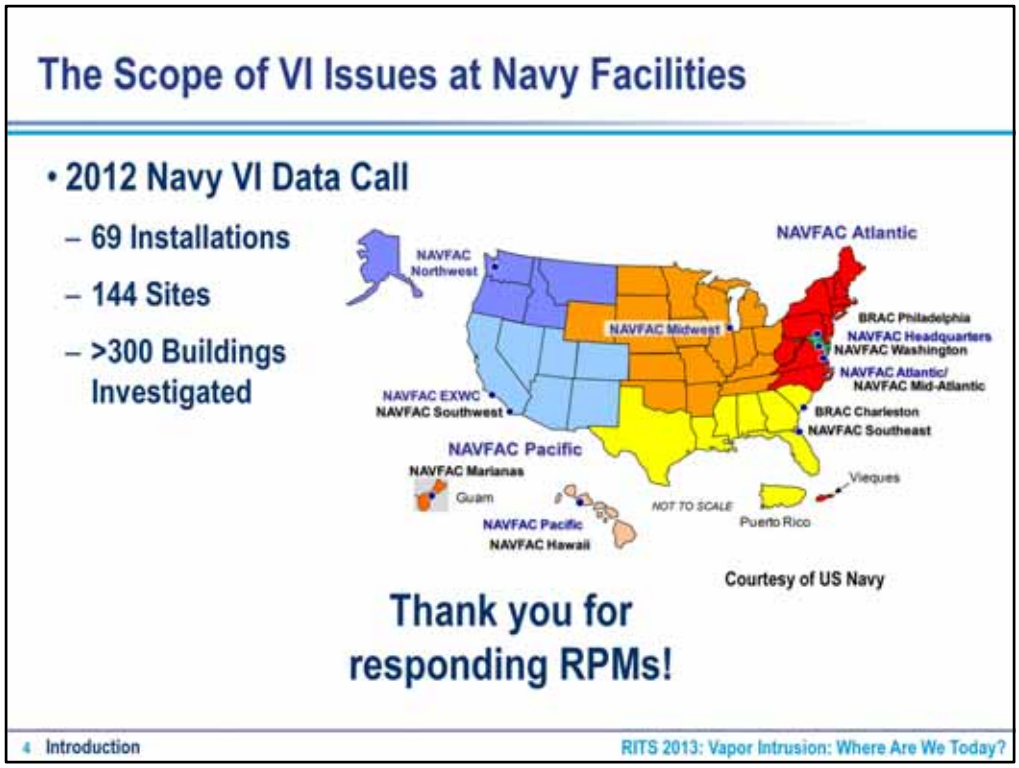
VI Conceptual Site Model (CSM)



Courtesy of US Navy

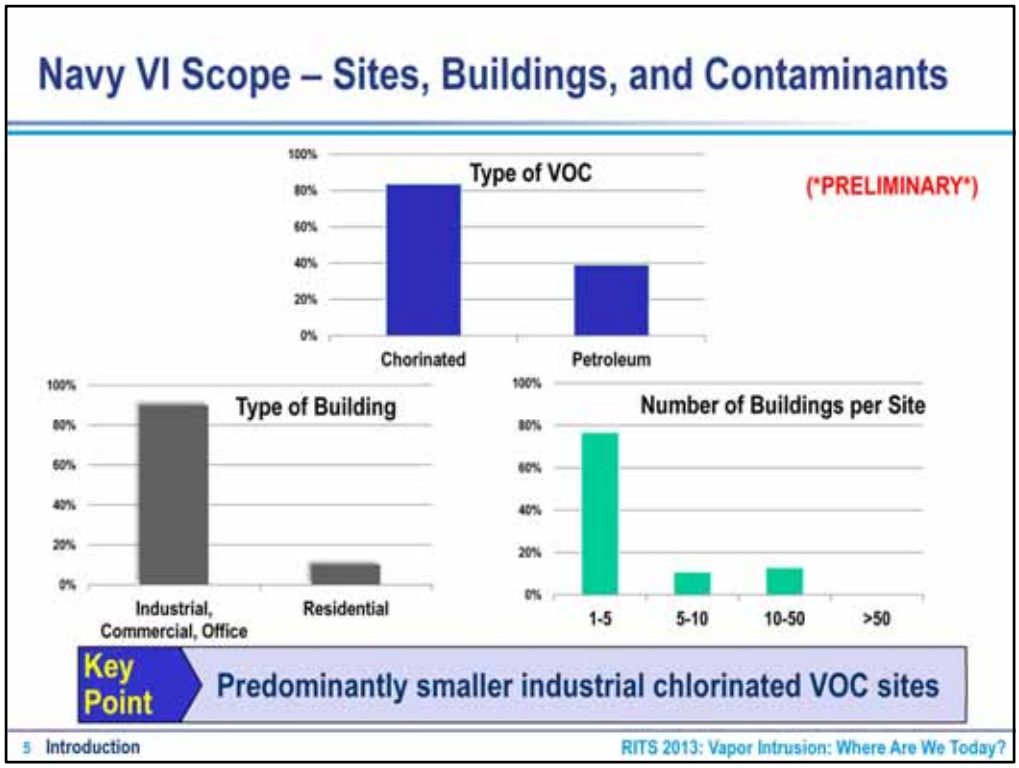
3 Introduction RITS 2013: Vapor Intrusion: Where Are We Today?

This slide of definitions is provided for your reference.



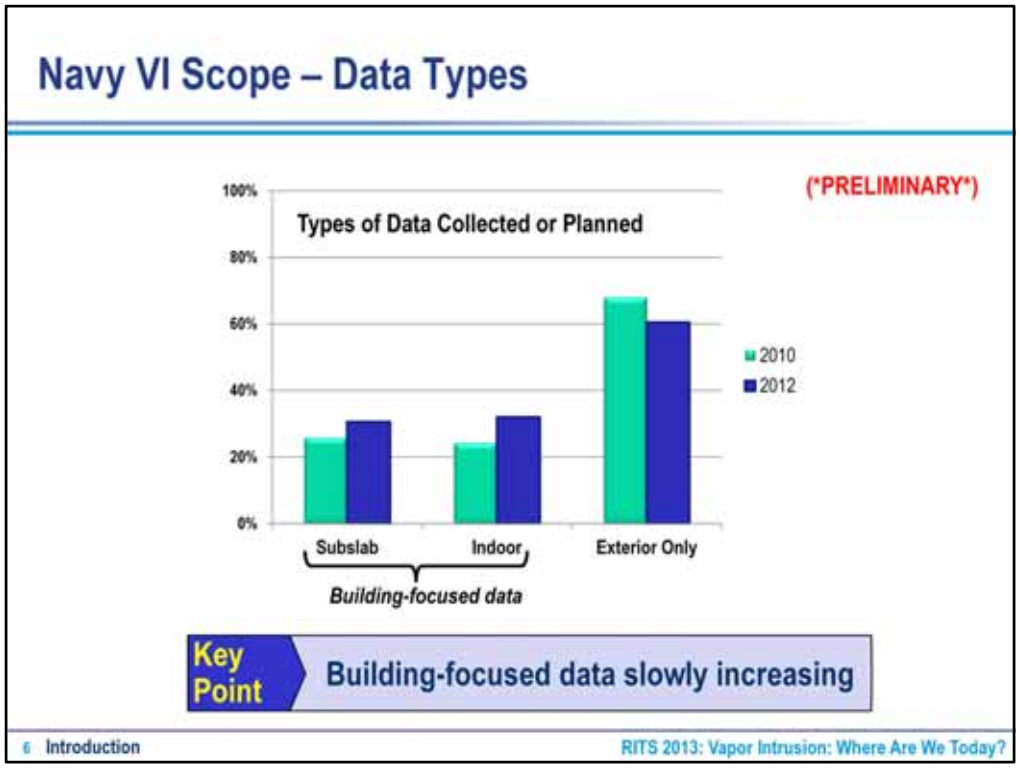
As many of you know, the Navy conducted another VI Data Call late last year to assess the current scope of VI issues at Navy facilities. We want to thank each of the RPMs for responding – your participation in the data call and today's training is important as the Navy continues to optimize its approach to vapor intrusion. The next few slides summarize the results of this VI data call.

Note: RPM participation in data calls and training (like this) is key to the Navy optimizing its approach to vapor intrusion.

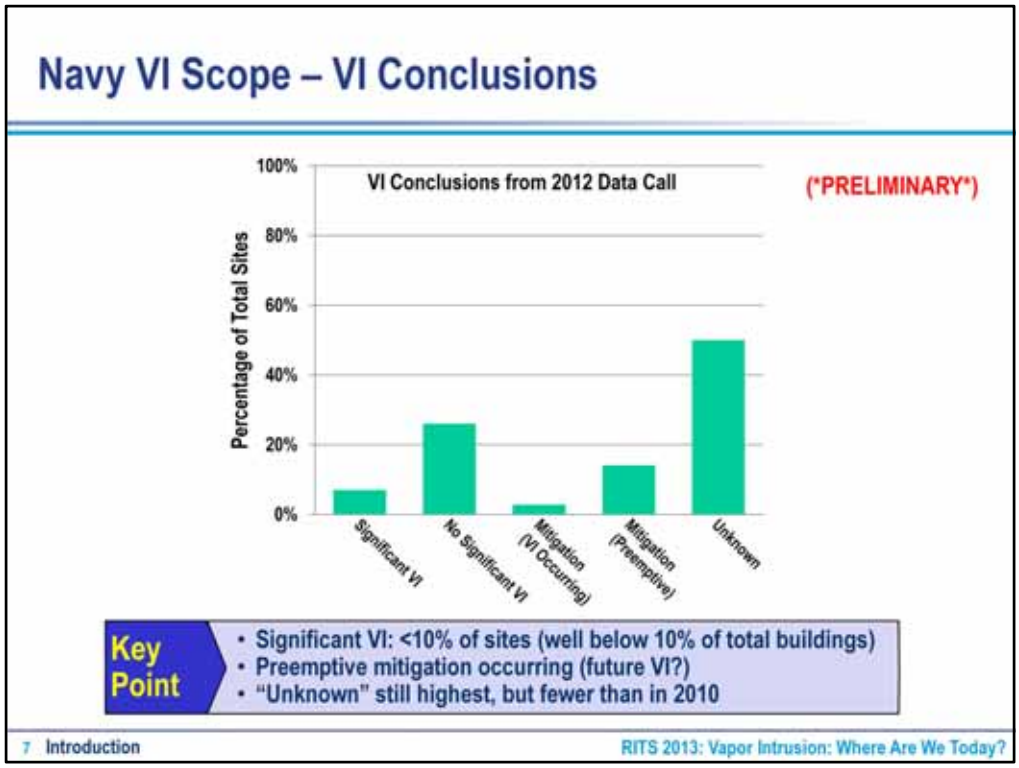


As you can see on this slide, VI investigations are conducted at mostly smaller, industrial chlorinated VOC sites. As you look closer at these bar graphs, you will see that the total for the type of VOCs is greater than 100% and that is because some sites have both chlorinated and petroleum VOCs.

Speaker Note: Point out that totals (adding percentages across columns) can be greater than 100% because some sites meet more than one criteria (*e.g.*, both chlorinated and petroleum VOCs present).



This slide compares the type of VI data collected or planned in 2010 with the 2012 data call results. As you can see, the amount of building-focused or subslab and indoor air data is slowing increasing. This is consistent with the increasing trend by regulators to request building-focused data.



This slide summarizes the overall VI conclusions. The good news is that there are very few (<10%) of the sites with significant VI occurring and this percentage is even lower when you consider the percentage relative to the total number of buildings investigated. Preemptive mitigation is occurring at about 15% of the sites, likely because of uncertainties about the potential for future impacts. Sites with unknown conclusions about VI is still the highest percentage, but has decreased since 2010.

Speaker note: The number of total buildings is estimated since the Data Call asked for a range (*e.g.*, 10-50 buildings).

Navy VI Scope – Costs

Investigation Costs

- $30K – $100K (per building)
- >$25M (total previous & planned)

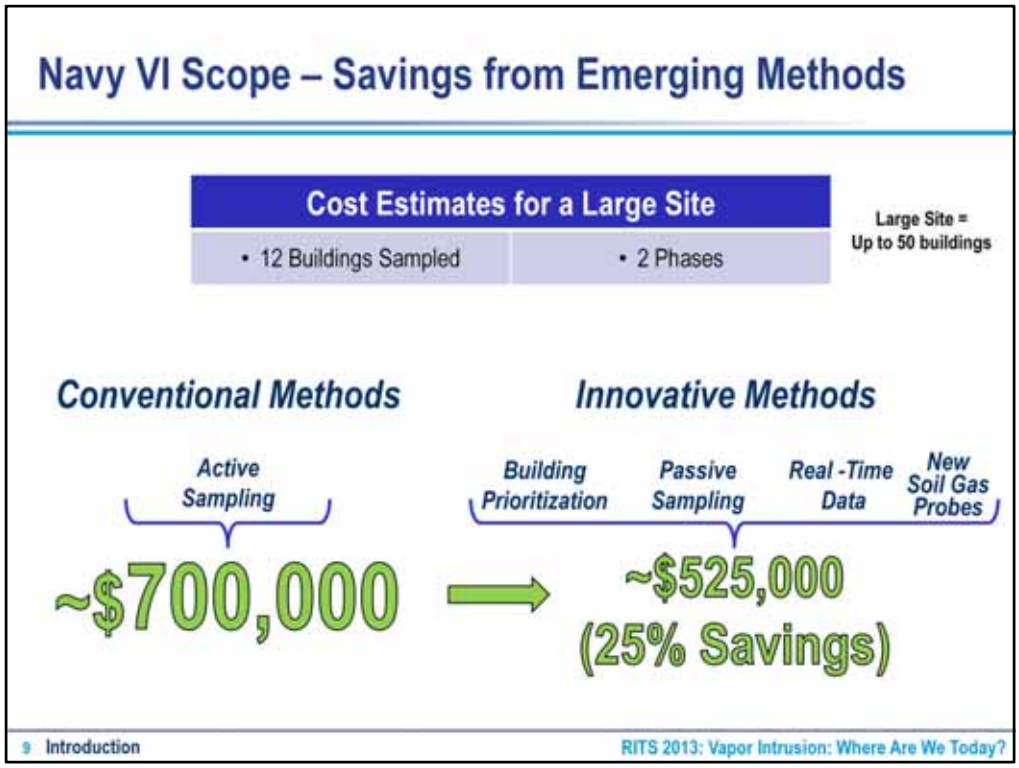
Mitigation Costs

- ~$10/ft^2 (capital cost)
- $25K+ per year per building (*e.g.*, O&M, sampling, reporting)
  - Building and technology dependent

8 Introduction RITS 2013: Vapor Intrusion: Where Are We Today?

This slides provides a rough order of magnitude estimate of the overall VI investigation and mitigation costs for the Navy. Investigation costs for previous and currently planned investigations exceed $25M. It is also important to consider mitigation costs as site investigations are completed. Although the mitigation costs are building and technology dependent, a reasonable estimate is ~$10/ft^2 to install the system and then at least $25K per year per building for the life of the system. Navy RPMs are always asking us if there is a way to reduce these costs. The next slide shows cost savings that could be realized if some of the emerging techniques are used during site investigations.

Speaker Notes: Cost are all inclusive – screening/prioritization, work plans, meetings, logistics/shipping/travel, field work, sampling/analysis, data validation, reporting.



As you can see, it is possible to save around 25% if emerging techniques such as passive sampling, real-time investigations, and some of the new subslab soil gas probes are used. This could be as much as ~175K for a large site with 15 buildings being investigated. Not all of the emerging techniques are accepted by regulators, but the science is sound and we are working on getting more regulators to accept these emerging techniques. We hope you as RPMs will be advocates for the emerging techniques and help us convince regulators of their benefits.

Speaker Notes: Savings based on

1. Reduced labor and shipping with passive samplers
2. High resolution spatial subslab mapping with real time data (replaces TO-15)
3. Identification of background sources in first round
4. Fewer data gaps to fill in Phase 2
5. Replacing old probe design and helium leak checking with modern probe and water-dam

Not all are currently accepted standard practices. We're working on that.

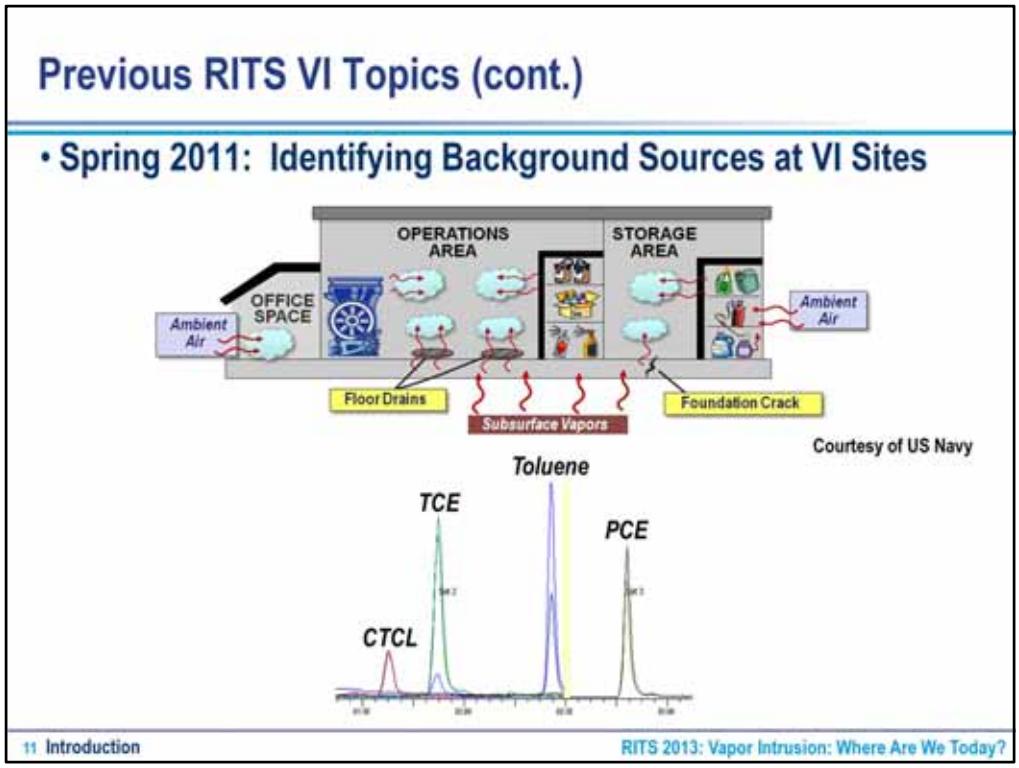
Previous RITS VI Topics

- Fall 2004
  - Practical Guide to VI
- Fall 2008
  - Assessing the VI Pathway

10 Introduction RITS 2013: Vapor Intrusion: Where Are We Today?

These next three slides are provided to emphasize the Navy's commitment to VI training and as a resource if you want additional details on VI. As you can see, vapor intrusion was a topic at the RITS training sessions in 2004 and 2008.

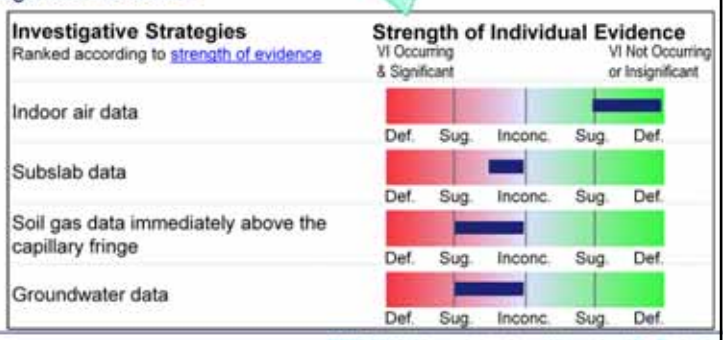
Note: This summary will help RPMs understand the progression of VI training that has been provided at previous RITS, along with an understanding of VI resources developed by the Navy.



There were two talks in the spring 2011 RITS: 1) one on identifying background VOC sources ....

Previous RITS VI Topics (cont.)

- **Spring 2011: Navy VI Assessment Tool**
  - **VI Fundamental Truths**
    - Multiple lines of evidence typically required
    - Not all lines of evidence created equal
    - Strength of evidence depends on VI CSM
    - Not all buildings are the same



Courtesy of US Navy

12 Introduction RITS 2013: Vapor Intrusion: Where Are We Today?

Presentation Overview

- Introduction
- ► Review of Key Vapor Intrusion (VI) Concepts
- Update on Recent or Expected VI Guidance Documents
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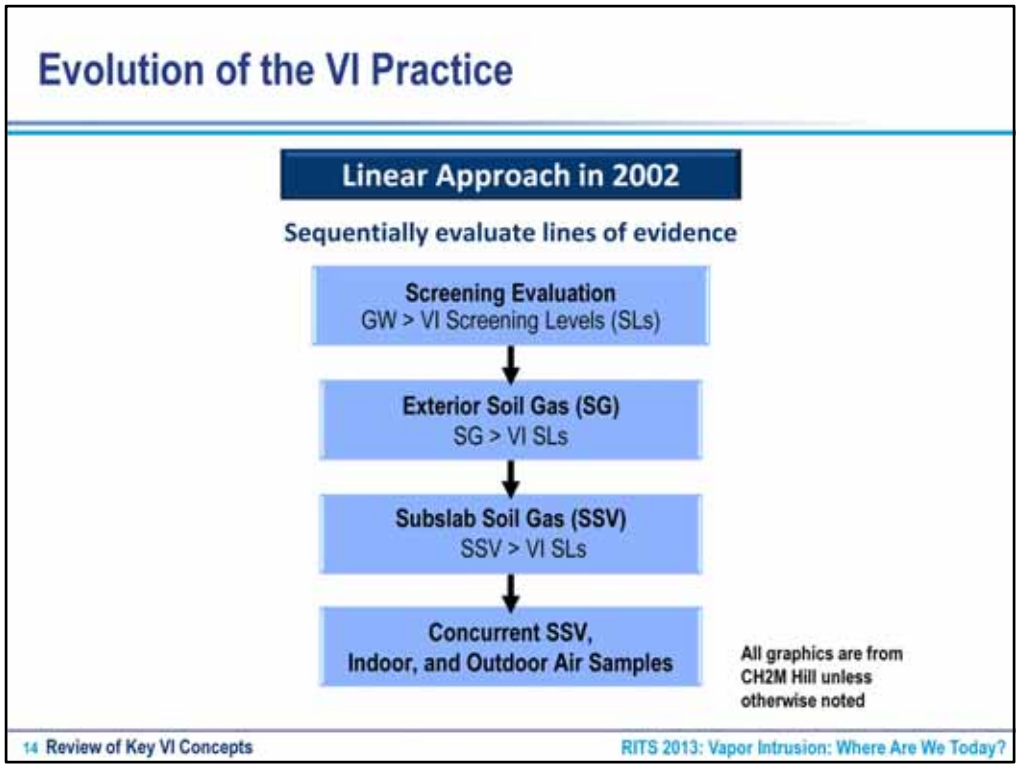
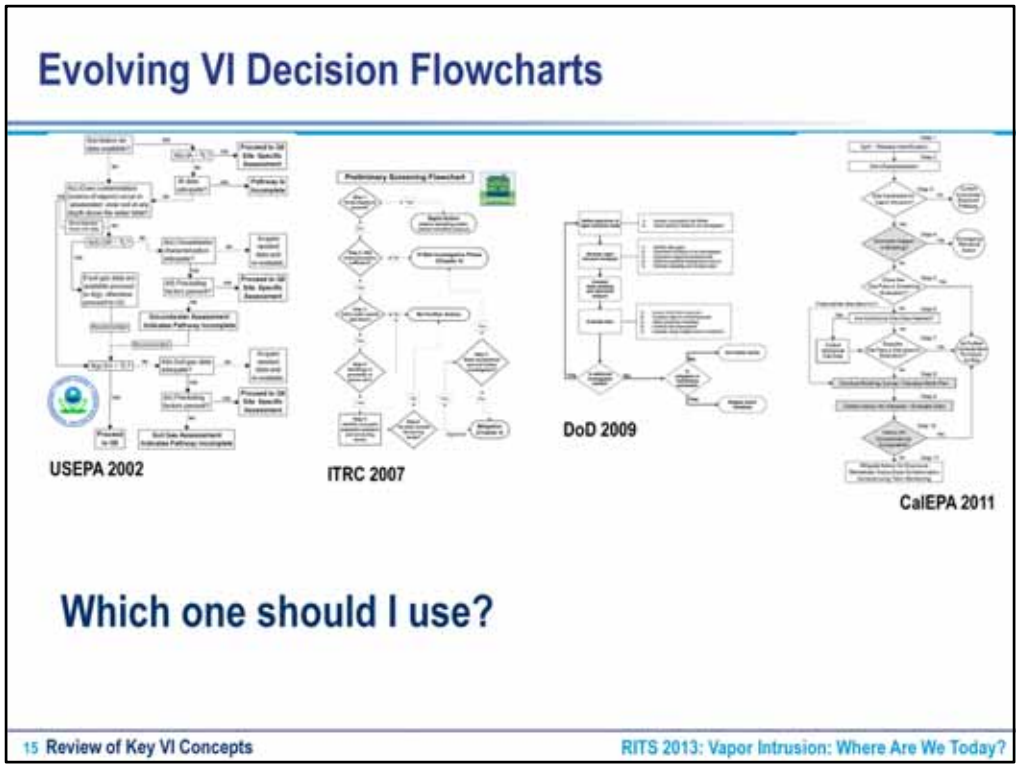
13 RITS 2013: Vapor Intrusion: Where Are We Today?

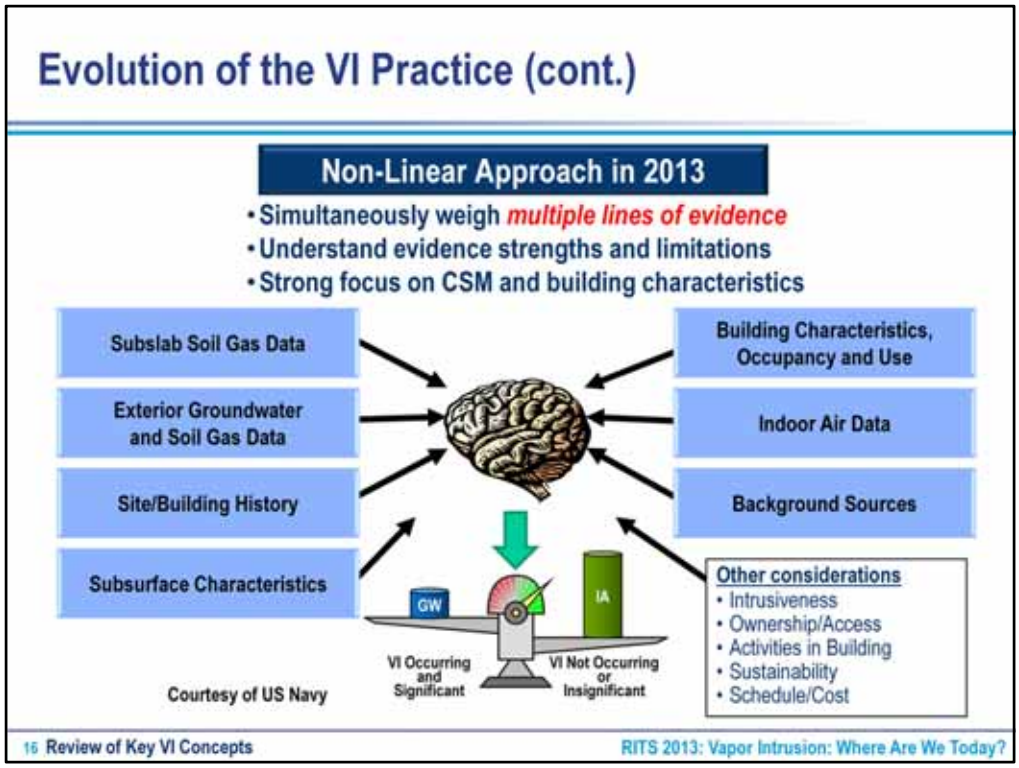
Now let's review some key VI concepts.



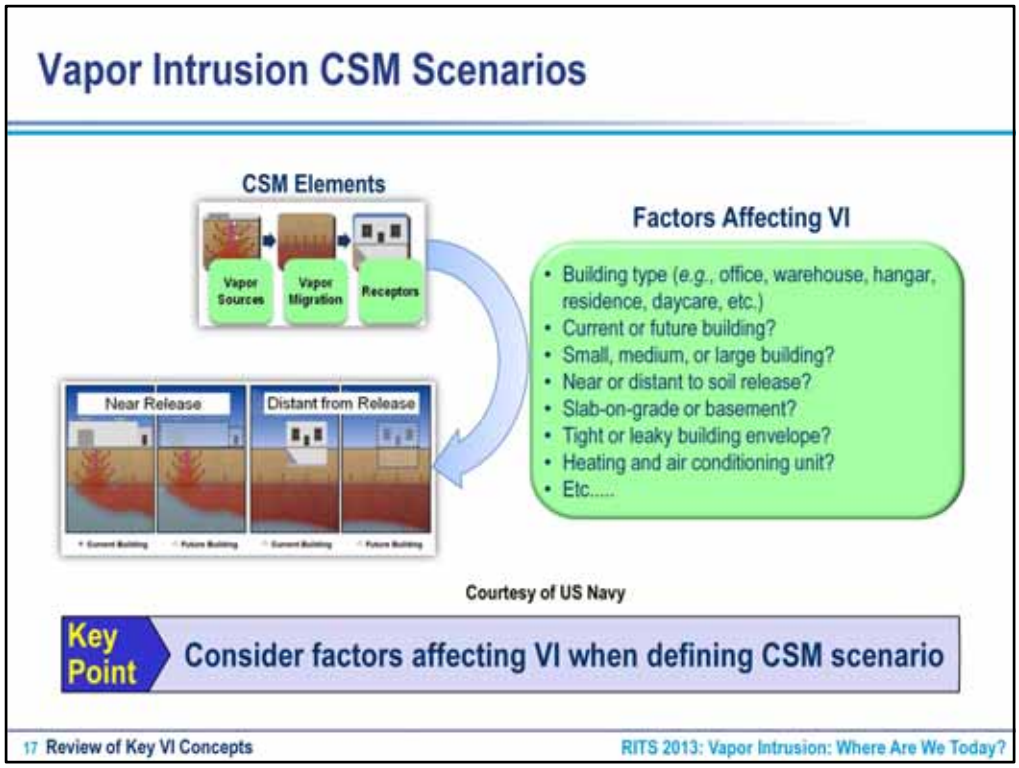
We used a fairly linear process back in 2002, and sequentially evaluated the lines of evidence.



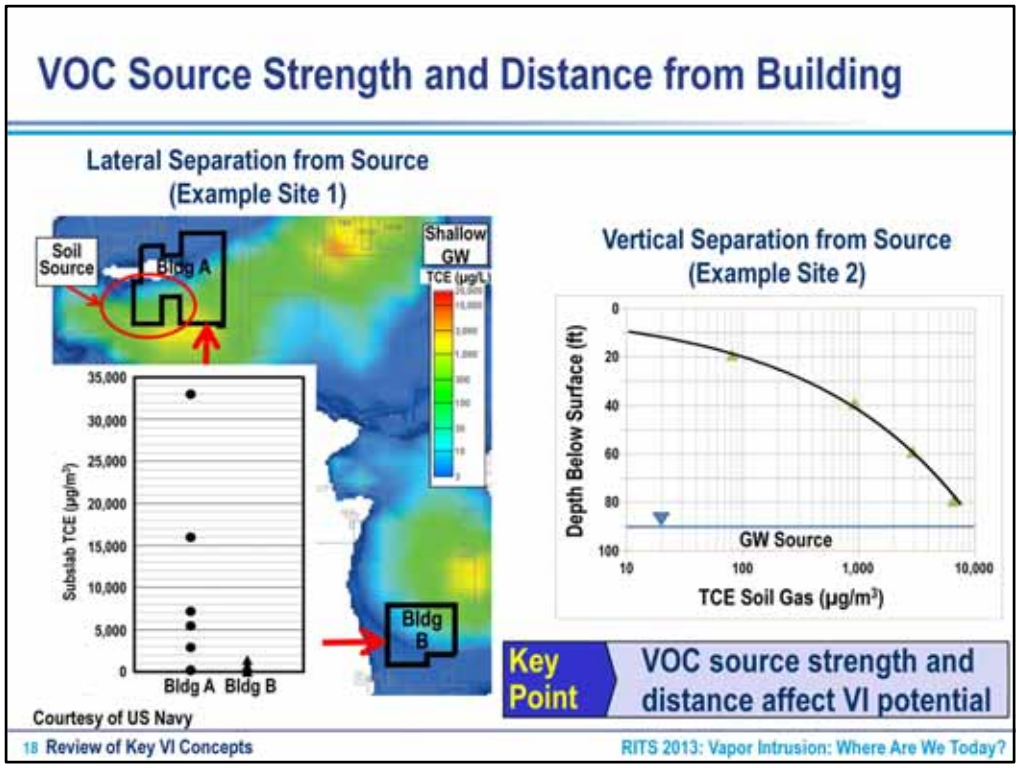
This led to a variety of decision flow charts and consequently, confusion as to which flow chart was appropriate.



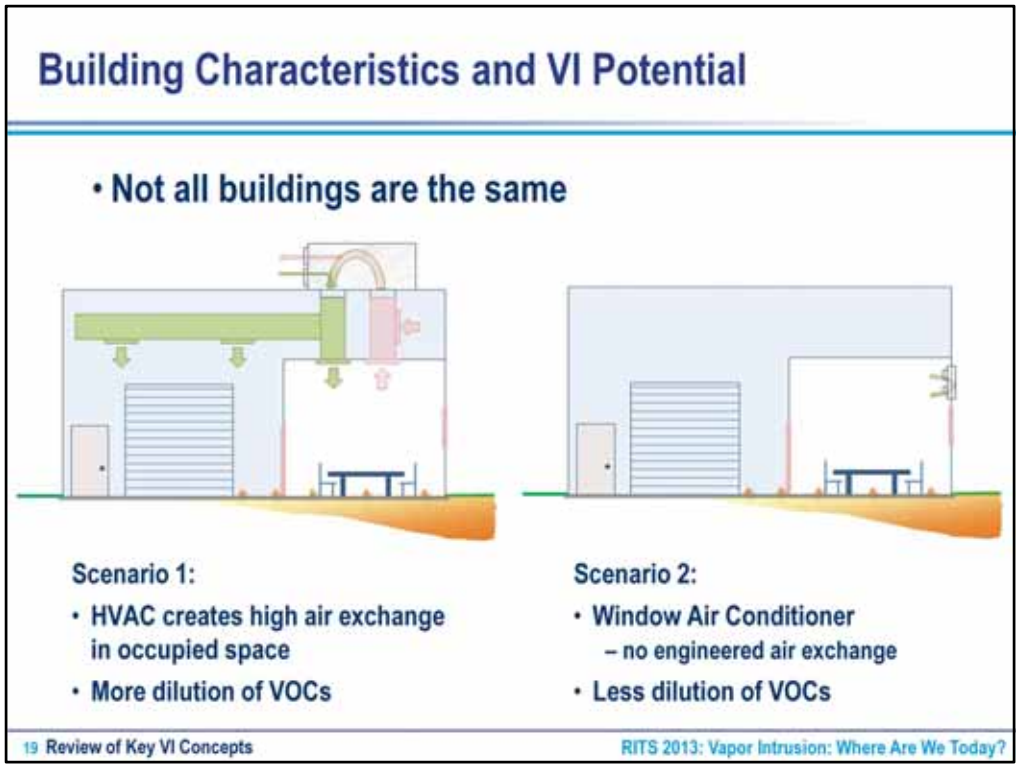
The practice has evolved in the last 10 years and we now use a non-liner approach where we simultaneously weigh MLE and focus on understanding each line of evidence's strengths and limitations, with a strong focus on the CSM and building characteristics. Ultimately, we consider the overall cumulative strength of all the lines of evidence, as represented by the scale shown on the bottom of this slide. Although I list a number of lines of evidence on this slide, the type and number of lines of evidence depend on the site. The next few slides summarize how some of the VI factors can affect VI potential.



It is also important to understand the factors that affect VI; examples are shown in this text box on the right. These factors are considered along with the VI CSM elements to define the VI CSM scenario that is being considered, such as a large, slab-on-grade industrial warehouse overlying a soil source. Before I discuss how some of these factors affect a VI assessment, I want to show you how the VI practice has evolved over the last 10 years.



Let's start with the effect of VOC source strength and the lateral distance from buildings. The graphic on the left shows a Navy site with a fairly wide-spread cVOC groundwater plume. Notice that Bldg A is located over a higher GW source strength, along with a soil source of VOCs, whereas Bldg B is located over only the GW plume, with lower dissolved TCE concentrations. Subslab TCE vapor samples were collected from beneath both buildings. Notice that Bldg A had much higher subslab concentrations as a result of its proximity to the soil and stronger VOC source concentrations. The figure on the left shows a similar effect with vertical separation distance, where TCE concentrations were shown to attenuate significantly as they migrated upward. Concentrations are shown on the x-axis and depth is shown on the y-axis. GW is at 90 ft bgs. The take home point from this slide is that source strength and distance definitely affect VI potential.



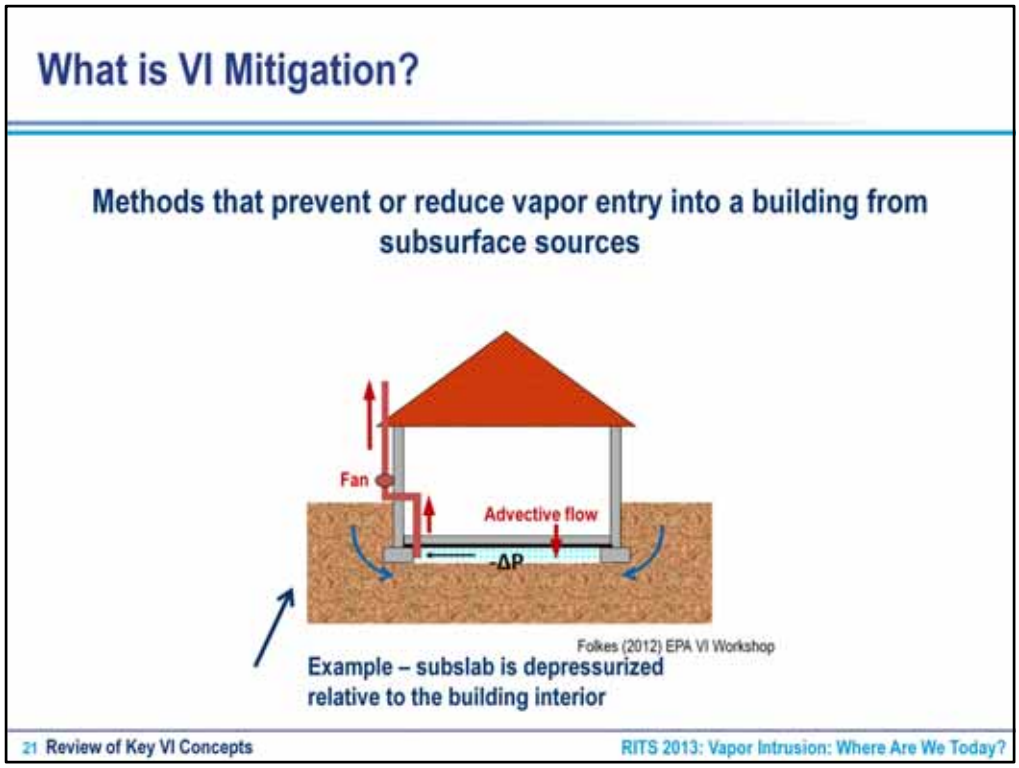
I wanted to highlight the importance of understanding building characteristics when assessing the VI pathway in these next two slides. As you can see with scenario 1 shown on the left here, an HVAC or air handling system that is pulling air from both the outside and the larger warehouse-type of space is going to result in more dilution of VOCs in the office space than scenario 2 where that same office space has no engineered air exchange and a window air conditioner may be the only source of outdoor air for mixing.

Building Characteristics and VI Potential

- Subsurface Vapor Entry Points
- Indoor Sources (*cis*-1,2-DCE)
- Indoor/Outdoor Air Exchange
- Compartmentalization

20 Review of Key VI Concepts RITS 2013: Vapor Intrusion: Where Are We Today?

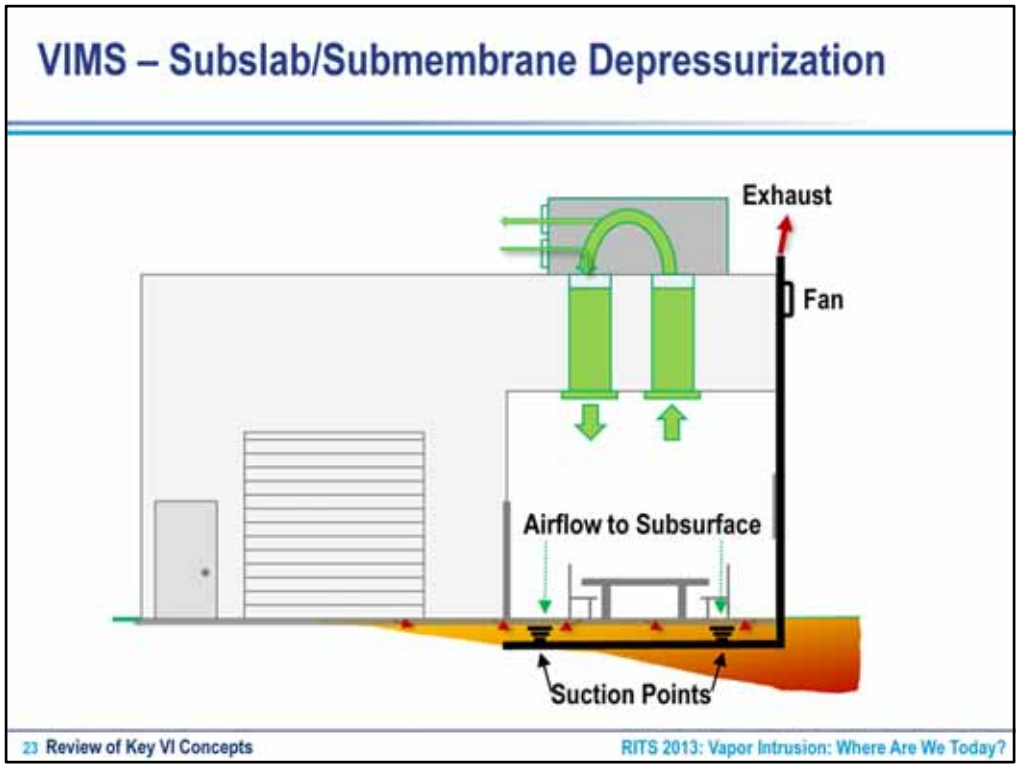
This slide shows some additional building characteristics that affect VI potential, including vapor entry points like this utility panel where looking down, you can even see the soil; indoor sources, leaky buildings like this building shown on the bottom left, and compartmentalization. I am going to shift gears now and talk about some key concepts related to vapor intrusion mitigation.



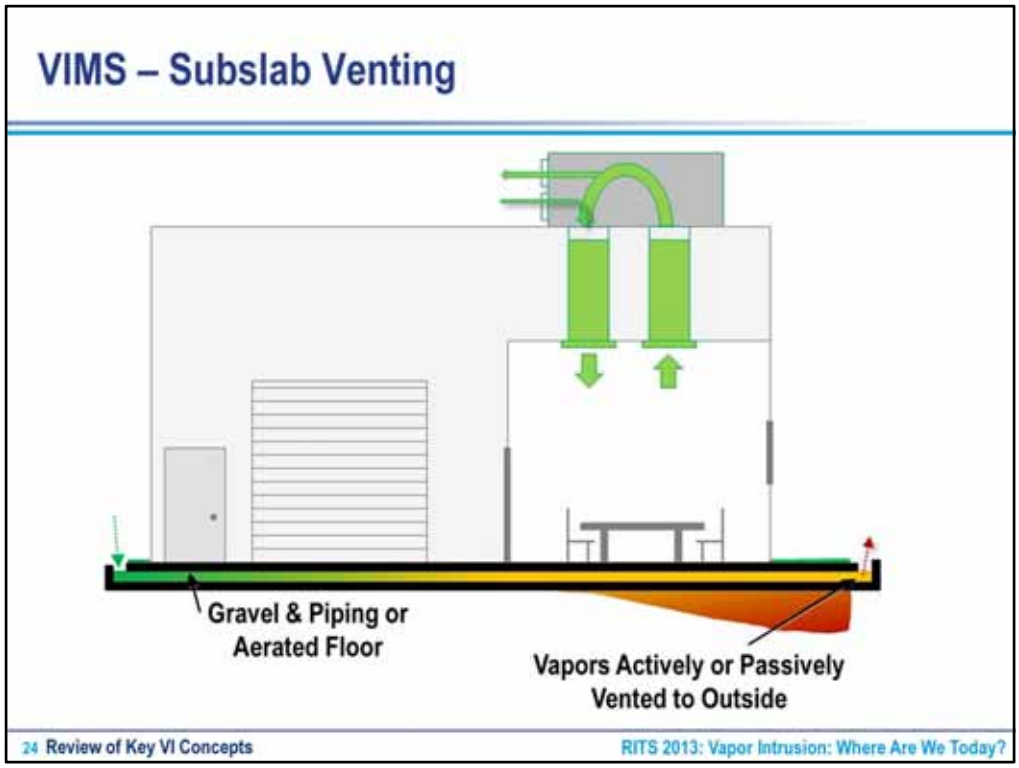
First, I want to define vapor intrusion mitigation as methods that prevent or reduce vapor entry into a building from subsurface sources. The example I show on the bottom left is a subslab depressurization mitigation system. The pictures on the right were taken at a Navy building with a mitigation system. I'm going to show you some of the current techniques used for VI mitigation on the next few slides.

Vapor Intrusion Mitigation Systems (VIMS)

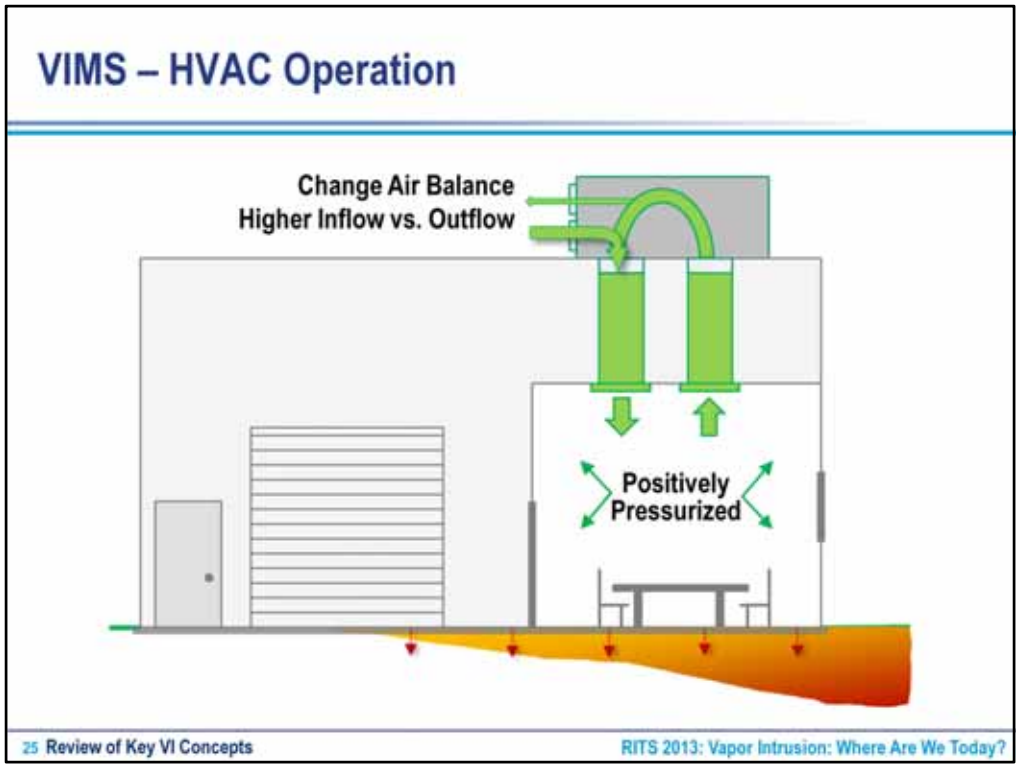
Technology	Active	Passive	How common?	Notes
Active Subslab Depressurization	x		Very	Most common (currently)
Subslab Venting	x	x	Increasing	"Green" solution if passive
HVAC Operation	x		Not very	Performance monitoring may be more intensive
"Temporary" Indoor Air Treatment	x		Not very	Usually not a long-term solution
VIMS – Sealing Vapor Entry Points		x	Used with other technologies	Not a stand-alone technology
Soil Vapor Extraction (SVE)	x		Increasing	Also treats VOC source



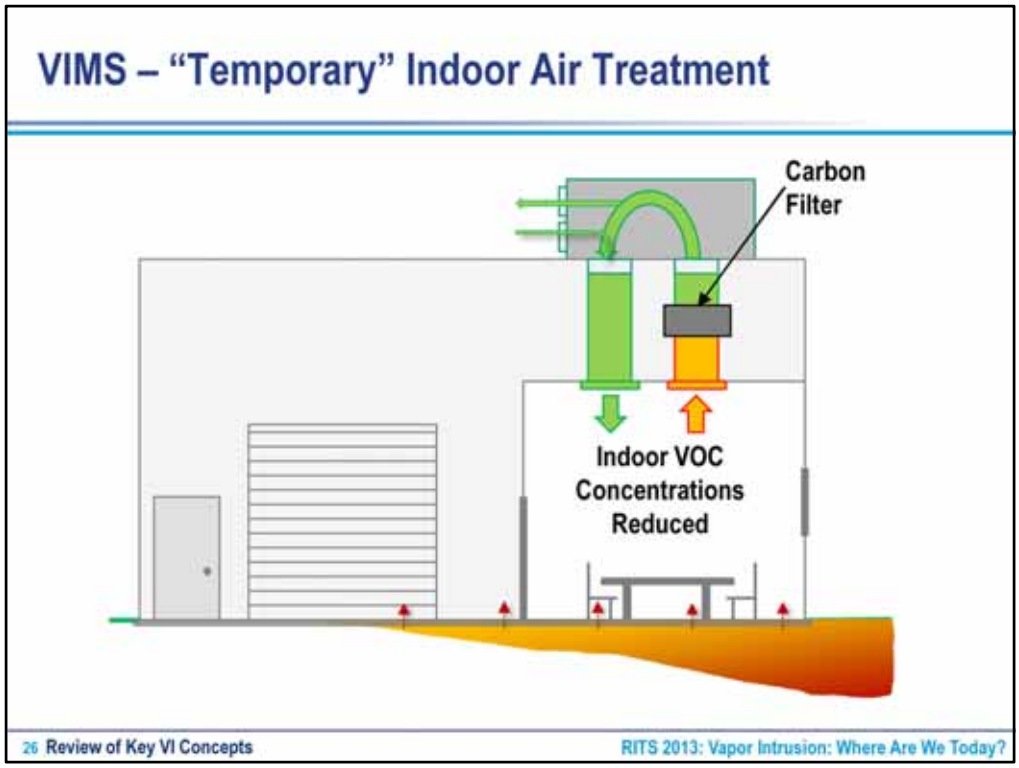
Let's start with a subslab/submembrane depressurization system, where suction points are installed through the slab and a vacuum is applied to depressurize the subslab and reverse or cut off the migration of vapors into the building. The air from beneath the slab is exhausted to the outdoors, with or without treatment.



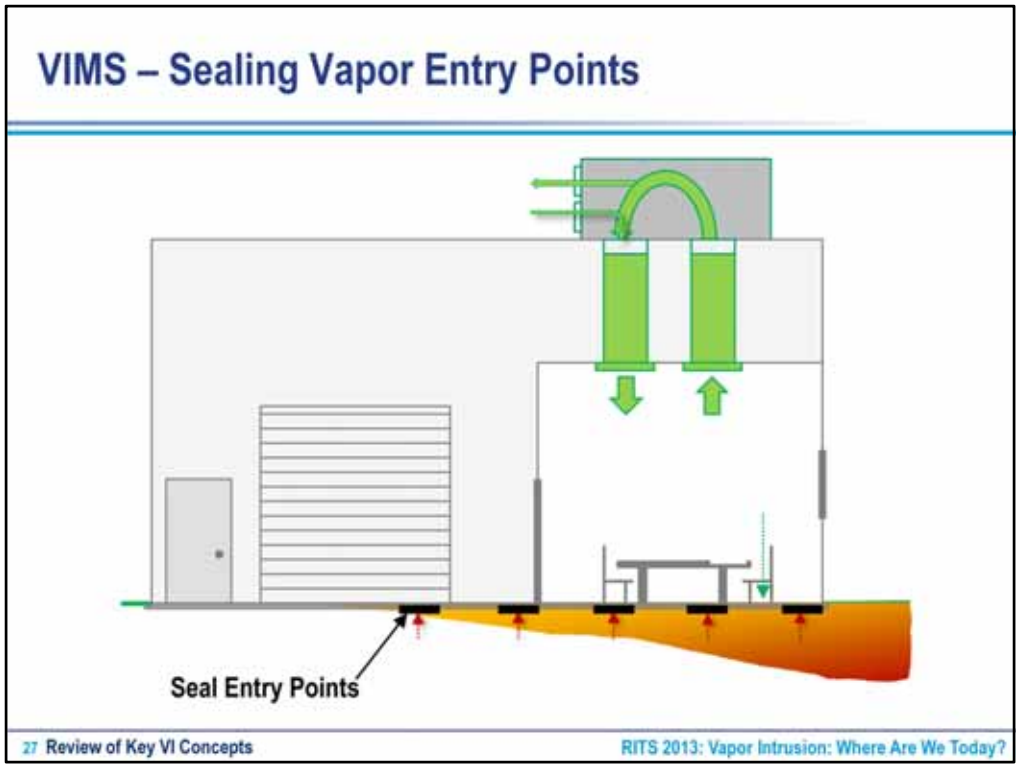
Subslab venting is a variation of the depressurization system, where air is vented through gravel and piping or an aerated floor and then actively or passively vented to the outside, again with or without treatment.



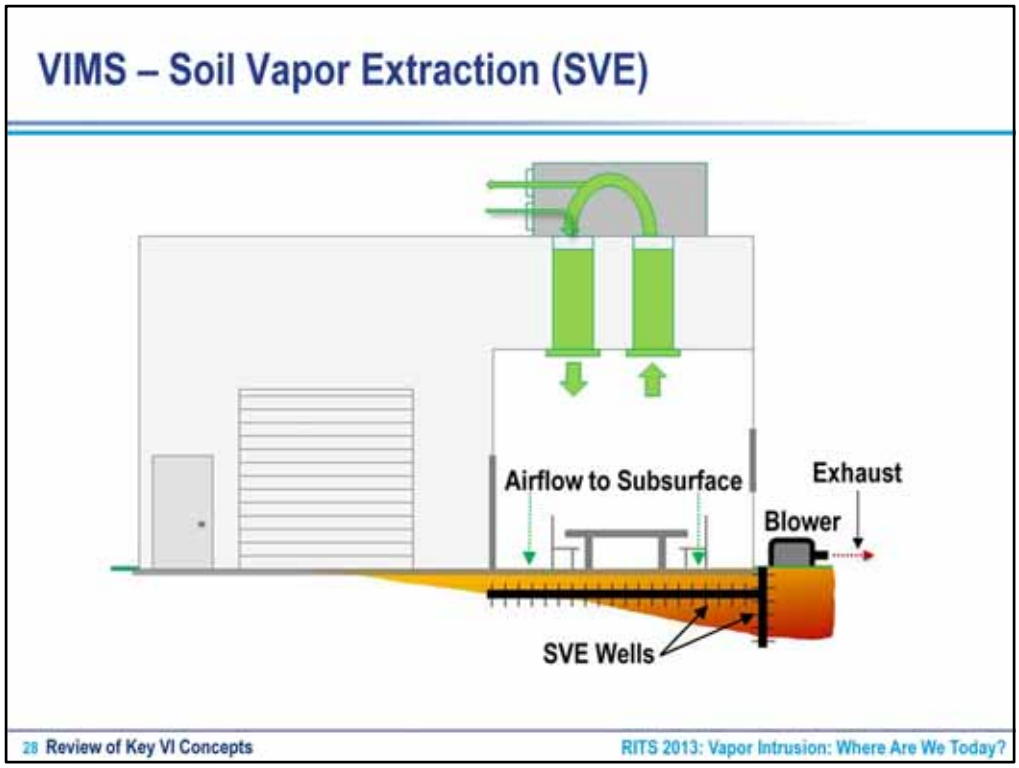
Modifying the air handling system is also a mitigation technique that can be used to pressurize the interior and force air downward, effectively preventing vapor intrusion into the building. You will need to be able to demonstrate that this system can continuously maintain a positive pressure for this technique to be effective.



Indoor air treatment targets the VOCs that have entered the building. It is often used as a temporary solution while a more permanent solution such as subslab depressurization is being designed and implemented.



Sealing vapor entry points is almost always performed in conjunction with other VI mitigation techniques and helps reduce or eliminate subslab vapor entry into the building.



The last technique I wanted to summarize is one where SVE is used as both a mitigation technique by depressurizing the subslab and forcing airflow into the subsurface, and a remediation technology that aggressively treats the subsurface source of vapors.

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29 RITS 2013: Vapor Intrusion: Where Are We Today?

The next few slides summarize issues related to VI guidance documents.

DoD June 2012 Comments on EPA's Efforts to Finalize VI Guidance

Comment	Addressed in April 2013 EPA Draft Final?	Useful/ Defensible?
Short-term exposure/rapid action	✓	–
Systematic decision framework	✓	+/–
Exit strategies	✓	+/–
Industrial building guidance	✓	–
AF database for industrial buildings	No	NA
Prioritizing sites	✓	+
Strategies to deal with temporal variability	✓	+/–
Sampling needs	✓	–
Background VOCs at industrial buildings	✓	–
Emerging techniques	✓	+/–

+ = useful – = not useful +/– = limited usefulness NA = not applicable

30 Update on Recent or Expected VI Guidance Documents RITS 2013: Vapor Intrusion: Where Are We Today?

As most of you know, EPA is in the process of updating their 2002 draft VI guidance. DoD formally submitted comments on EPA's efforts in June of last year. Those comments are summarized in this table. I included a column to show whether the 2013 draft final version of the revised guidance included text that addressed the DoD comments. I also included a column that shows how useful or defensible those edits are for those of us in the trenches conducting VI investigations. As you can see, there are questions about how useful the edits will be as written in the current draft final version. I do not have time to get into further details about the usability/defensibility conclusions, but would be happy to answer questions or talk with any of you after.

Notes:
http://www.regulations.gov/#!documentDetail;D=EPA-HQ-RCRA-2002-0033-0069
Provide procedures to assess short-term exposure
Incorporate systematic decision framework
Develop exit strategies for VI assessment and mitigation
Provide industrial building guidance and attenuation factor database
Include procedures to prioritize sites with multiple buildings
Provide specific guidance on addressing temporal variability
Incorporate procedures to determine how much sampling is needed
Develop/provide background VOC information for industrial buildings
Allow use of defensible emerging investigative/mitigation methods

April 2013 Draft Final EPA VI Guidance

- Significant differences from 2002 Draft
  - Short-term exposure and Rapid Action Levels (RALs)
  - Preemptive mitigation
    - Implementation, O&M, termination, institutional controls
  - Indoor air sampling earlier in assessment
- Additional responses to EPA OIG (2009) recommendations
  - Updated VI screening levels – VISL calculator
  - Multiple lines of evidence over tiered approach
  - Assess VI during 5-year reviews
  - Companion EPA OUST petroleum VI guidance

31 Update on Recent or Expected VI Guidance Documents RITS 2013: Vapor Intrusion: Where Are We Today?

I did want to briefly mention three significant differences in the Draft Final 2013 version compared with the 2002 draft. These include a section that EPA has incorporated on short-term exposure and rapid response levels that relies on the EPA R9 ad hoc RAL method they used for TCE. I will talk more about this in a later slide; however, I will say that there are technical concerns with the EPA R9 method. The 2013 version includes more information on preemptive mitigation, which is not surprising given comments made by EPA HQ folks the last few years. It is also not surprising that the 2013 draft emphasizes indoor air sampling earlier in the assessment; as I mentioned earlier, this is something EPA has been recommending for a number of years.

Assessing VI During 5-Year Reviews

- ***Assessing Protectiveness at Sites for Vapor Intrusion: Supplement to the "Comprehensive Five-Year Review Guidance"*** *OSWER 9200.2-84 (11/2012)*

Standard 5-Yr Review Criteria	Remedy functioning ?	Assumptions, toxicity data, cleanup levels, and remedial action objectives still valid?	New information ?
5-Year Review for VI	• Apply standard 5-yr review criteria • Assess specific VI factors • Multiple lines of evidence versus tiered approach		

Key Point — **VI must be considered during 5-year reviews, even if not assessed previously**

32 Update on Recent or Expected VI Guidance Documents — RITS 2013: Vapor Intrusion: Where Are We Today?

EPA has also recently released (in early Jan 2013) a supplemental OSWER Directive that requires an assessment of VI during 5-yr reviews. The standard 5-yr review questions apply, but with additional requirements to assess the VI pathway. Bottom Line: VI must be considered during 5-yr reviews, even if not assessed previously.

NAVFAC VI Protectiveness Guidance

NAVFAC Fact Sheet: Interpretation of EPA Nov 12 Guidance

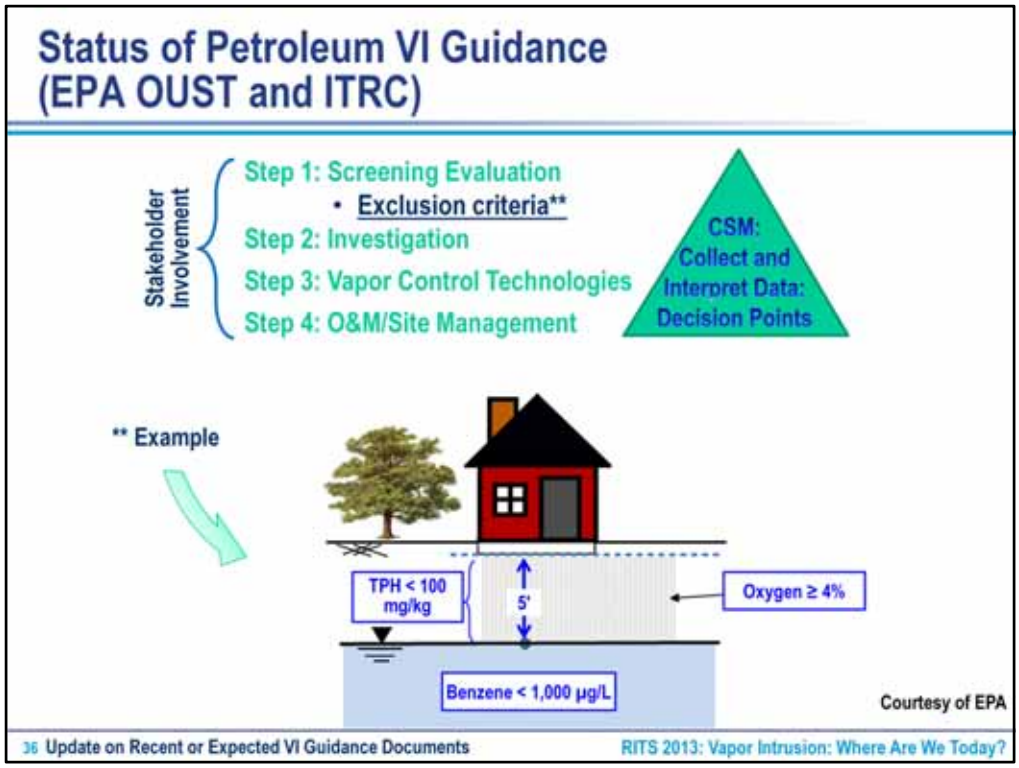
- Use multiple lines of evidence to assess current potential exposure
- Lack of VI assessment or uncertainty of VI occurring does not necessitate "Protectiveness Deferred"
- Measures can always be taken to prevent current uncontrolled exposure

NAVFAC VI Protectiveness Guidance (cont.)

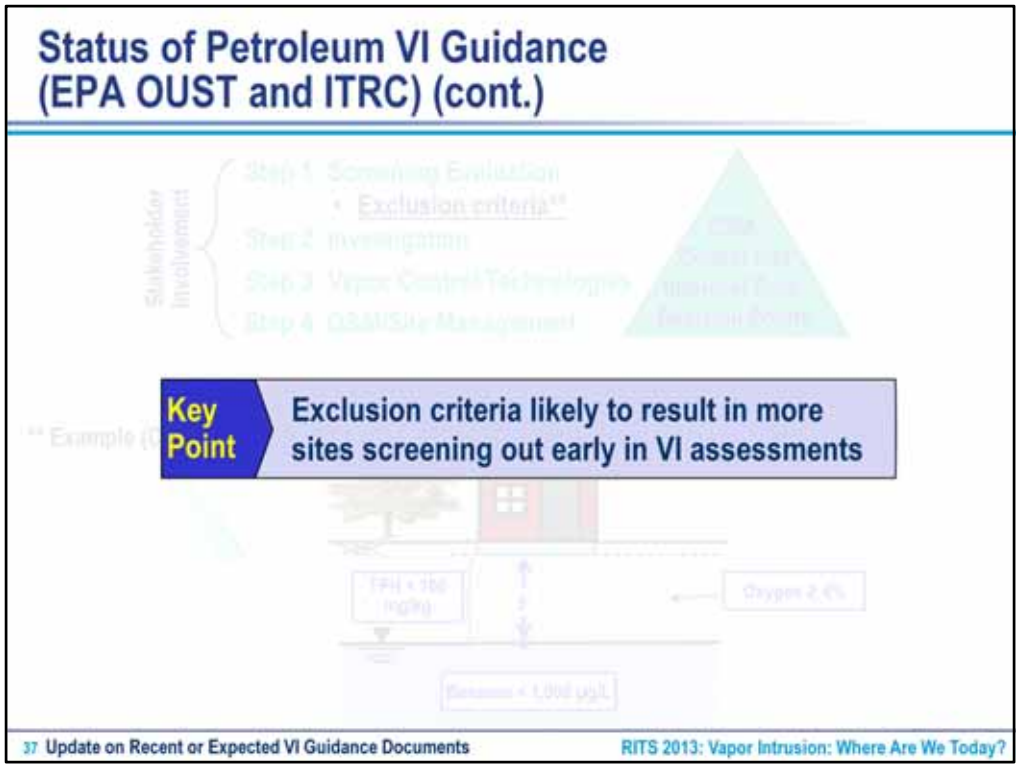
Scenario: **Protectiveness Statement**	VOC groundwater remedy in place. VI not yet evaluated. Nearby building is aircraft hanger with open bay doors and thick concrete slab. **Protective in the Short-Term**
Scenario: **Protectiveness Statement**	High levels of VOCs in soil immediately beneath building. Basement sump is potential preferential vapor pathway. HVAC adjusted to maintain positive pressure. Further VI study needed to ensure long-term protectiveness. **Protective in the Short-Term**
Scenario: **Protectiveness Statement**	High levels of VOCs in soil immediately beneath building. Basement sump is potential preferential vapor pathway. The building has no HVAC system. Further VI study needed to assess protectiveness. **Protectiveness Deferred**

Key Point There should never be the need for a "Not Protective" statement with respect to VI issues

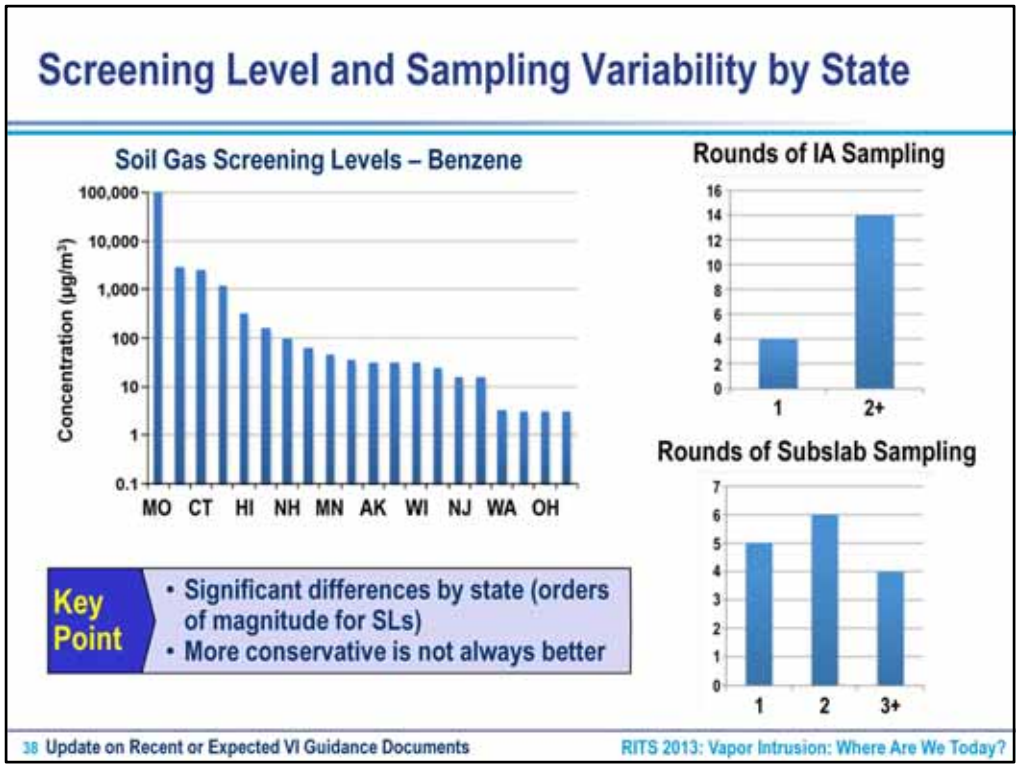
This slide is provided as a reference and shows where EPA is compiling all of the publically available information about VI. Before I talk about the status of state regulatory VI guidance, I did want to give a brief update on the status of petroleum VI guidance.



As you can see on this slide, both the EPA OUST and ITRC are developing petroleum VI guidance. The steps of the current draft versions are shown at the top of this figure. The idea of exclusion criteria seems to be the item that interests most folks. The bottom slide shows an example of exclusion criteria that have been incorporated recently into CalEPA UST policy. A structure that meets these criteria for at least 5 ft of clean soil above the source, benzene concentrations below 1,000 ug/L and at least 4% of oxygen is excluded from further VI evaluations. Exclusion criteria for pVI are based on multiple years of data and likely will allow more UST sites to be excluded from further VI investigations.



Notice how in late 2012, almost all states now have VI guidance. You might ask why this and the previous slides were included. Before I talk about the variability in state VI guidance documents, I wanted to use a minute or two to conduct a survey. By show of hands, how many of you think risk management decisions can be made based on an inherent order of magnitude in chemical concentrations? Now, what about two orders of magnitude. What about 3 orders of magnitude. An lastly... do you think you can make decisions if there are 4 orders of magnitude difference in regulatory screening levels? Next slide.



Soooo... consider the result of our quick and dirty survey, how do you feel about the 3 ½ to 5 orders of magnitude in the variability in state VI SG screening levels shown on this figure on the left? Notice also that the majority of surveyed states require two or more rounds of IA and SS sampling, as shown on the figures at the right. The key points are that there are significant differences in SLs by state (orders of magnitude) and more conservative is not always better.

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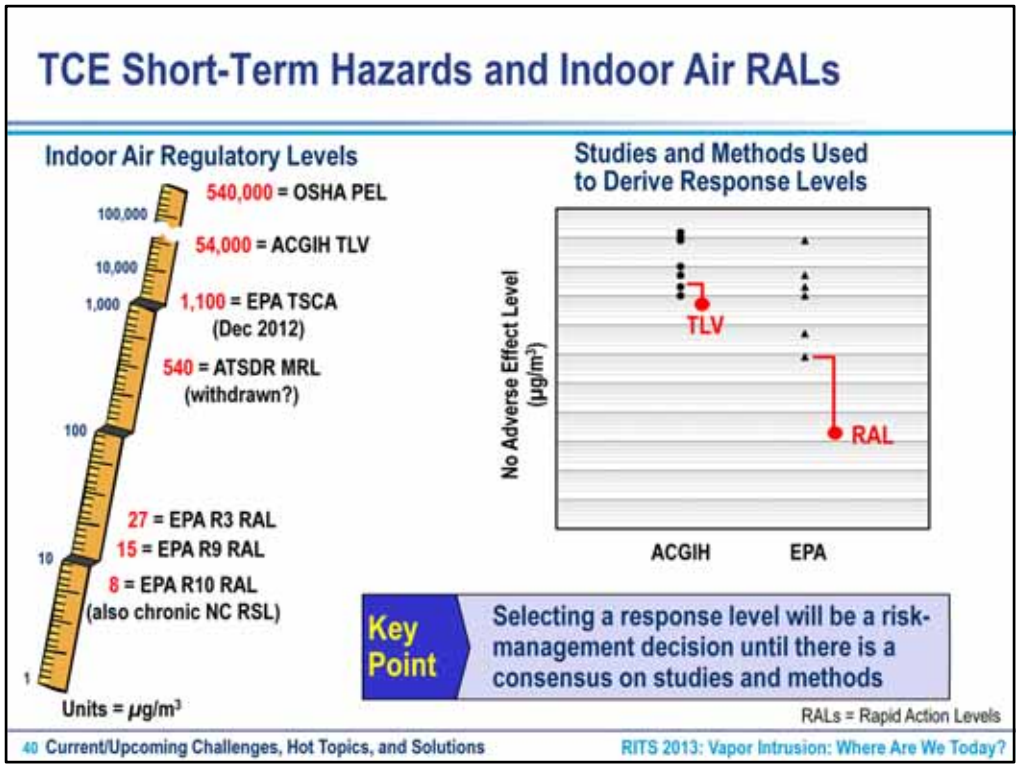
39 RITS 2013: Vapor Intrusion: Where Are We Today?

I am now going to move on to the challenges, hot topics, and solutions for assessing or mitigating VI.



This talks more about the short-term hazard and rapid response level issues, using TCE as an example. EPA Regions 10, 9, and 3 have recently developed "ad-hoc" TCE RALs in air based on concerns about developmental effects (these levels are listed on the ruler shown on the left) while the latest ATSDR, EPA TSCA, and industrial hygiene RALs are orders of magnitude higher. There are two fundamental reasons why this is the case:

1) The industrial hygiene organizations have a tendency to select studies that they believe are more relevant to an occupational scenario and typically, have high "no adverse toxic effect" levels. EPA generally includes a larger range of studies in selecting the starting point and generally picks one with a lower starting concentration, and

2) Industrial hygiene organizations tend to incorporate smaller "safety factors" than EPA when developing the response levels, which I am representing by the red lines and dots. Ultimately, this can result in the criteria being orders of magnitude different.

Interim Recommendations for RPMs Regarding the TCE Rapid Response Issue

- Notify Environmental Restoration (ER) manager
- Prepare risk communication factsheet
- Discuss rapid response metrics with stakeholders prior to sampling
- Identify short term measures to mitigate exposure while workers remain in the building
- Contact NAVFAC LANT and EXWC for technical support
- Notify base health and safety personnel
- Brief base leadership and building superintendents
- Engage NMCPHC to plan for OSHA versus CERCLA risk communication

41 Current/Upcoming Challenges, Hot Topics, and Solutions RITS 2013: Vapor Intrusion: Where Are We Today?

Until all this gets resolved as to how to handle the various RALs, if this issue comes up at a site:
1) Notify ER Manager
2) Prepare risk communication factsheet
3) Discuss rapid response metrics with stakeholders prior to sampling
4) Identify short term measures to mitigate exposure while workers remain in the building
5) Contact LANT or EXWC for Technical Support
6) Notify based health and safety folks
7) Brief base leadership/building superintendents
8) Engage NMCPHC to plan for OSHA vs CERCLA risk communication

The next challenge I want to talk about is achieving consistency and technical defensibility in VI assessments. Take for example the decision of whether and how to screen groundwater.

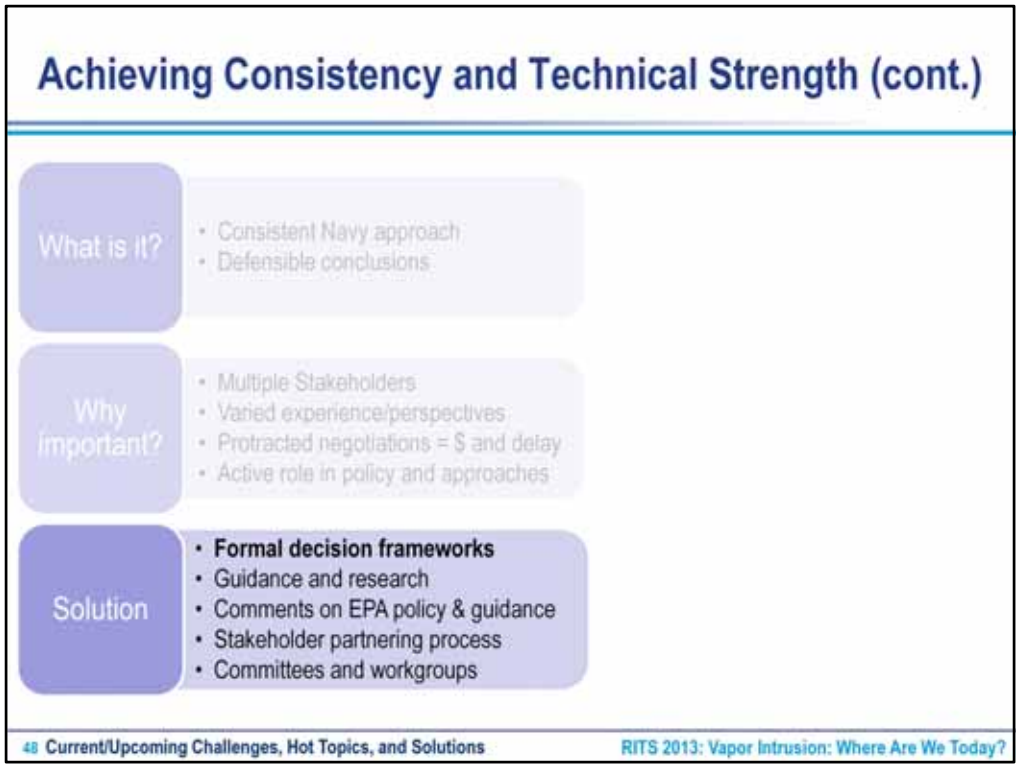
Achieving consistency and technical strength is important because multiple stakeholders with varied experience and perspective are involved. For example, this stakeholder may want to use the most conservative vapor attenuation factor....

This one may question if GW data are appropriate...

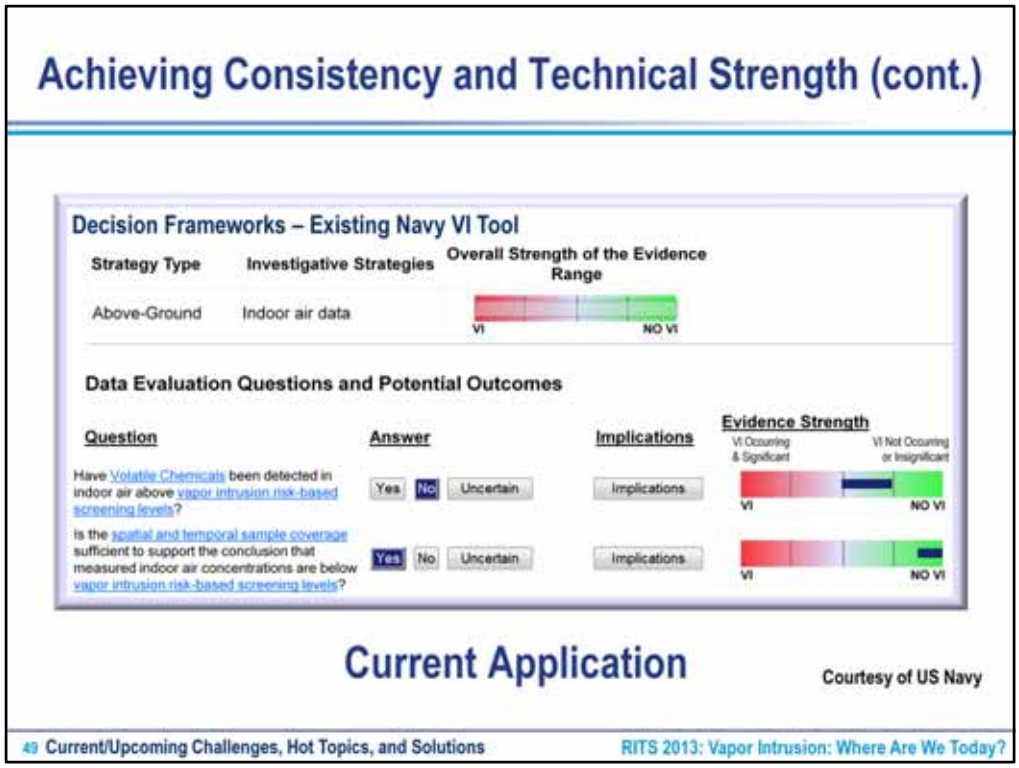
This one wants to sample inside the building...

and this one may want to develop a site-specific attenuation factor.

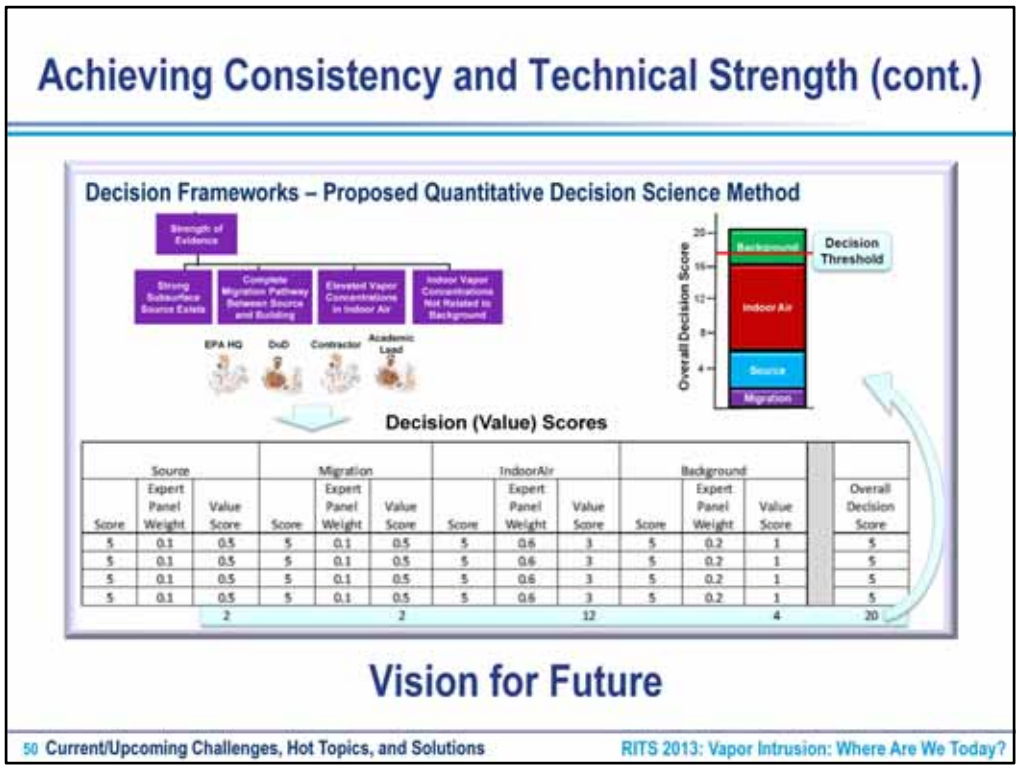
The RPM is thinking "Ughh!"



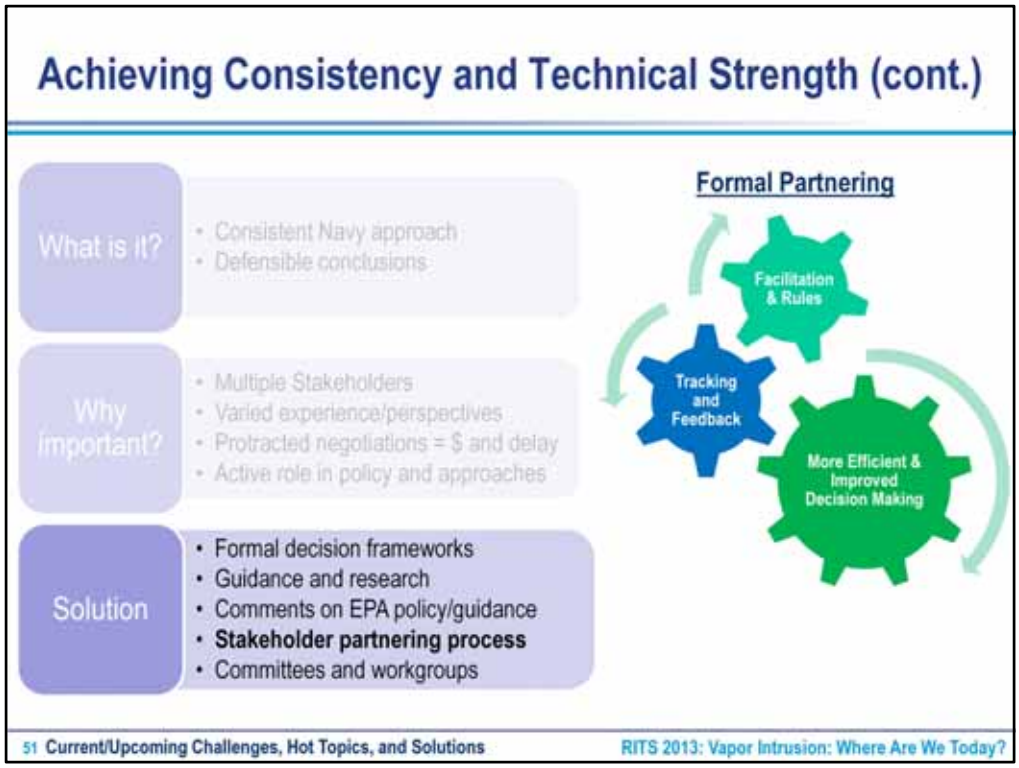
Sooo... what are some of the solutions to this dilemma? The first one I'll mention is using formal decision frameworks.



This includes the current application of the Navy VI web-tool. You can refer to the 2011 RITS for more details on this tool.



There are ongoing discussions about taking the decision process to the next level and applying quantitative decision science when assessing VI. The bar graph on the right shows an example of how each stakeholders perspective can get rolled up into an overall quantitative decision score. Wouldn't that be nice?



Another solution is continuing to implement and improve upon the stakeholder partnering process.

Speaker Notes: Many of these things like comments and workgroups are going on behind the scenes but have direct benefits for RPMs and the Navy

Achieving Consistency and Technical Strength (cont.)

What is it?
- Consistent Navy approach
- Defensible conclusions

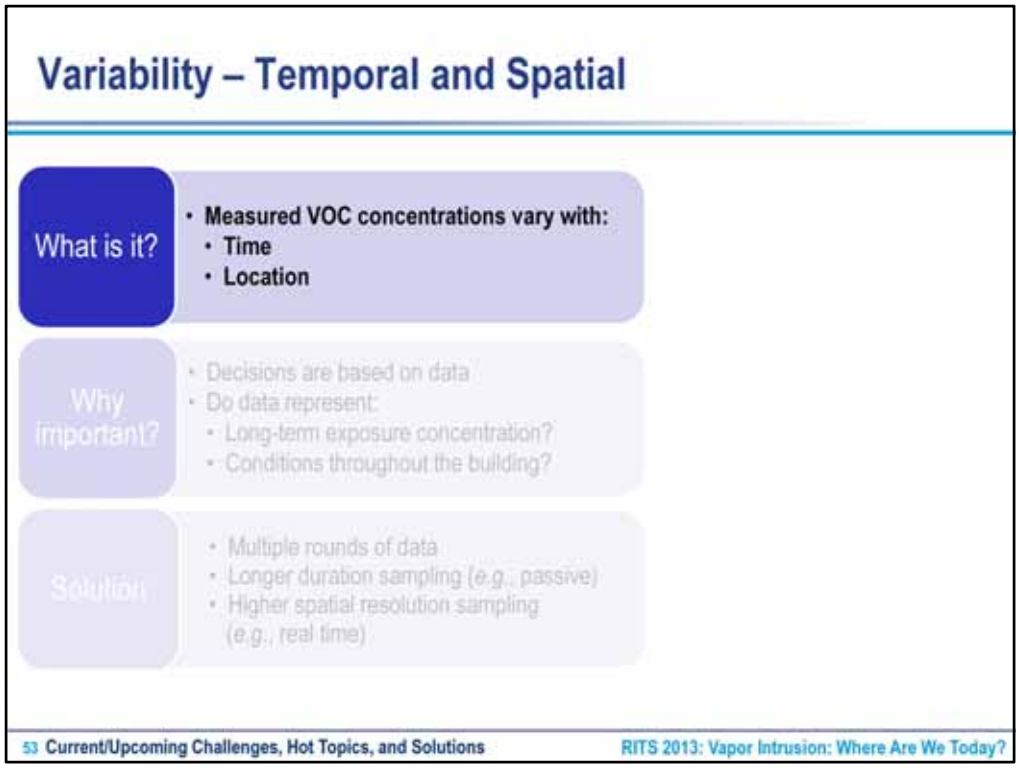
Why important?
- Multiple Stakeholders
- Varied experience/perspectives
- Protracted negotiations = $ and delay
- Active role in policy and approaches

Solution
- Formal decision frameworks
- Guidance and research
- Comments on EPA policy/guidance
- Stakeholder partnering process
- **Committees and workgroups**

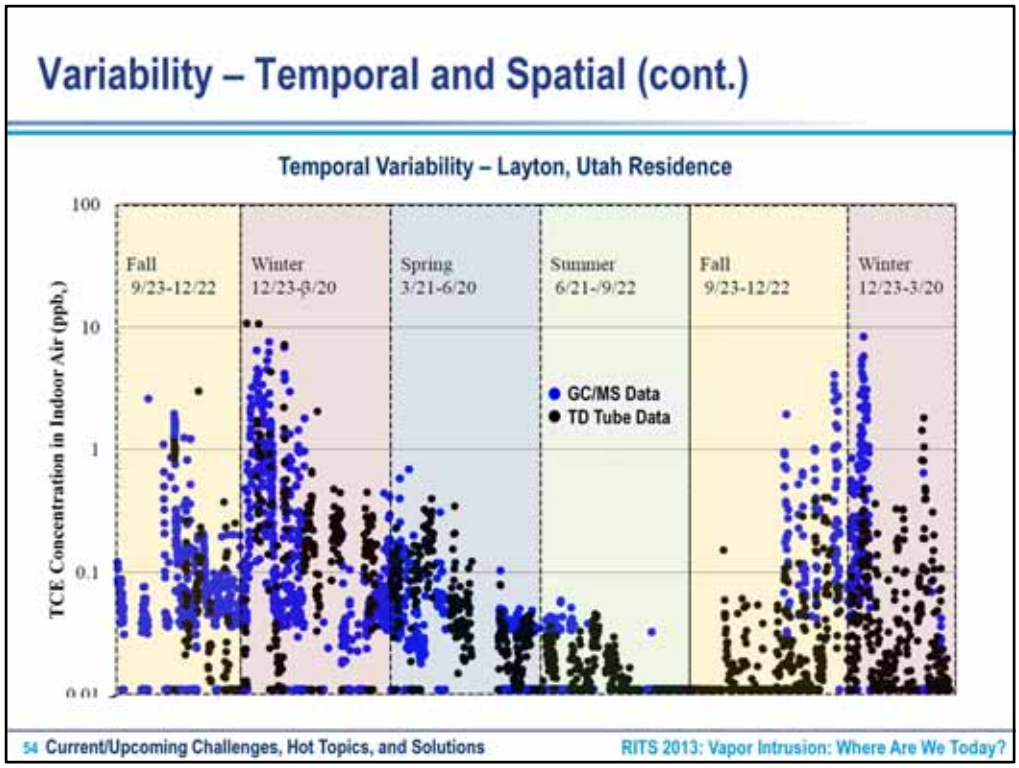
Committees and Workgroups
- Navy VI Focus Group
- ITRC Petroleum VI Workgroup
- EPA Federal Remediation Technologies Roundtable
- Tri-services Workgroup
- DoD Cleanup Committee

52 Current/Upcoming Challenges, Hot Topics, and Solutions — RITS 2013: Vapor Intrusion: Where Are We Today?

Lastly, continuing to participate in committees and workgroups will have a positive effect on achieving consistency and technical strength.



The next challenge I want to talk about is dealing with the fact that VOC vapor concentrations vary with time and location.



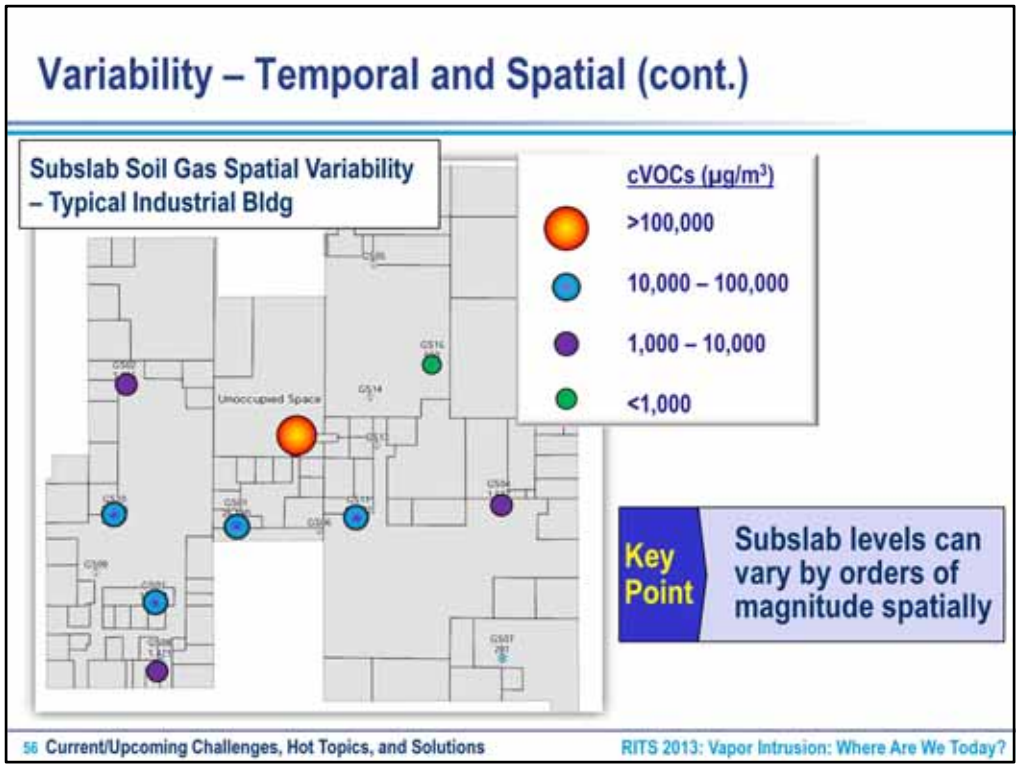
Here is a time series plot showing how short-term TCE indoor air concentrations vary over 1 ½ years at a residential house in Utah. As you can see, these very short-duration results varied by up to 3 orders of magnitude.

Variability – Temporal and Spatial (cont.)

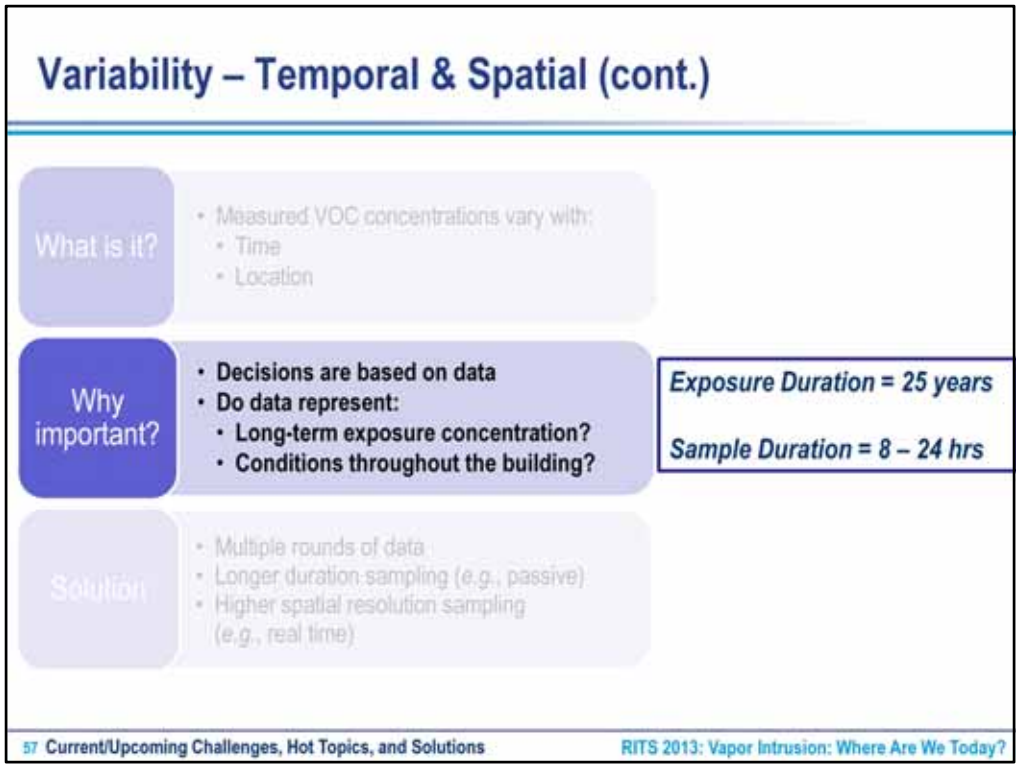
Temporal Variability - Layton, Utah Residence (Johnson, 2012)

Key Point Residential indoor air concentrations can vary with time by orders of magnitude

55 Current/Upcoming Challenges, Hot Topics, and Solutions RITS 2013: Vapor Intrusion: Where Are We Today?



This slide shows how subslab soil gas concentrations can also vary by 3 orders of magnitude in a typical Navy industrial building, with the size and color of the bubbles representing concentrations from <1,000 to over 100,000 ug/m3.



It is important to recognize that variability is real because our conclusions and decisions are only as good as the data. Do the data represent long-term exposure concentrations? Remember, risk estimates are driven mostly based on long-term exposure, like 25 years. Does an 8 or 24 hr sample provide a good estimate of a 25 yr exposure duration?

Variability – Temporal & Spatial (cont.)

What is it?

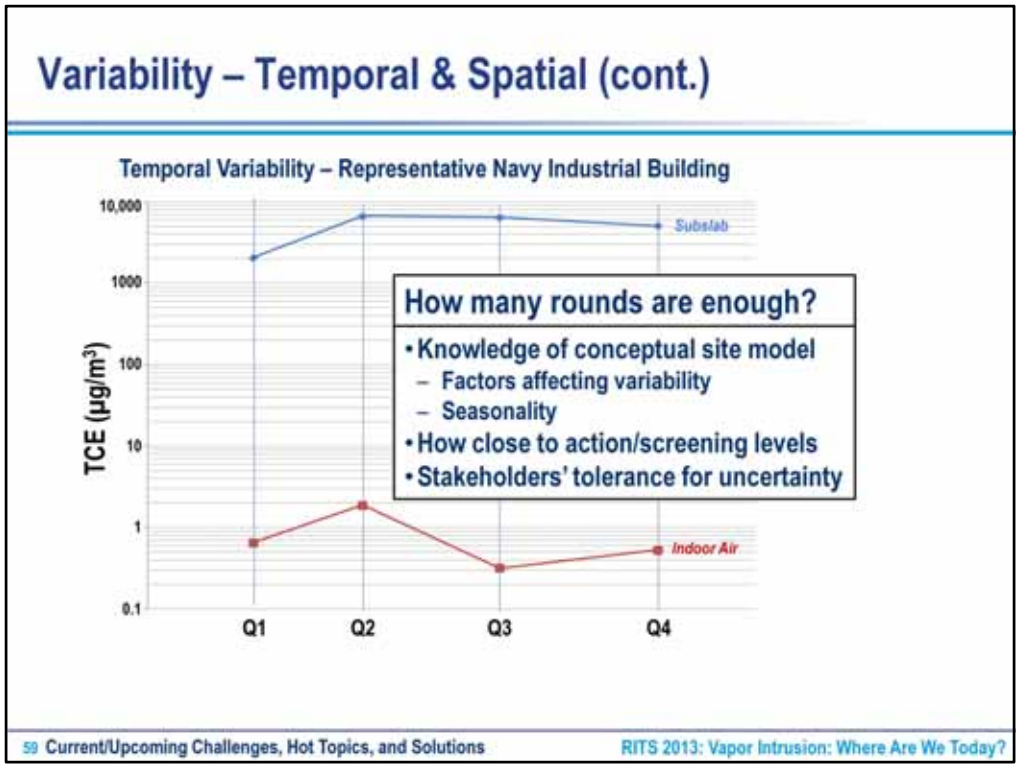
- Measured VOC concentrations vary with:
  - Time
  - Location

Why important?

- Decisions are based on data
- Do data represent:
  - Long-term exposure concentration?
  - Conditions throughout the building?

Solution

- **Multiple rounds of data**
- Longer duration sampling (*e.g.*, passive)
- Higher spatial resolution sampling (*e.g.*, real time)



Here is an example showing 4 rounds of 24-hr samples at a representative Navy industrial building. Note that these levels only varied by a factor of approximately 5.... contrast this with what I just showed you for the Utah residence. I will talk more about these differences during the case study later in the talk. It is important to consider the factors affecting variability, the SLs, and stakeholders' tolerance for uncertainty when deciding how many rounds are enough.

Variability – Temporal & Spatial (cont.)

What is it?

- Measured VOC concentrations vary with:
  - Time
  - Location

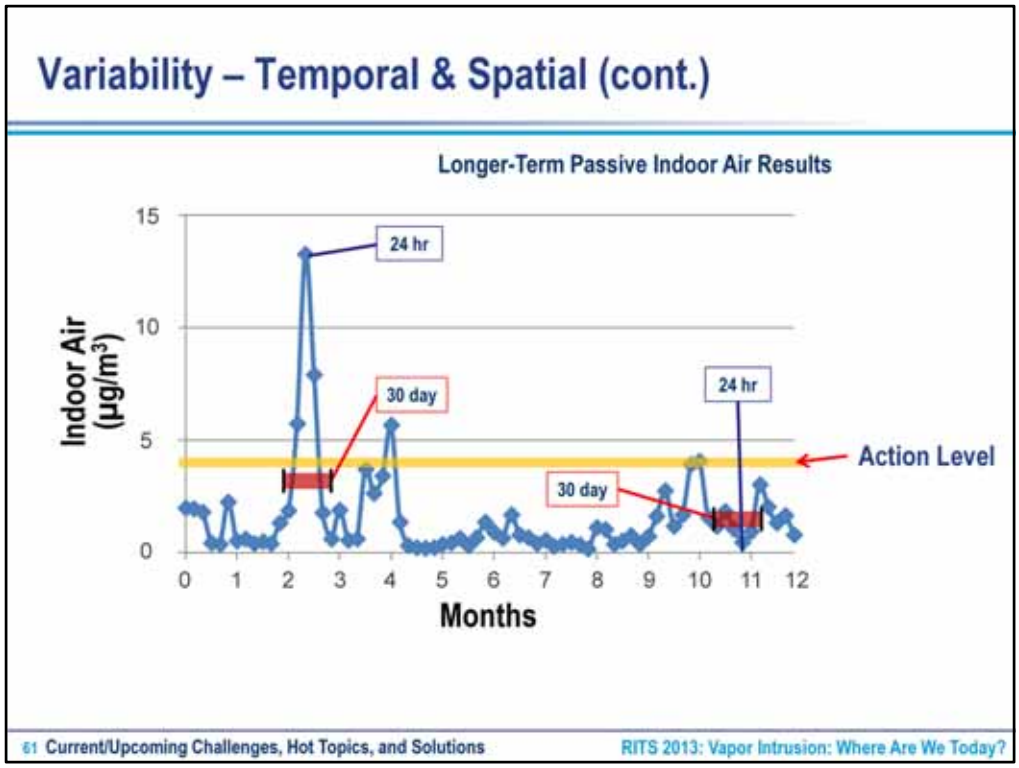
Why important?

- Decisions are based on data
- Do data represent:
  - Long-term exposure concentration?
  - Conditions throughout the building?

Solution

- Multiple rounds of data
- **Longer duration sampling (*e.g.*, passive)**
- Higher spatial resolution sampling (*e.g.*, real time)

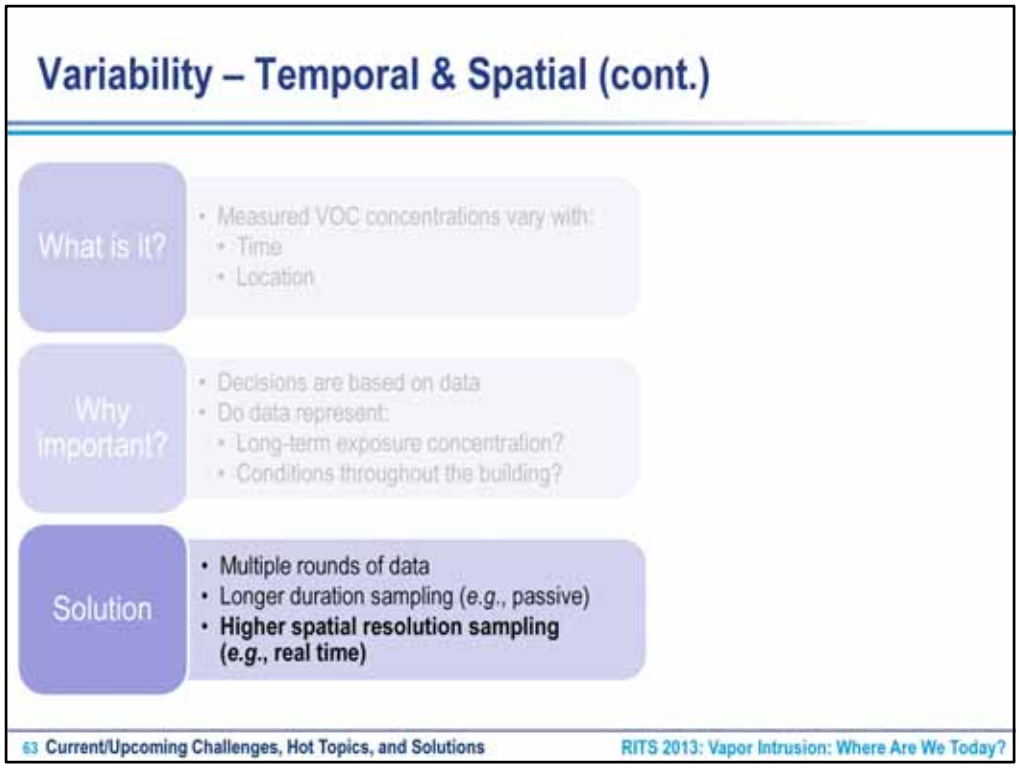
Longer sampling durations can also resolve uncertainties about temporal variability.



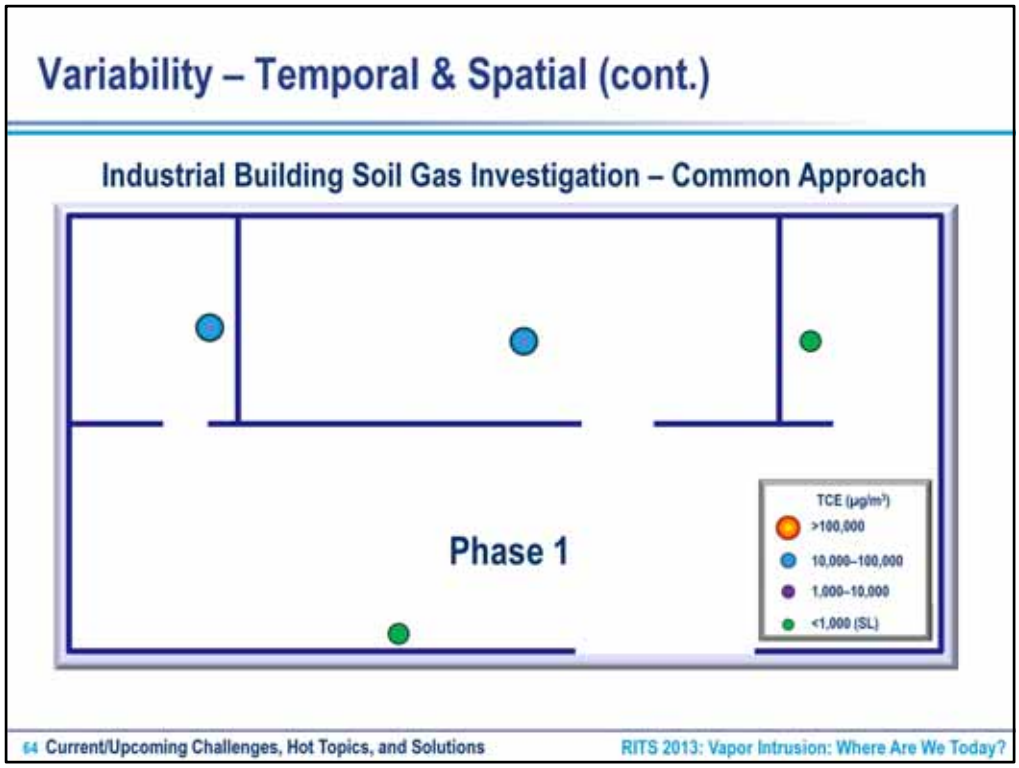
Assume you have a building with this type of 24 hr time series profile, with an action level of about 4 ug/ m3. If you were to collect a 24 hr sample on the date of the maximum concentration, you would exceed the action level. However, if you happened to collect a 24-hr sample during one of the dates where the concentrations are low, you would be well below the action level. Consider if you were to use a longer-term sampling device to collect a 30-day sample. The 30-day concentrations would be the average of multiple 24-hr samples and would not vary as much as the 24-hr results.

Variability – Temporal & Spatial (cont.)

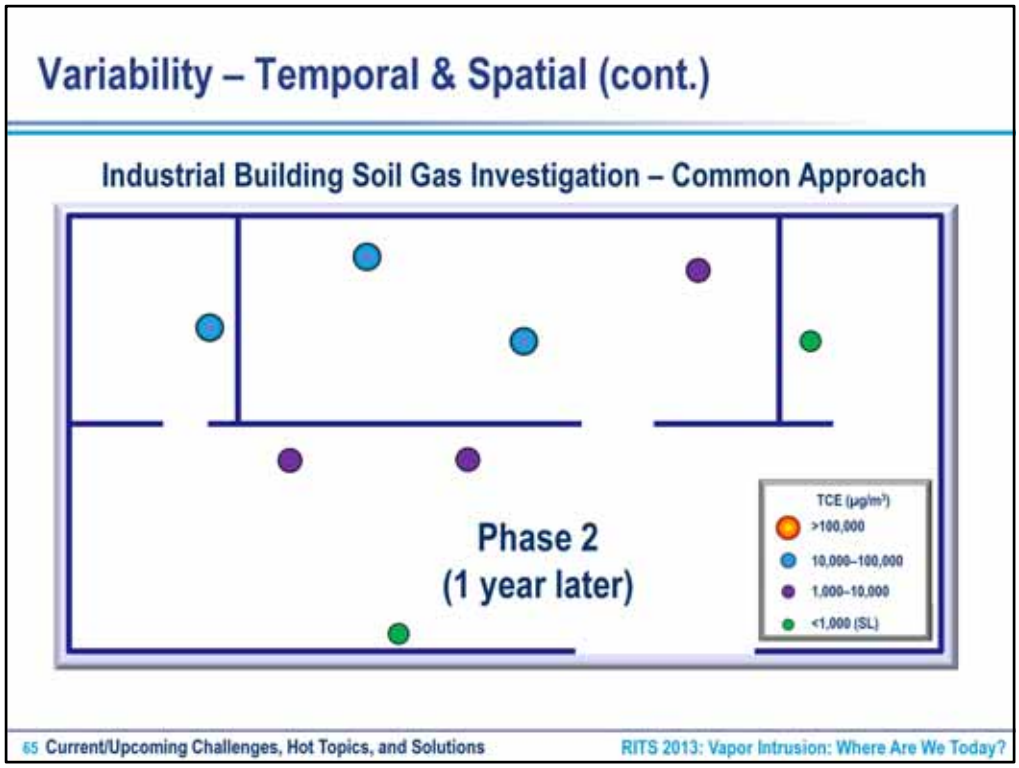
Key Point Indoor air results may vary significantly less with longer sampling durations



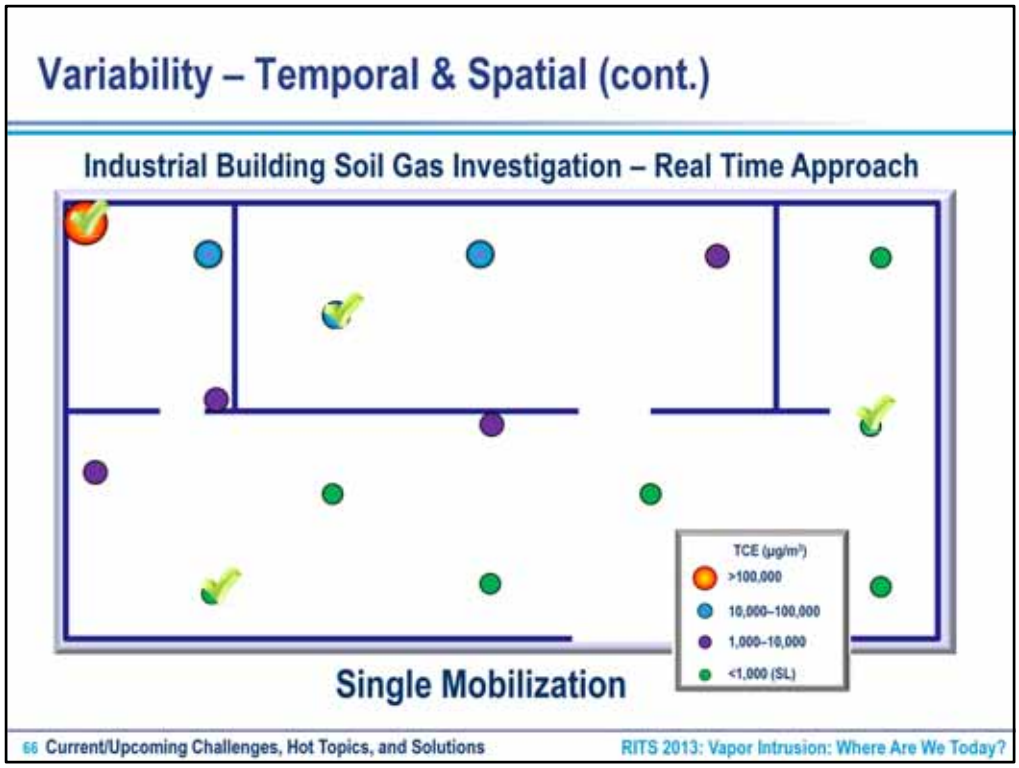
This 3rd solution is focused on addressing spatial variability, particularly in the subslab. It involves using real-time sampling to collect more samples. To better understand this solution, I want to first show you the approach commonly used.



This picture represents a typical medium-sized industrial building (say 15,000 ft^2) with multiple rooms. We think the source is located beneath the northern ½ of the building. We install two subslab probes in the assumed source area and then two probes to the south and east and collect 24-hr samples in Summa canisters during Phase 1. These two northern locations have concentrations that exceed the VI SLs.



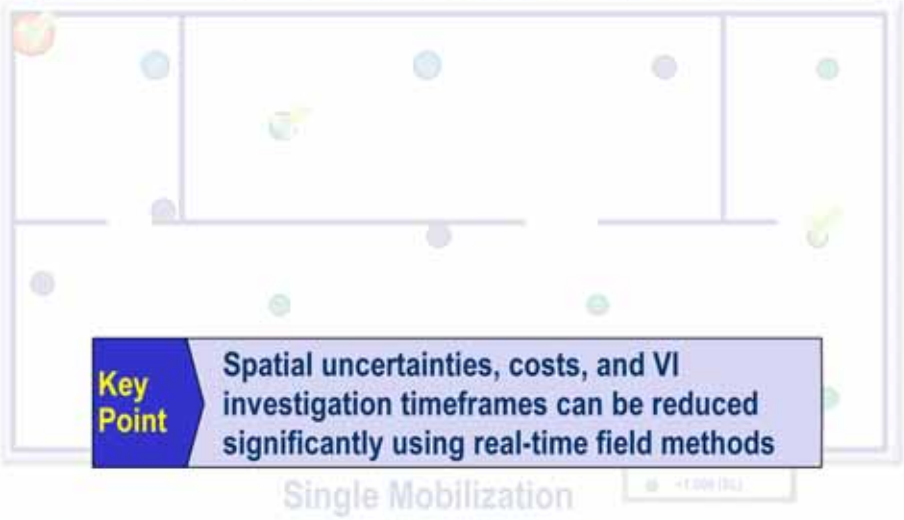
Soooo... about 1 year later we install 4 additional step-out probes to further characterize subslab impacts. We often worry about whether we have enough samples, the costs of additional samples, and the time it takes to conduct a phased investigation.



Most of these concerns could be resolved if using field real-time methods that allow us the option to collect more data for the same cost and make decisions about the need for additional data during a single mobilization. For example, we could systematically collect the first set of samples using a more dense sampling density in an objective grid pattern. The real-time results show concentrations above the SLs in these 4 samples. We could collect additional step-out samples and then based on the results, we could even then select the most appropriate Summa canister locations if needed, all during a single mobilization. The overall costs would be less and the spatial uncertainties reduced.

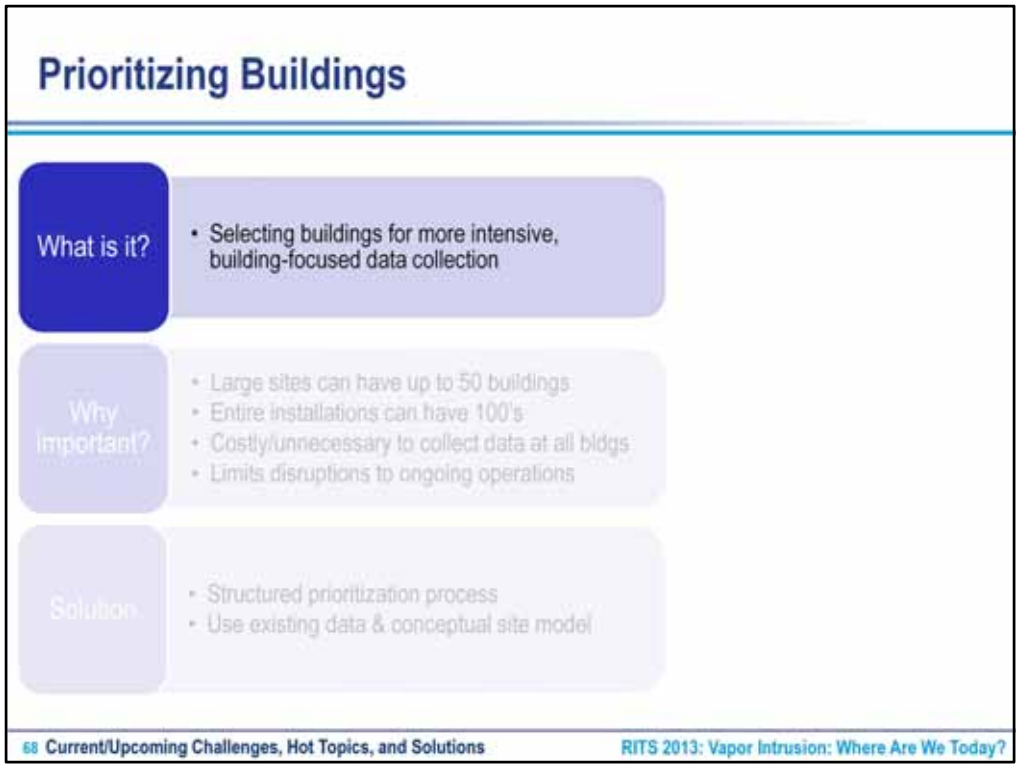
Variability – Temporal & Spatial (cont.)

Industrial Building Soil Gas Investigation – Real Time Approach

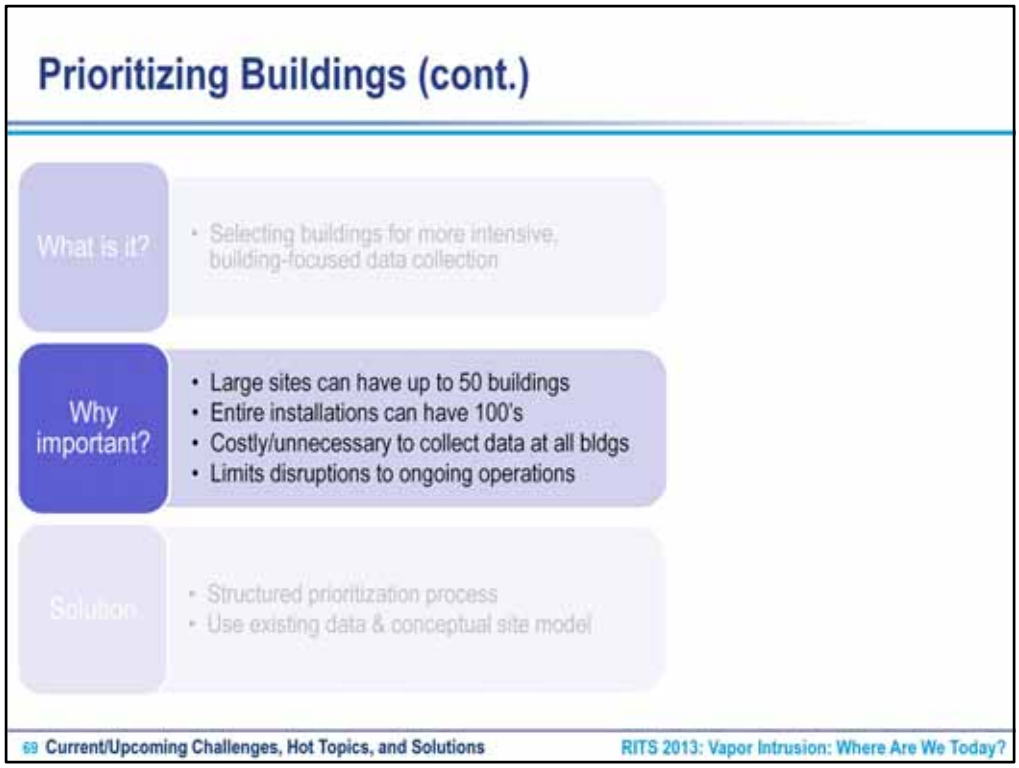


Key Point

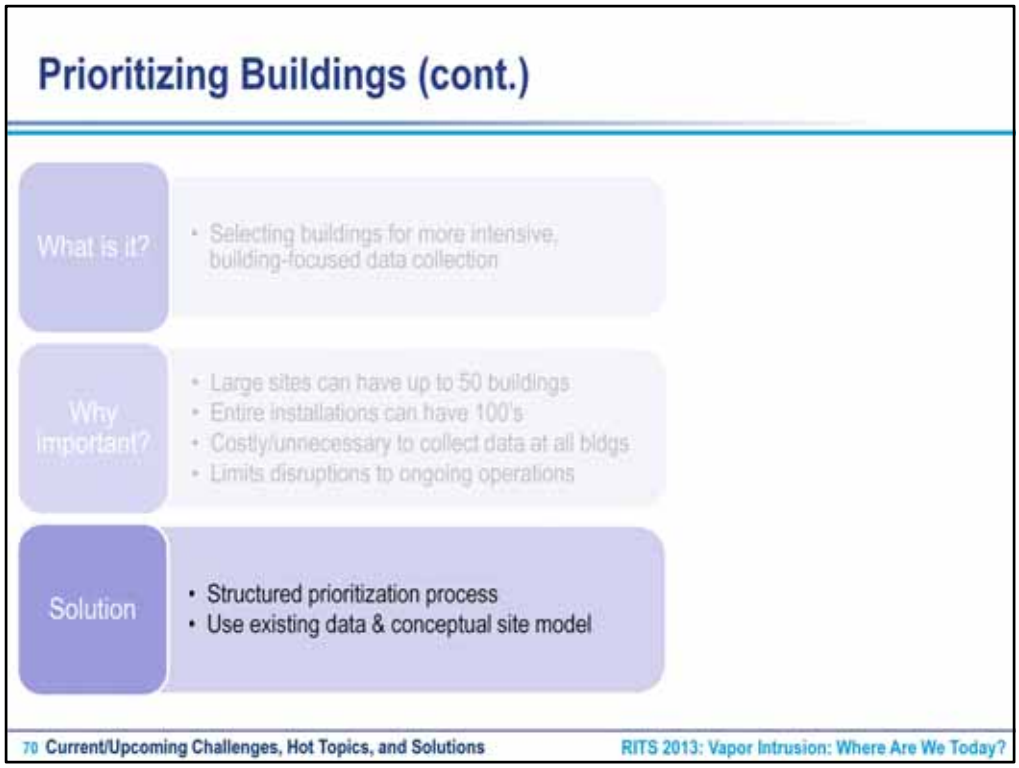
Spatial uncertainties, costs, and VI investigation timeframes can be reduced significantly using real-time field methods



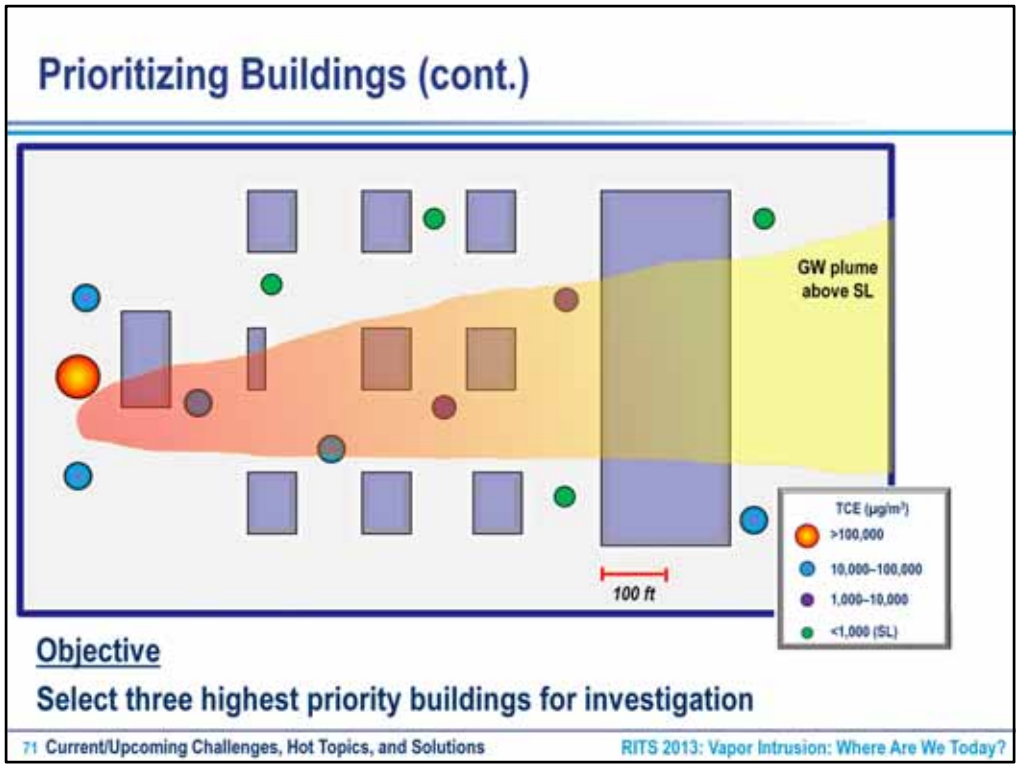
Another challenge that we often face at bases with multiple buildings is selecting buildings for more intensive data collection, realizing that it would likely be cost-prohibitive to investigate all buildings.



Large sites can have 50 buildings or more, with entire installations having 100s of buildings. EPA is also very interested in being able to effectively prioritize buildings, particularly as they consider adding VI as a component of the NPL hazard ranking system process.



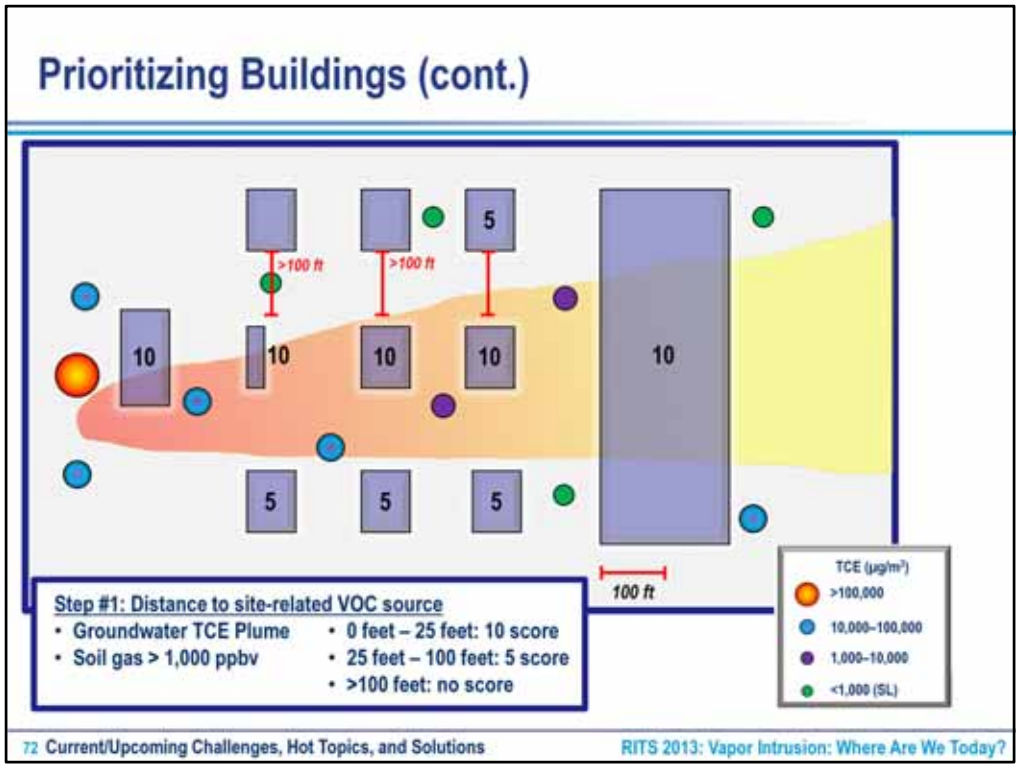
I want to discuss using a structured and objective prioritization process developed at one Navy installation.



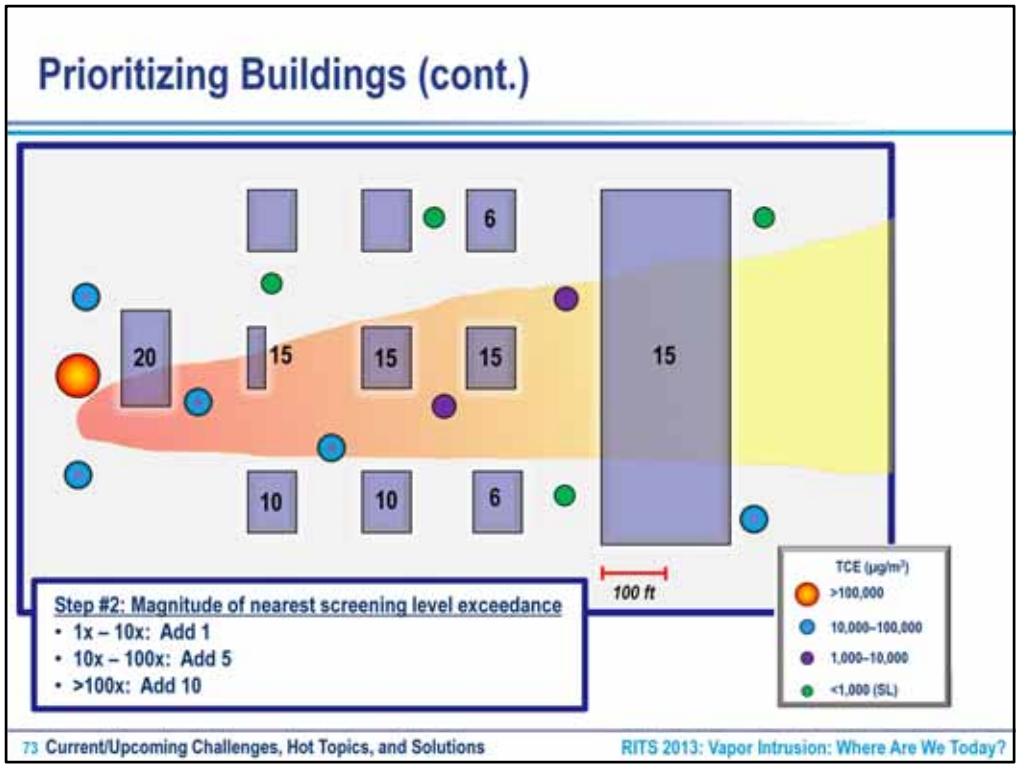
Assume this is a representative site with multiple buildings located over or near GW with TCE impacts above.

The SL and exterior soil gas concentrations are shown here.

The objective is to select the 3 highest priority buildings for investigation.

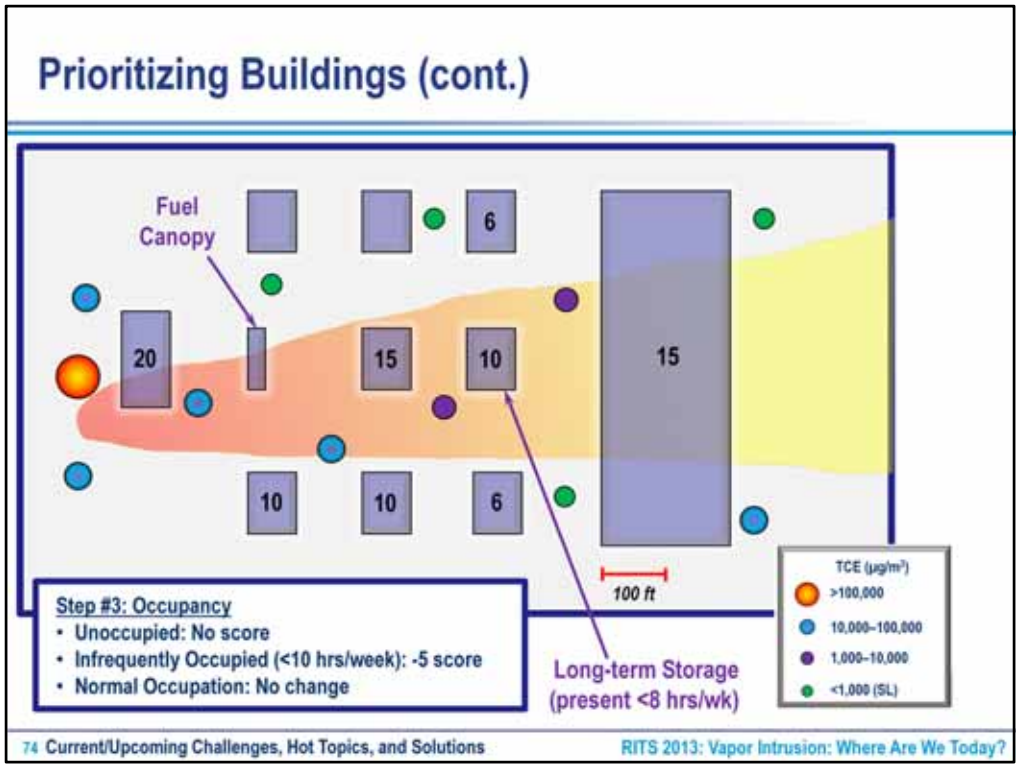


Step 1 involves determining the distance of each building from the VOC source and then assigning a prioritization value to each building based on the relative distances shown in the text box. The priority values are shown in red.

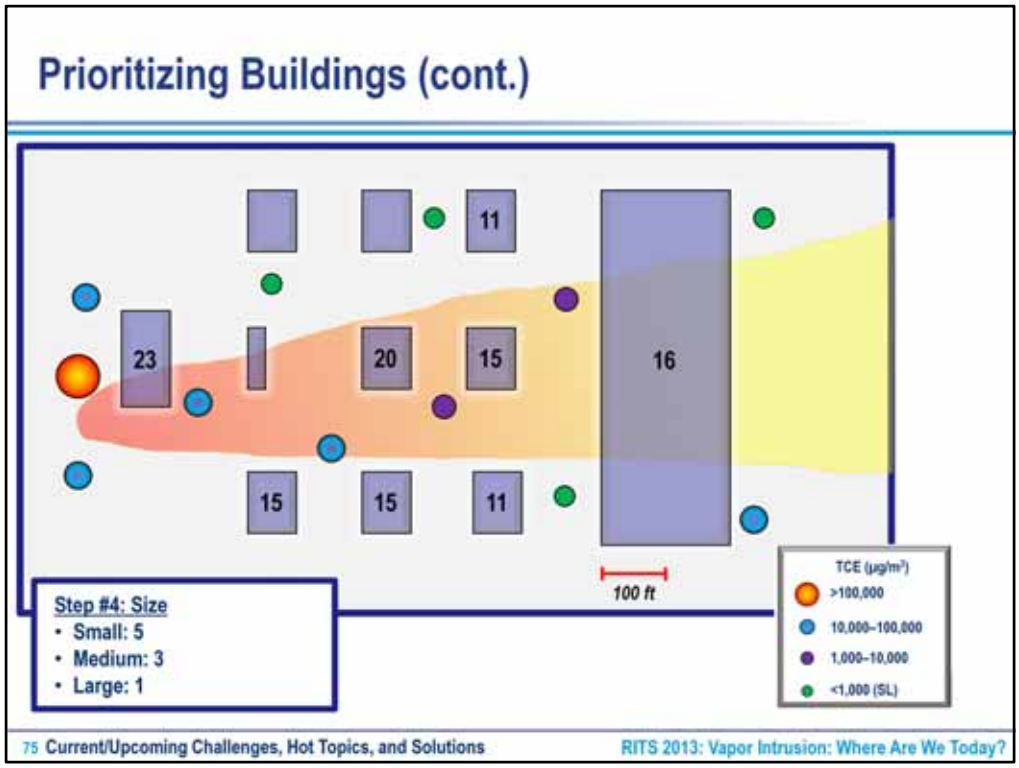


Step 2 considers the source strength using the relative weights shown in the text box. Notice that the buildings closest to the highest source strengths receive the higher priority values.

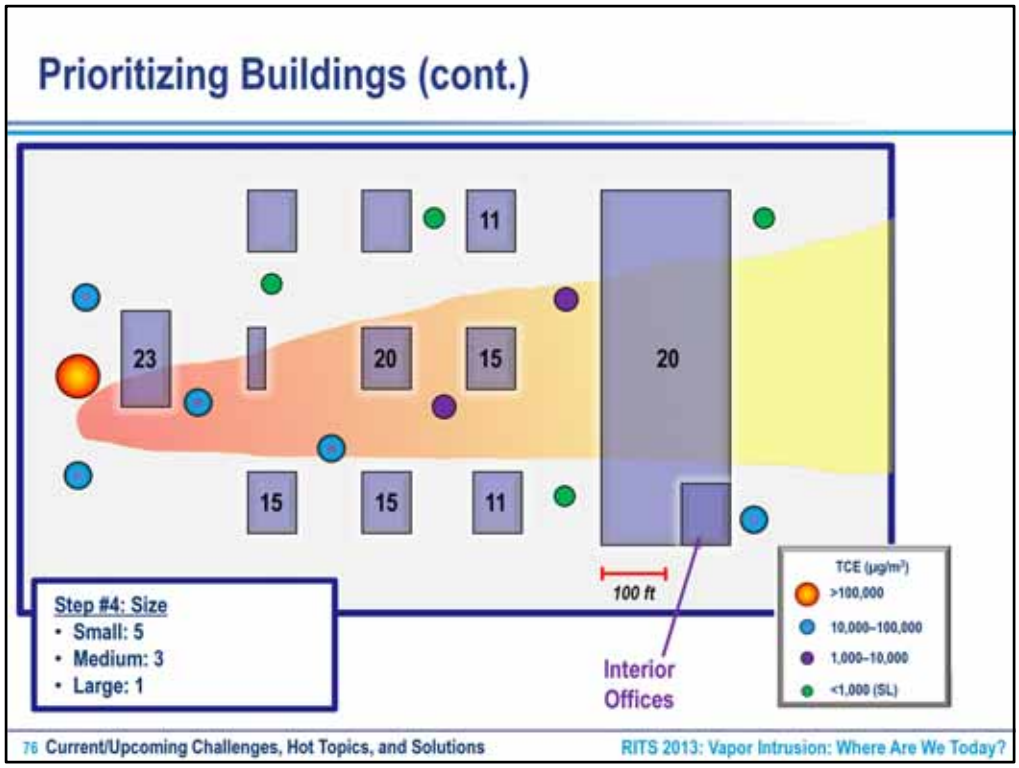
Note: Use the indoor Attenuation Factor (AF) when calculating SLs, not the default EPA residential AF.



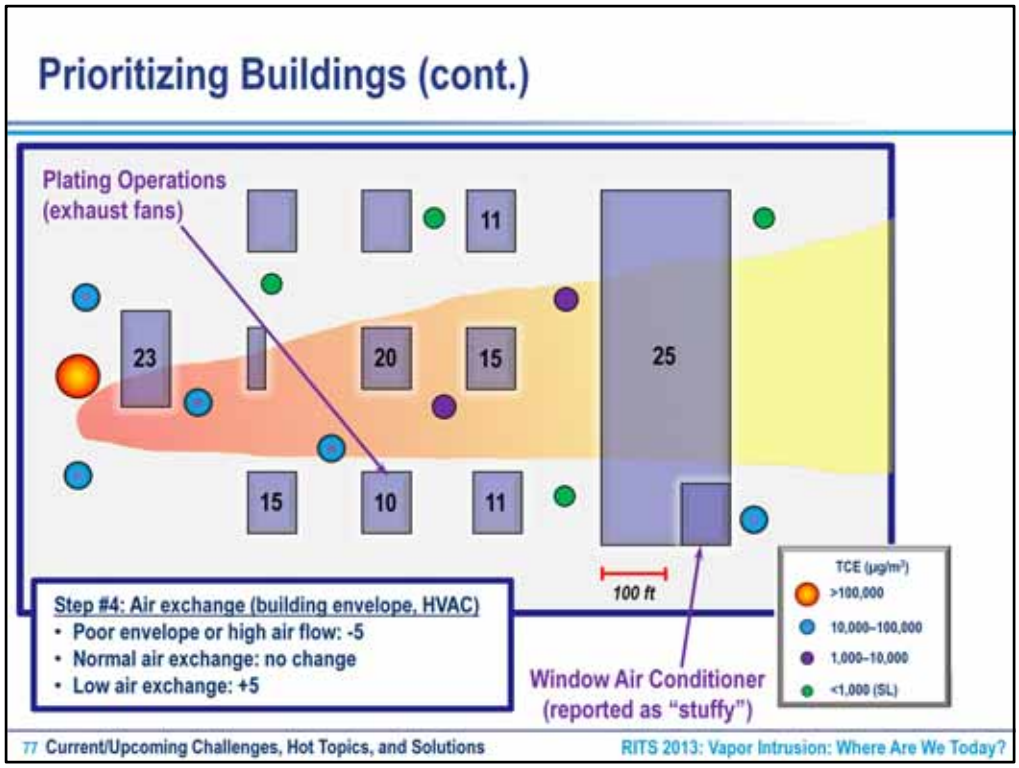
The occupancy status is considered during the next step using the values shown in the text box. As an example, assume that this structure is really a fuel canopy that is not fully enclosed and this structure is actually used for long-term storage with people only being present less than 8 hrs per week. The rest of the buildings have normal occupation and the scores do not change. Here are the adjusted scores.



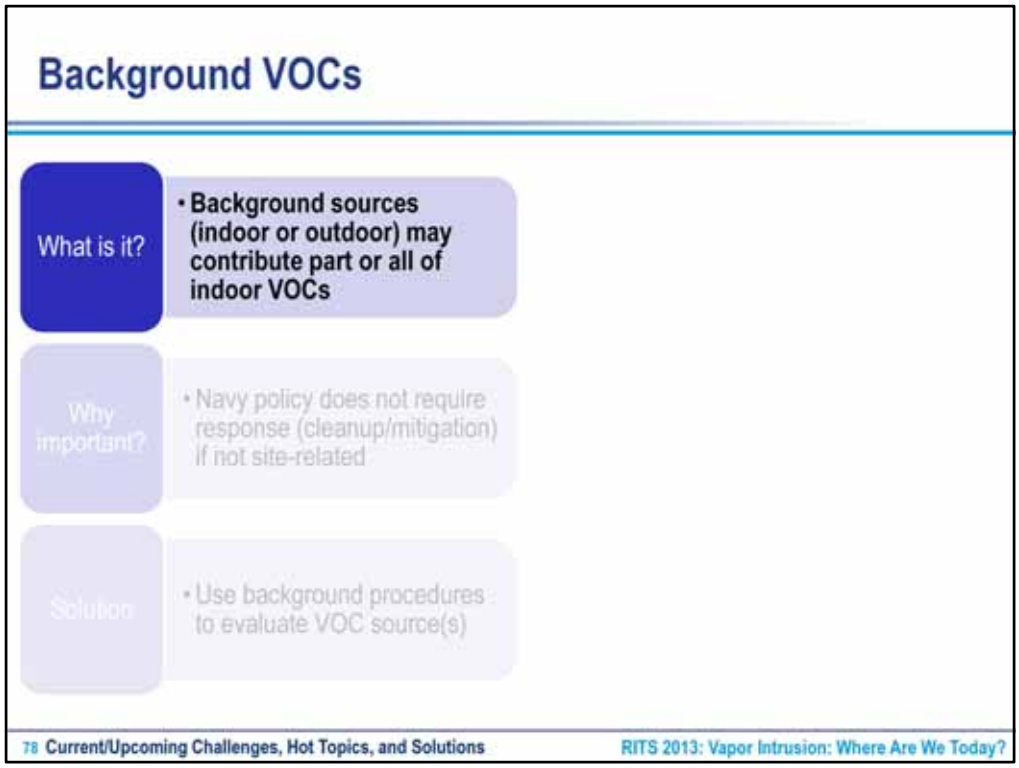
Step 4 considers the size of the building, with larger buildings receiving a lower score because of the large amount of space for dilution and mixing of air. Here are the initial adjusted scores. However..... (next slide)



However, you realize in this large building there are some interior offices in the SE corner. As a result, the score for this building overall is adjusted using the small building value of 5.



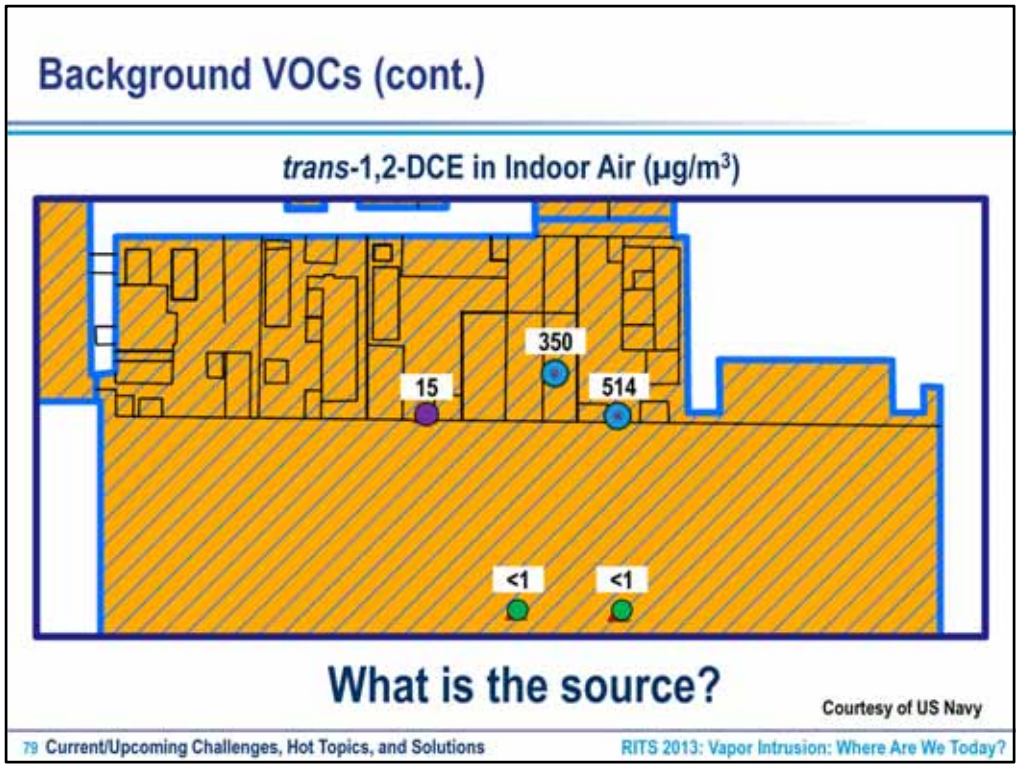
The final step in the prioritization process considers the level of air exchange, such as high, normal, or low air exchange. For example, you learn that plating operations occur in this building, with very high air exchanges, but this small office in the SE corner of the large building only has a window air conditioner and is reported as being stuffy. The final prioritization scores are shown in red, and the 3 buildings with the highest scores are selected for further investigation.



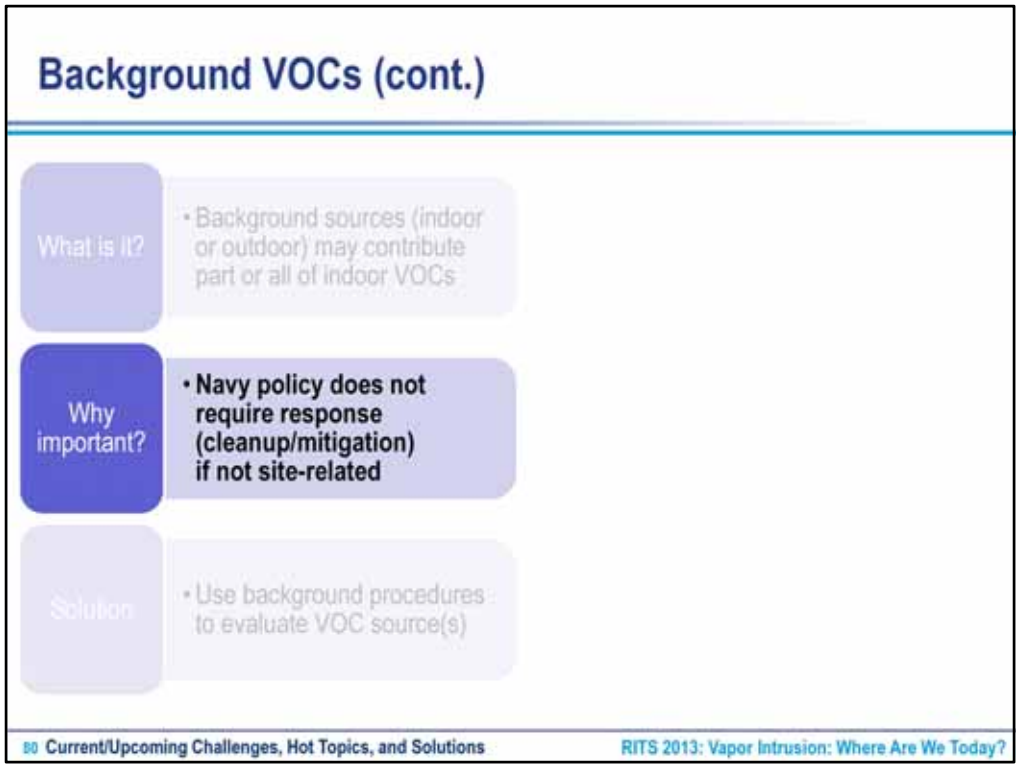
The next challenge I want to talk about is considering background VOCs in a VI investigation since these background VOCs can contribute part or all of the indoor air VOCs.

Notes:
Challenge for data analysis
Impacts on performance evaluation for mitigation systems
<u>Solution/Responses:</u>

- Emerging technologies including real-time analytics
- Building pressure cycling
- Compound-specific isotope analysis (CSIA)



Here is an example of a Navy building where 1,2-DCE was detected at relative high levels in this office, but nearby offices and the warehouse space had orders of magnitude lower concentrations. You need to consider the possibility that background VOCs could be contributing to the measured concentrations.



This is important because Navy policy does not require action if the measured concentrations are not site related.

Background VOCs (cont.)

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
2000 NAVY PENTAGON
WASHINGTON, D.C. 20350-2000

IN REPLY REFER TO

5090
Ser N45C/N4U732212
30 January 2004

From: Chief of Naval Operations
To: Commander, Naval Facilities Engineering Command

Subj: NAVY POLICY ON THE USE OF BACKGROUND CHEMICAL LEVELS

Encl: (1) Navy Policy on the Use of Background Chemical Levels

Courtesy of US Navy

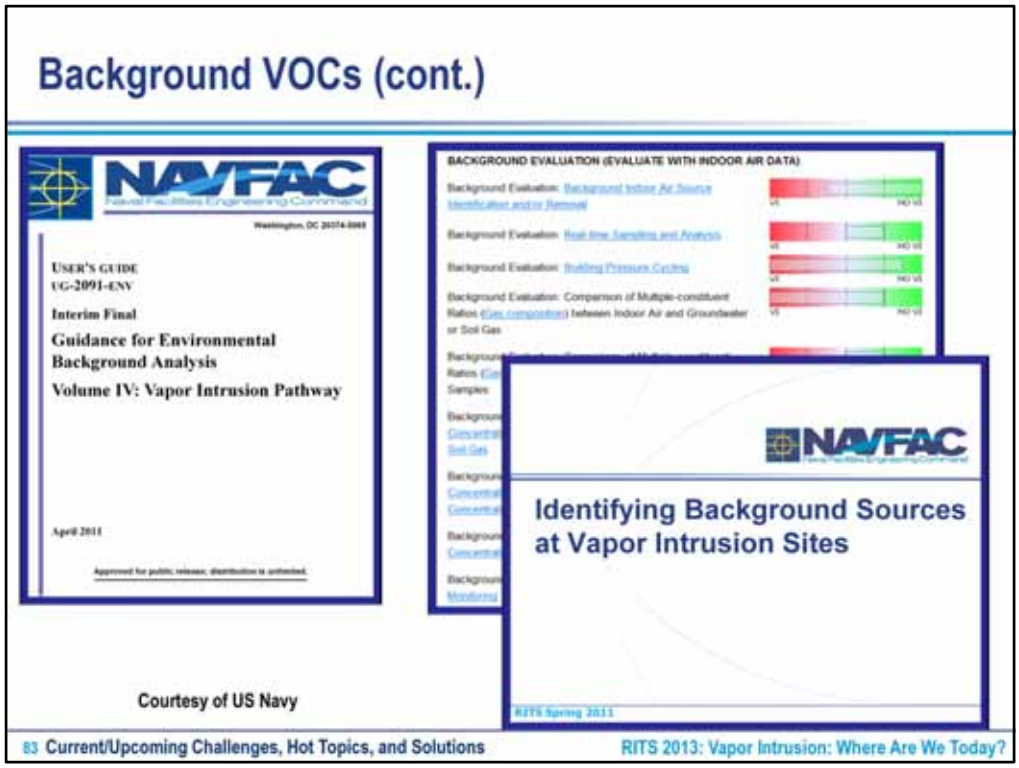
Here is a screen shot of the policy on background.

Background VOCs (cont.)

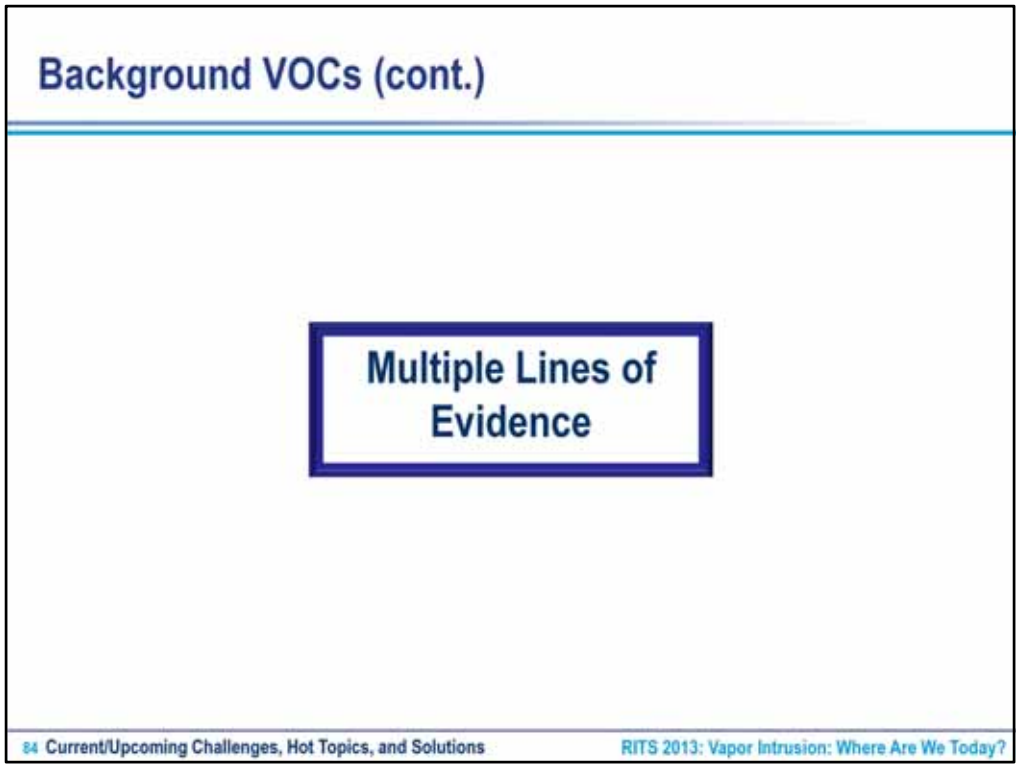
What is it?	• Background sources (indoor or outdoor) may contribute part or all of indoor VOCs
Why important?	• Navy policy does not require response (cleanup/mitigation) if not site-related
Solution	• **Use background procedures to evaluate VOC source(s)**

82 Current/Upcoming Challenges, Hot Topics, and Solutions RITS 2013: Vapor Intrusion: Where Are We Today?

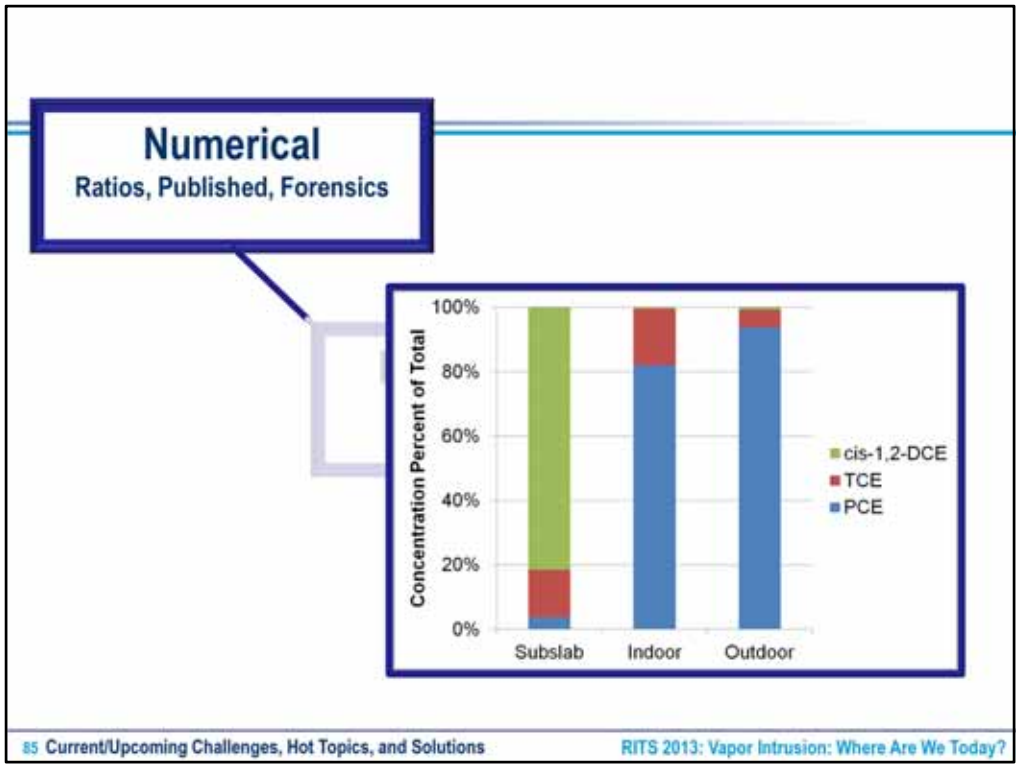
The solution to this challenge is using current and emerging techniques to tease out background. We've come a long way in the last 10 years in developing these procedures.



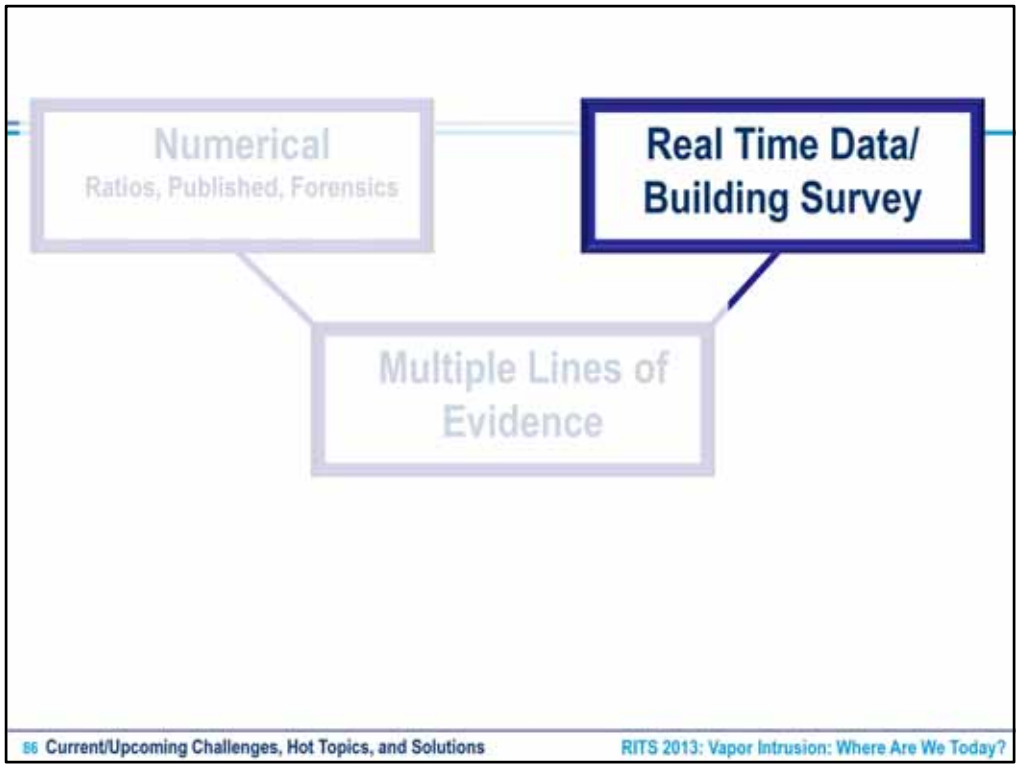
The procedures described in the Navy background VI guidance, included in the Navy VI web tool, and presented at the 2011 RITS training can be used.



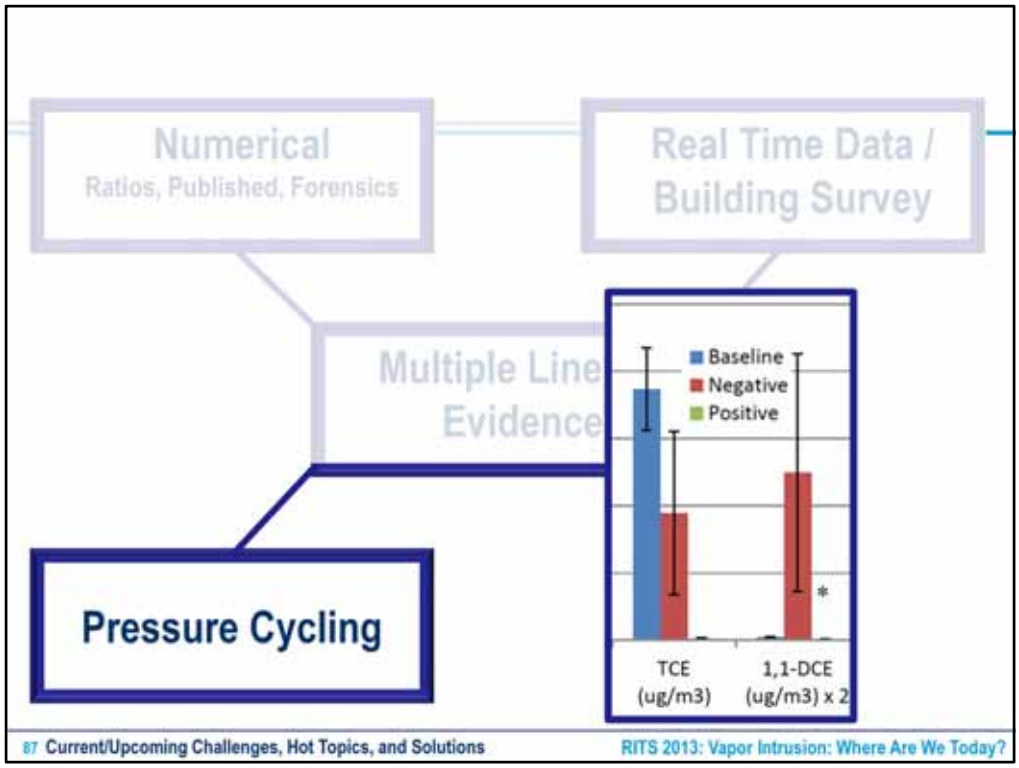
The procedures are based on using multiple lines of evidence.



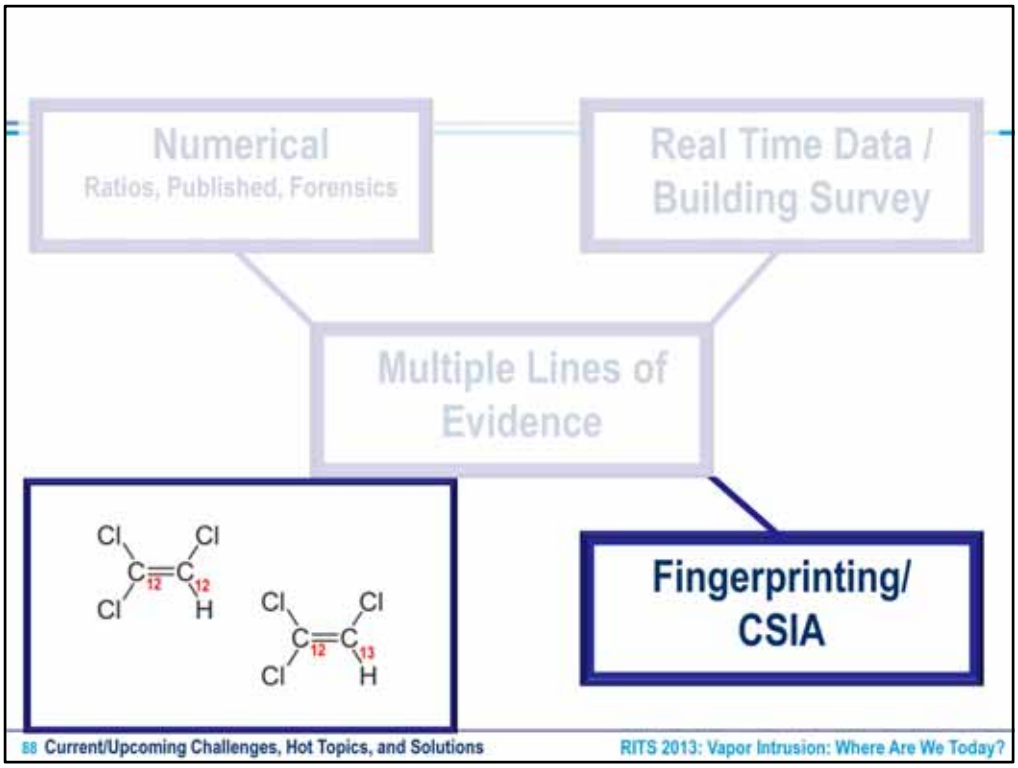
Constituent ratios can be used to assess the source of the measured concentrations. For example, the percentage of each VOC in the indoor, outdoor, and subsurface source samples can be calculated and compared. In this example, the percentages in the indoor and outdoor samples are similar, but distinctly different from those in the subsurface source sample, suggesting an outdoor source impacted the indoor air.



One powerful tool that has been added to the VI tool box involves collecting real-time data with a portable field instrument, such as a portable GS/MS.



Pressure cycling is also a recently emerged technique. The example on the right here shows baseline indoor air concentrations for TCE and DCE (see the blue bars). Consider the TCE results... where under negative pressurized conditions VI in theory should be turned on, the TCE concentrations actually went down... this is not what would be expected if VI is turned on through negative pressurization. Contrast that with the 11DCE at another building, where concentrations increased significantly when the building was negatively pressurized, providing evidence that VI was occurring.



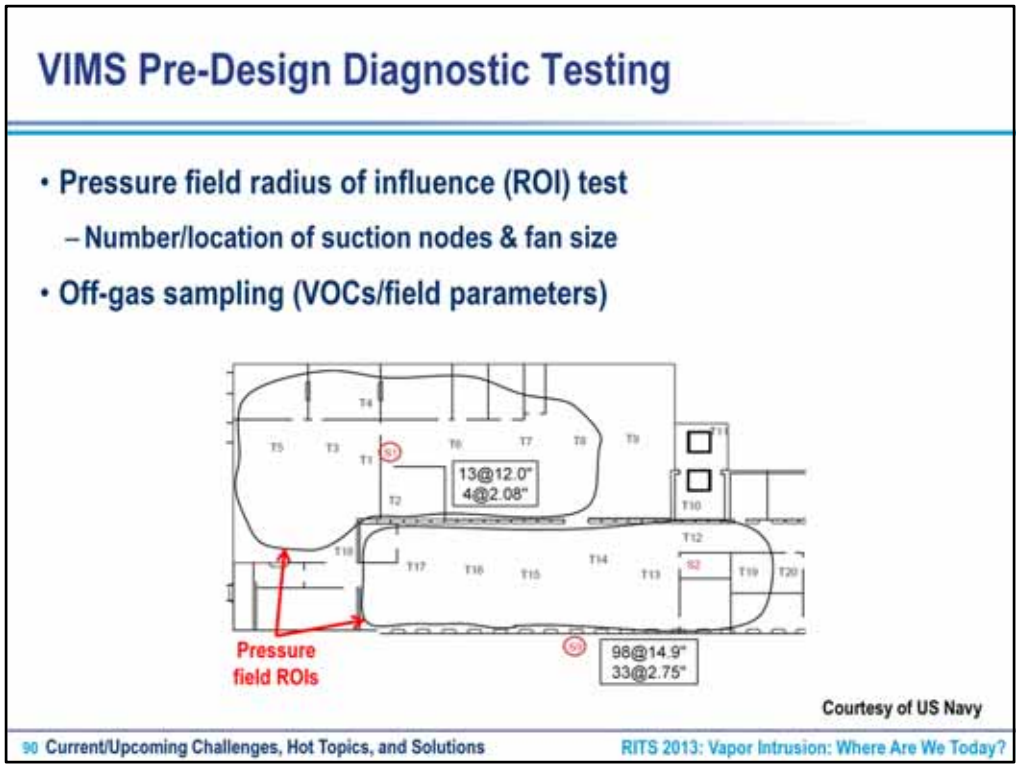
Fingerprinting or compound specific isotopic analysis is also an emerging technique that could be used and is based on unique fingerprint or CSIA signatures for each of the potential sources. Now I am going to transition to some of the challenges associated with installing, operating, and maintaining VI mitigation systems.

VIMS Installation Safety/Installation Considerations

- Utilities and Subsurface Features
- Concrete Drilling/Coring
- Ladders, Scissor Lifts, Roof-Top Activities
- Other:
  - Rebar, abandoned features, asbestos, lead paint
  - Off-gassing during installation
  - Methane at petroleum sites

89 Current/Upcoming Challenges, Hot Topics, and Solutions RITS 2013: Vapor Intrusion: Where Are We Today?

These challenges are as basic as some of the safety considerations, such as identify utilities and subsurface features, concrete drilling, and ladder or lift safety. It is also important to consider things such as asbestos and lead paint, off-gassing during installation, and whether methane is present. Sewer line pic from free-ed.net



One of the most critical challenges is being able to measure the radius of influence of a vacuum field when designing a depressurization system. This helps determine the number and location of the suction nodes, along with the appropriate fan size. The solution is making sure to conduct pre-design diagnostic pressure field extension testing. This is done by selecting some test suction node locations, drilling through the concrete, and then connecting a temporary vacuum... notice the high tech vacuum. Vacuum pressures are then measured in temporary step-out locations. These results are then used to determine the pressure field ROIs, as shown on this figure.

VIMS – Sealing Cracks and Vapor Entry Points

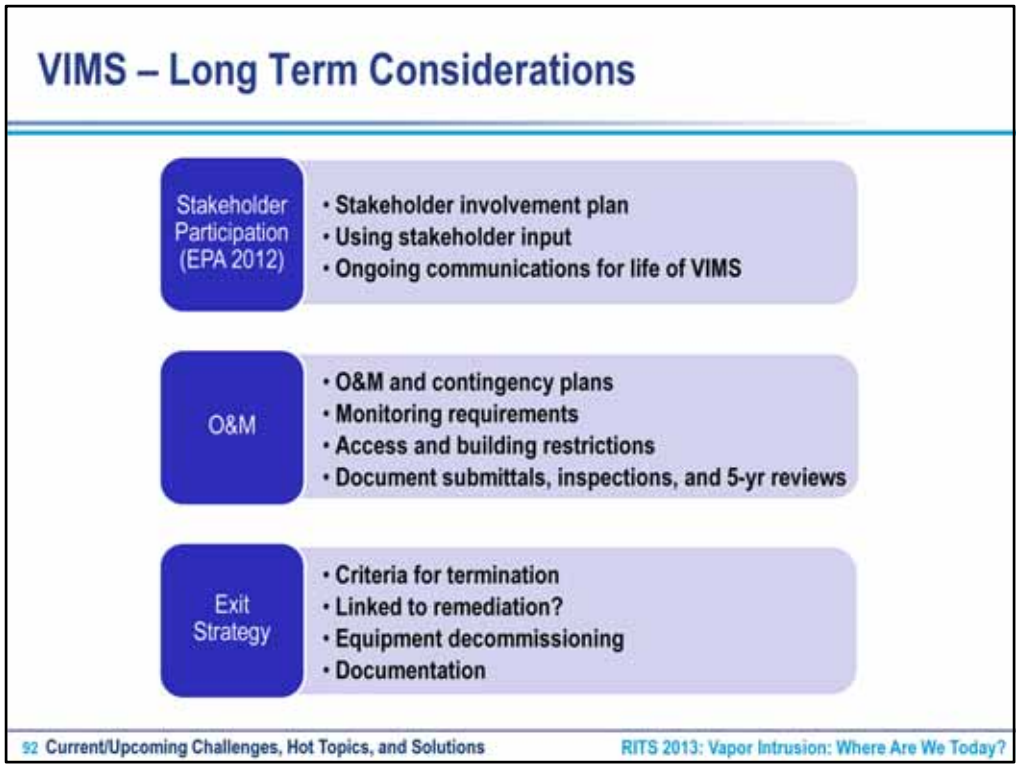
- Visually Identify Cracks and Vapor Entry Points
- Seal Cracks/Entry Points
- Measure ("sniff") VOCs in Field

Key Point

- VIMS may not be effective if cracks/entry points are not identified and sealed
- Inspection/maintenance part of O&M

91 Current/Upcoming Challenges, Hot Topics, and Solutions RITS 2013: Vapor Intrusion: Where Are We Today?

As I have mention earlier, it is important to identify and seal cracks and vapor entry points. The mitigation systems may not be effective otherwise. Don't forget to incorporate inspection and maintenance as part of the O&M program.



Lastly, it is important to account for the mitigation long-term considerations shown on this slide, including stakeholder participation, O&M, and developing an exit strategy for discontinuing the VIMS operation. VIMS are typically considered a temporary solution while remediation is occurring.

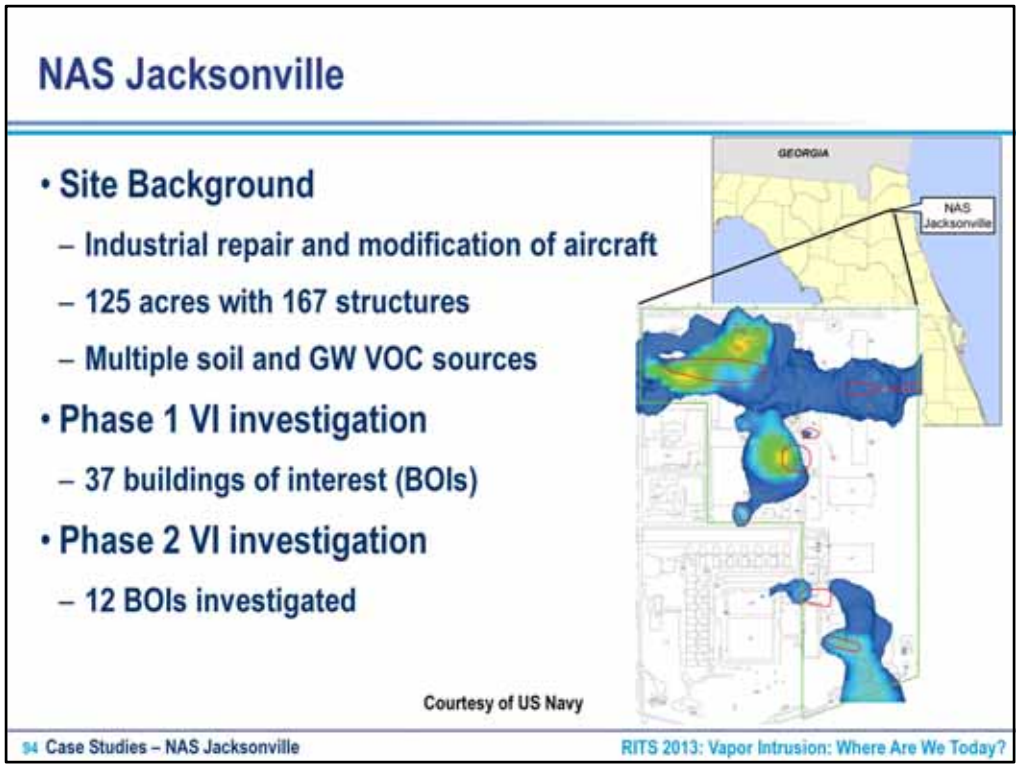
Note: Reference CalEPA VIMS advisory

Presentation Overview

- Introduction
- Review of Key Vapor Intrusion (VI) Concepts
- Update on Recent or Expected VI Guidance Documents
- Current/Upcoming Challenges, Hot Topics, and Solutions
- ► Case Studies
  - NAS Jacksonville
    - Prioritization
    - Variability
    - Method Comparability
    - Background VOCs
  - NWS Yorktown
  - MCIEAST-MCB Camp Lejeune
- Summary

93 RITS 2013: Vapor Intrusion: Where Are We Today?

The remainder of today's presentation will focus on 3 case studies. I will start with NAS Jacksonville.



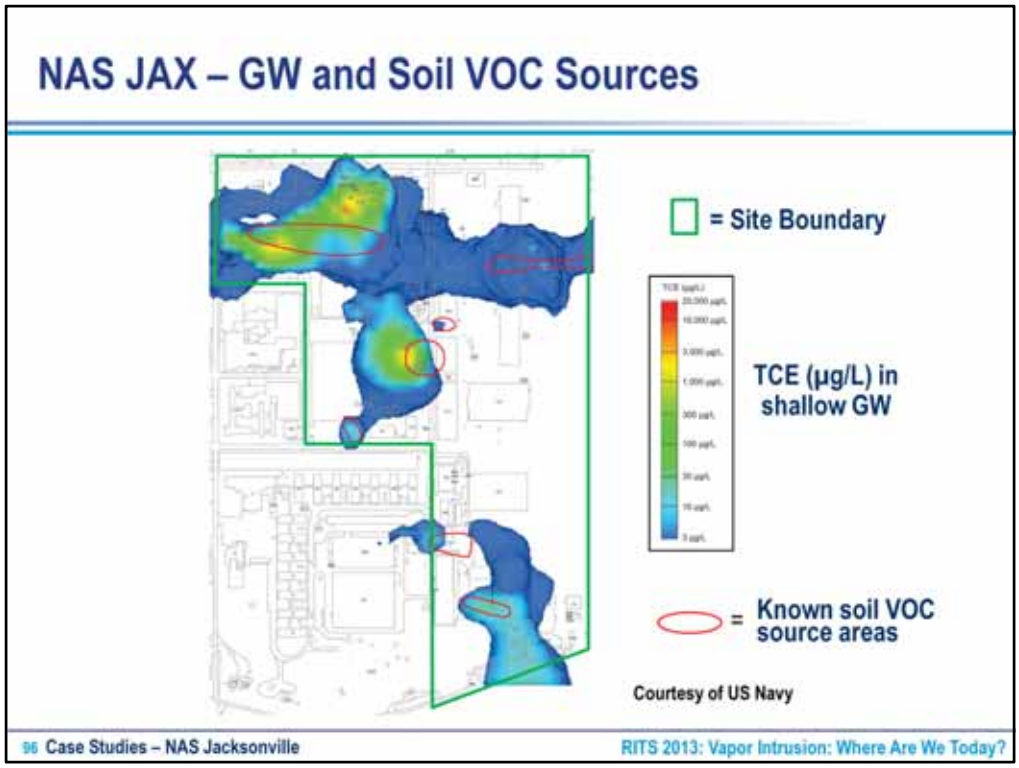
Industrial repair and modification of aircraft is the primary use of this site at NAS JAX. It is a large site with 167 structures and multiple soil and GW VOC sources. The Phase 1 VI investigation identified 37 BOIs, with 12 BOIs being investigated during Phase 2.

NAS JAX – Challenges, Hot Topics, and Solutions

- Prioritizing Buildings
- Temporal and Spatial Variability
- Method Comparability
  - Real-time GC/MS, TO-15, and passive
- Background VOCs
- Bonus

95 Case Studies – NAS Jacksonville RITS 2013: Vapor Intrusion: Where Are We Today?

This case study will highlight solutions for prioritizing buildings, addressing variability and method comparability, and dealing with background.



This figure shows the TCE shallow GW concentrations, with blue representing 3 ug/L and red 20,000 ug/L. The red outlines are known VOC soil source areas.

NAS JAX – Prioritizing Buildings (Phase 1)

Phase 1 Prioritization

- 167 buildings and structures
- Screening using generic and site-specific screening levels
- Soil gas and groundwater
- 37 buildings of interest

Courtesy of US Navy

Final 37 Buildings of Interest Identified During Phase 1

97 Case Studies – NAS Jacksonville

RITS 2013: Vapor Intrusion: Where Are We Today?

Prioritization during Phase 1 consisted primarily of comparing groundwater and some limited soil gas concentrations to screening levels.

NAS JAX – Prioritizing Buildings (Phase 2)

Phase 2 Prioritization

- Factors considered
  - Magnitude of SL exceedance
  - Proximity to vadose-zone source(s)
  - Building characteristics
- Identified 12 Phase 2 priority buildings
  - Indoor, outdoor, subslab sampling
  - Emerging technologies

Final 37 Buildings of Interest Identified During Phase 1

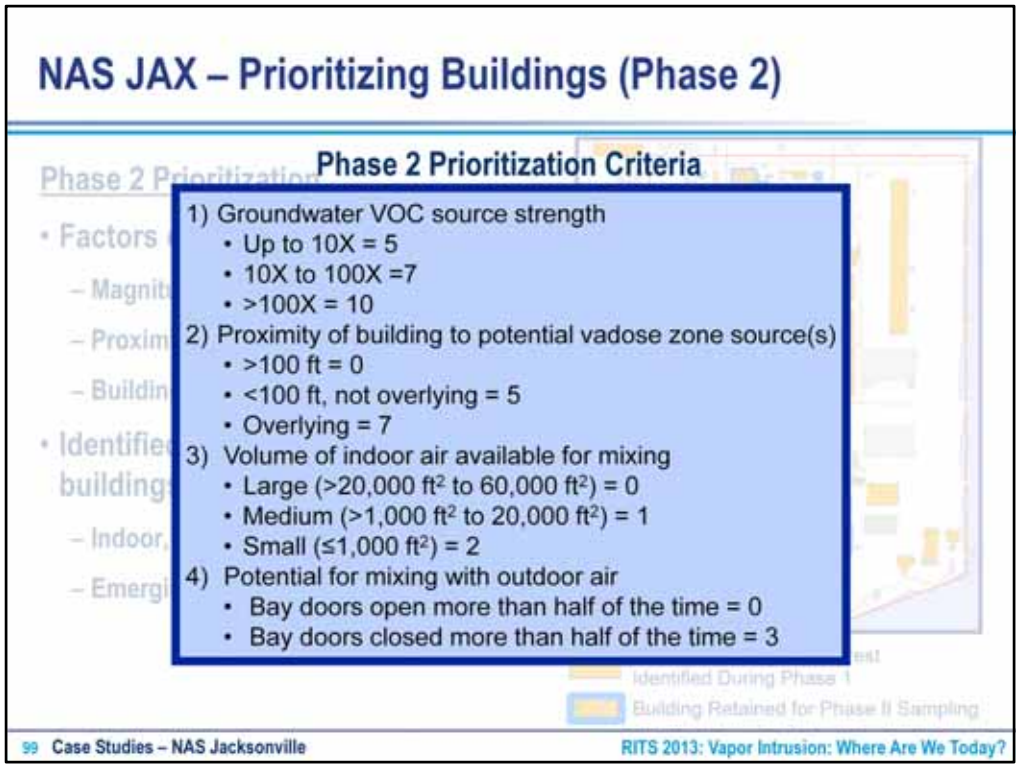
Building Retained for Phase II Sampling

Courtesy of US Navy

98 Case Studies – NAS Jacksonville

RITS 2013: Vapor Intrusion: Where Are We Today?

The prioritization methods described earlier were applied to identify the 12 Phase 2 highest priority buildings for indoor, outdoor, and subslab sampling. We also applied some emerging techniques in 2 of the 12 buildings.



This call-out text box was included to show some the quantitative prioritization rankings applied to each of the criteria I described earlier.

NAS JAX – Assessing Variability

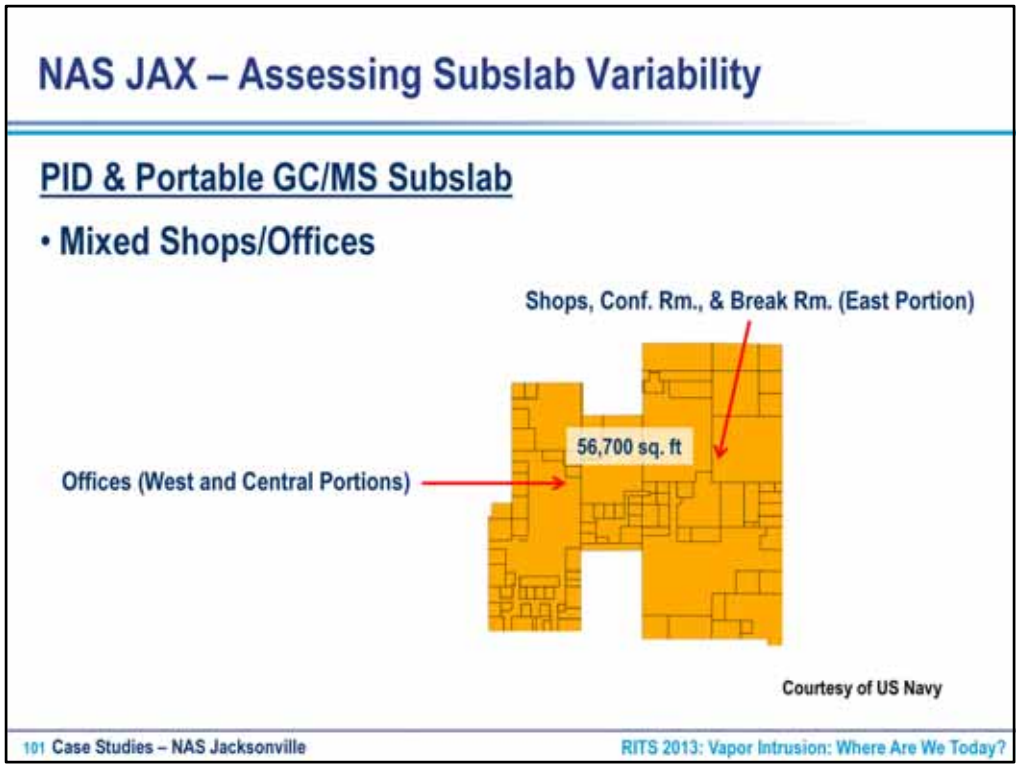
Spatial Variability

- PID and portable GC/MS subslab surveys (2 buildings)
- Portable GC/MS indoor air survey (12 buildings)

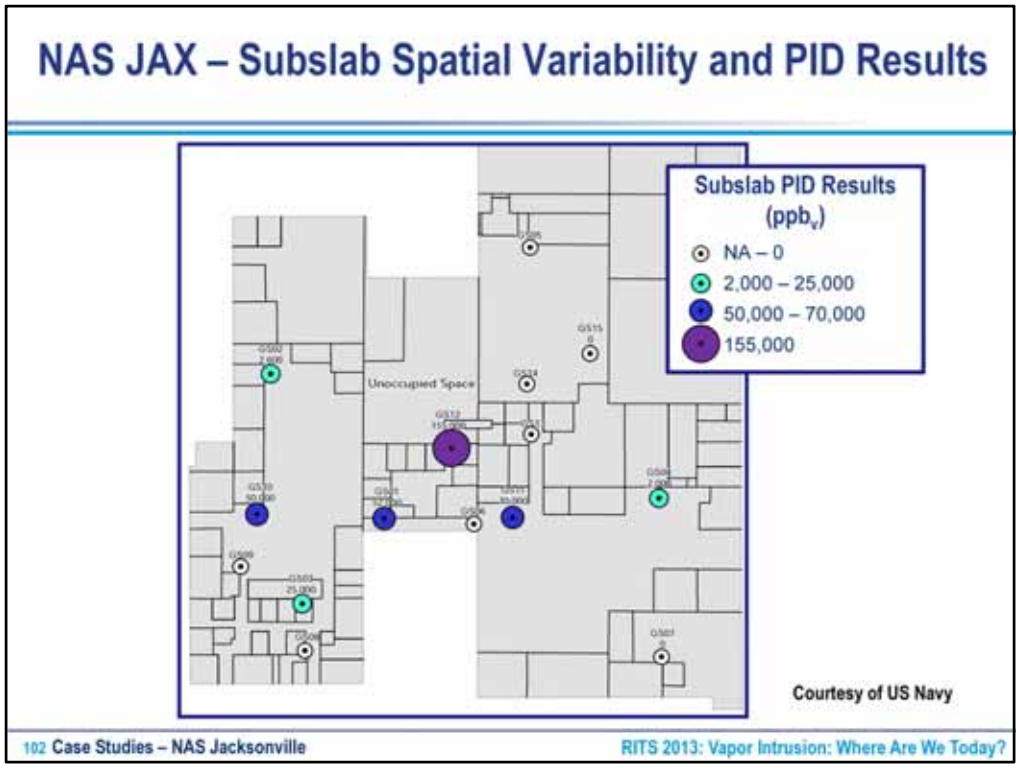
Temporal Variability – Indoor Air

- 5 minute (Portable GC/MS)
- 24-hour (TO-15)
- 14-day (Passive/TO-17)

I am going to start with the approach used to assess variability. For spatial variability, we conducted real time PID and portable GC/MS subslab surveys and also used the portable GC/MS to perform an indoor air survey. 5 min, 24-hr, and 14-day co-located samples were collected to assess temporal variability.



The PID and portable GC/MS survey was conducted in this building with mixed shops and offices. The offices were located in the west and central areas.



The PID subslab survey results are shown on this figure. The highest PID readings were observed in the central portion of the building, with 155,000 ppbv represented by the purple dot.

NAS JAX – Portable GC/MS "Sniff" versus "Quantitative" Modes

"Sniff" Mode

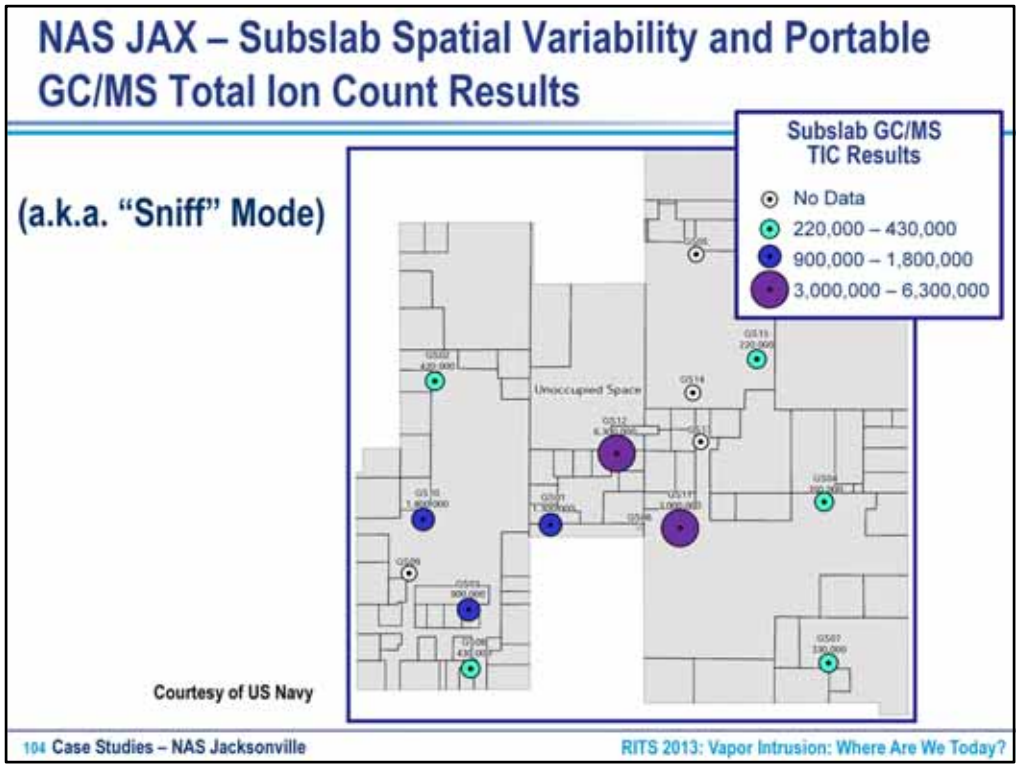
- Bypass column. Instantaneous reading
- Specific target ions (unlike PID)
- Relative concentrations (total ion count/TIC)
- Good for real-time source location

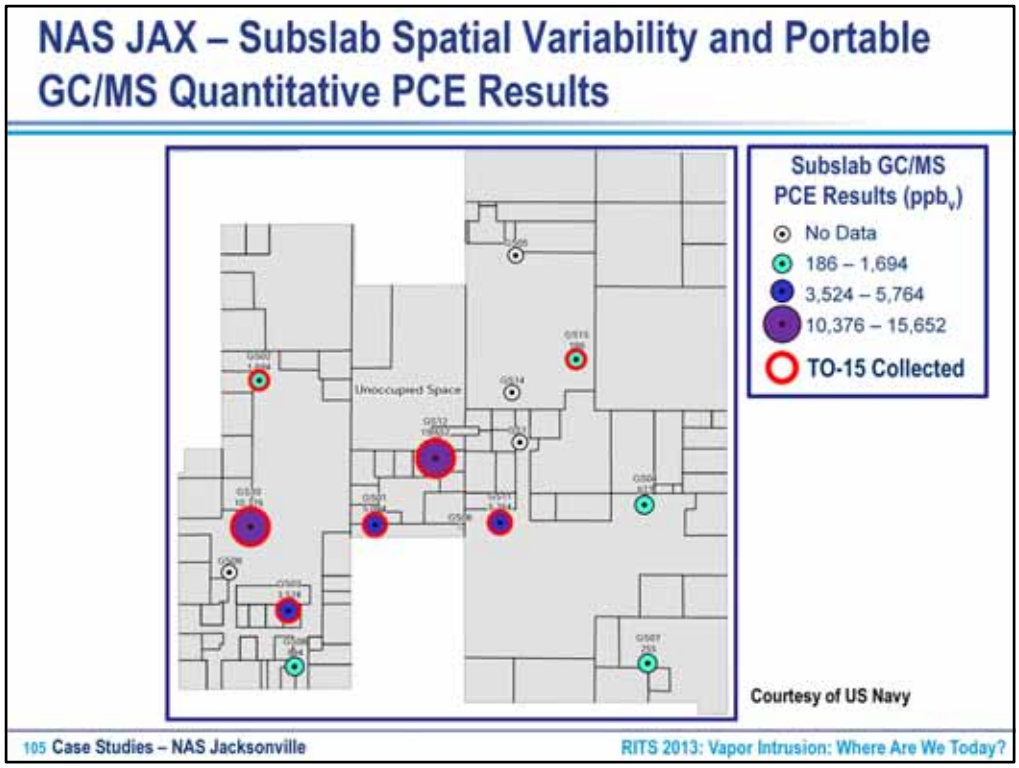
Quantitative Mode

- VOCs separated on column
- Quantitative concentration (*e.g.*, $\mu g/m^3$)
- Very sensitive

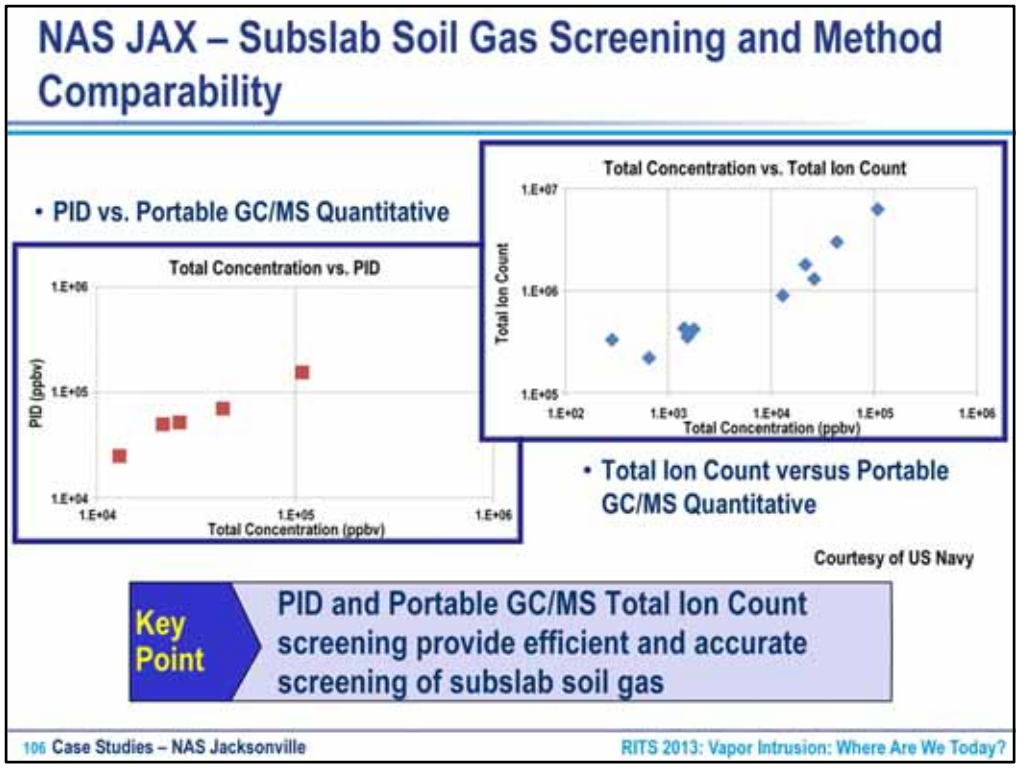
103 Case Studies – NAS Jacksonville RITS 2013: Vapor Intrusion: Where Are We Today?

We also collected results using the portable GC/MS in what we call the "sniff" mode. This is where the sample bypasses the column and the total ion count for the target compounds is reported. We saw a similar trend, with the highest readings in the central portion of the building.


NAS JAX – Subslab Spatial Variability and Portable GC/MS Total Ion Count Results
(a.k.a. "Sniff" Mode)
Subslab GC/MS TIC Results
No Data
220,000 – 430,000
900,000 – 1,800,000
3,000,000 – 6,300,000
Unoccupied Space
Courtesy of US Navy
104 Case Studies – NAS Jacksonville
RITS 2013: Vapor Intrusion: Where Are We Today?



We also collected quantitative results for each target VOC using the portable GC/MS and then followed that up with Summa canister samples from select locations shown with the red outline. A similar pattern of high subslab concentrations in the central portion of the building was observed.



Soo... how did these various methods compare? We plotted the total VOC concentration measured by the portable GC/MS against the PID readings ... the y-axis on the left figure; and the total ion count ... the y-axis on the right figure. As you can see, there was a nice linear relationship. Therefore, PID and Portable GC/MS Total Ion Count screening provide efficient and accurate screening of subslab soil gas.

NAS JAX – Method Comparability (Indoor Air Results)

Subslab Vapor

		Results (µg/m³)	
	Method:	TO-15	Portable GC/MS
	Sample Duration:	24 hours	~5 minute
	Sample QC Type:	Normal	Normal
	Column ID:	1	2
In-building Location	**Analyte**		
GS-01	*cis*-1,2-Dichloroethene	21,000	36,580
	Tetrachloroethene	28,000	34,468
	trans-1,2-Dichloroethene	23,000	41,566
	Trichloroethene	5,500	7,185
	Tetrachloroethene	7,200	11,487

Courtesy of US Navy

Key Point

- Generally < 2x analytical variability
- Compare to <10,000x spatial variability

107 Case Studies – NAS Jacksonville RITS 2013: Vapor Intrusion: Where Are We Today?

We also compared the portable GC/MS quantitative VOC results shown in the right column of this table with co-located TO-15 24-hour results, shown in the 2nd column from the right. Even with the difference in sampling durations, the analytical variability between the two methods was <5-fold. Compare this with up to 10,000 fold spatial variability. We tend to worry a lot about the representativeness of using screening field data; however, this clearly demonstrates the usefulness of portable GC/MS data.

NAS JAX – Comparability and Temporal Variability of Indoor Air Results

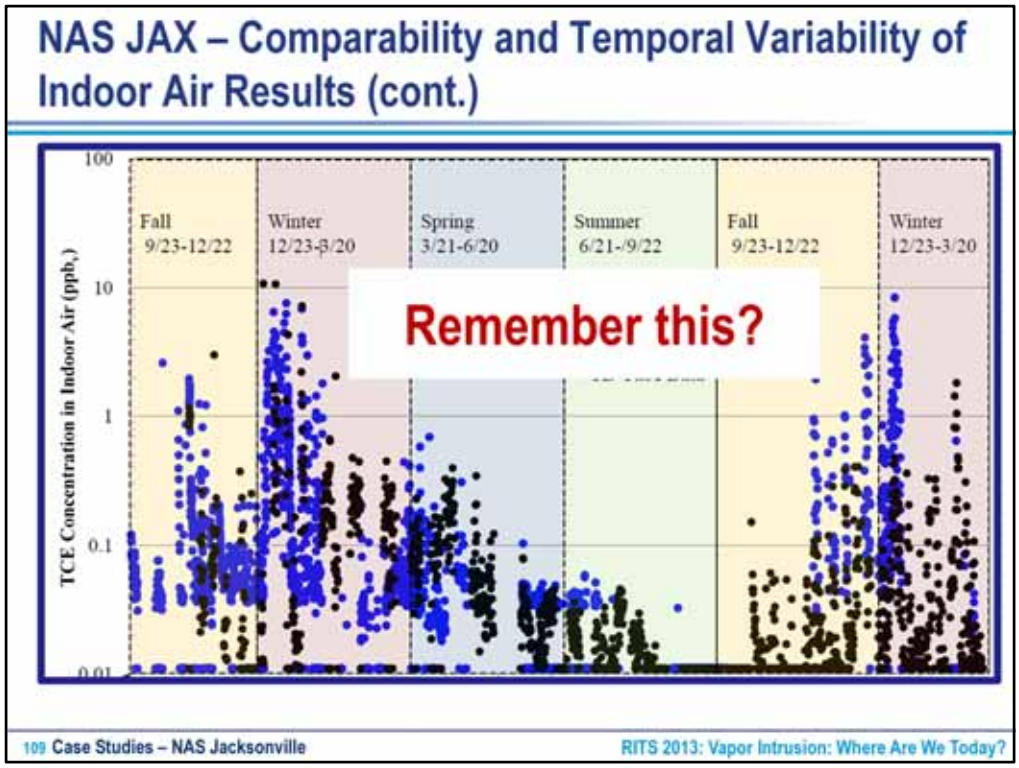
Indoor Air

In-building Location	Analyte	TO-15 24 hours		TO-17 14 days	
AI03	*cis*-1,2-Dichloroethene	**4.8**		**2.33**	
	Tetrachloroethene	**3.4**		**3.42**	
	trans-1,2-Dichloroethene	**3.8**		**1.47**	
	Trichloroethene	**1.2**		**1.32**	
AI06	*cis*-1,2-Dichloroethene	**0.19**	J	0.40	U
	Tetrachloroethene	**0.43**	J	**0.45**	J
	trans-1,2-Dichloroethene	**0.26**	J	0.40	U
	Trichloroethene	0.46	U	0.11	U

Courtesy of US Navy

108 Case Studies – NAS Jacksonville RITS 2013: Vapor Intrusion: Where Are We Today?

This slide compares TO-15 24 hr results, shown in the 2nd column from the right with 14-day co-located passive results, shown in the right column. The similarity in concentrations between the 24 hr sample and a two week is not what would have been predicted if it were assumed that the variability observed at the Utah residential house applied to all buildings.



Remember this graph of the temporal variability at the Utah residence?

NAS JAX – Comparability and Temporal Variability of Indoor Air Results (cont.)

Well, check this out!

Three totally different methods

		Results (µg/m³)		
	Method:	Portable GC/MS	TO-15	TO-17
	Sample Duration:	~5 minute	24 hours	14 days
	Analyte			
103/Indoor Air AI103/H-IA103	Tetrachloroethene	2.2	3.40	3.4
	Trichloroethene	1.8	1.20	1.3

>4,000-fold range in sample duration!

Courtesy of US Navy

Key Point

- Would not have predicted similar results if variability at Utah residence applied to all buildings
- Fundamental Truth: Not all buildings are the same!

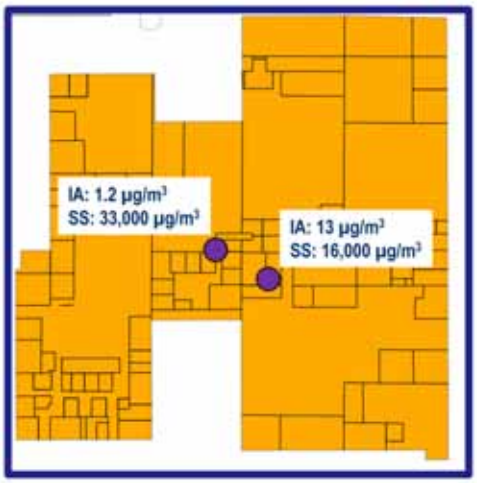
110 Case Studies – NAS Jacksonville

RITS 2013: Vapor Intrusion: Where Are We Today?

Well.... check this out. Results were similar using 3 totally different methods and a >4000-fold range in sampling duration. This highlights the point I made at the beginning of today's talk that, "Not all buildings are the same." It provides a good start to make the case that temporal variability in industrial buildings is significantly lower than residential buildings.

NAS JAX – Assessing Background Indoor Air VOCs

- One TCE detection (13 µg/m^3) above indoor SL (3 µg/m^3) in small office
- TCE in adjacent small office (~1.2 µg/m^3)
- Nearby subslab (16,000 – 33,000 µg/m^3)

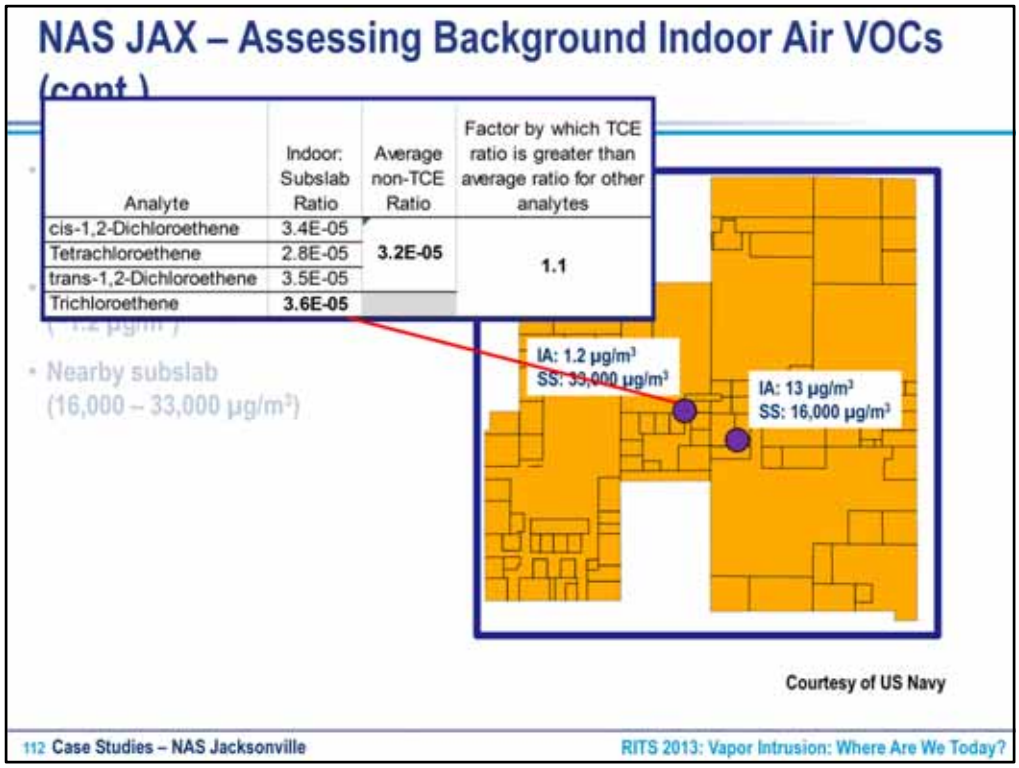


Courtesy of US Navy

111 Case Studies – NAS Jacksonville

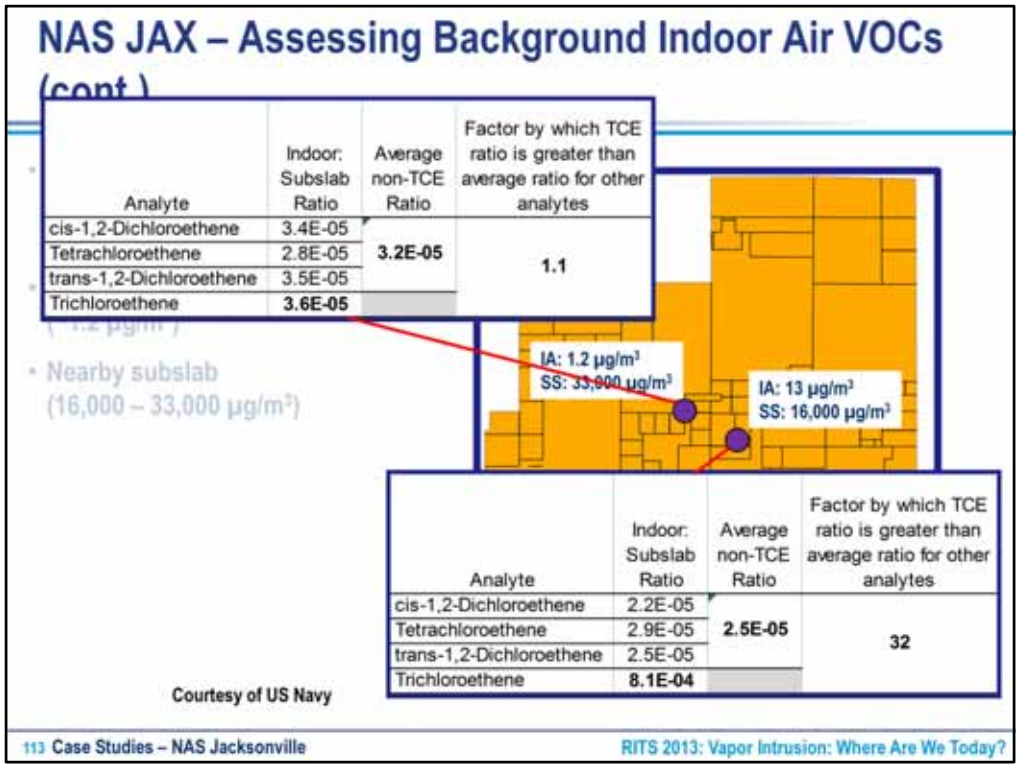
RITS 2013: Vapor Intrusion: Where Are We Today?

These next few slides show the importance of assessing background VOCs during a VI investigation. TCE was detected above the indoor air SL in a small office shown here on the right, but was 10-times lower in an adjacent small office. Both locations had similar subslab concentrations.



Analyte	Indoor: Subslab Ratio	Average non-TCE Ratio	Factor by which TCE ratio is greater than average ratio for other analytes
cis-1,2-Dichloroethene	3.4E-05		
Tetrachloroethene	2.8E-05	**3.2E-05**	**1.1**
trans-1,2-Dichloroethene	3.5E-05		
Trichloroethene	**3.6E-05**		

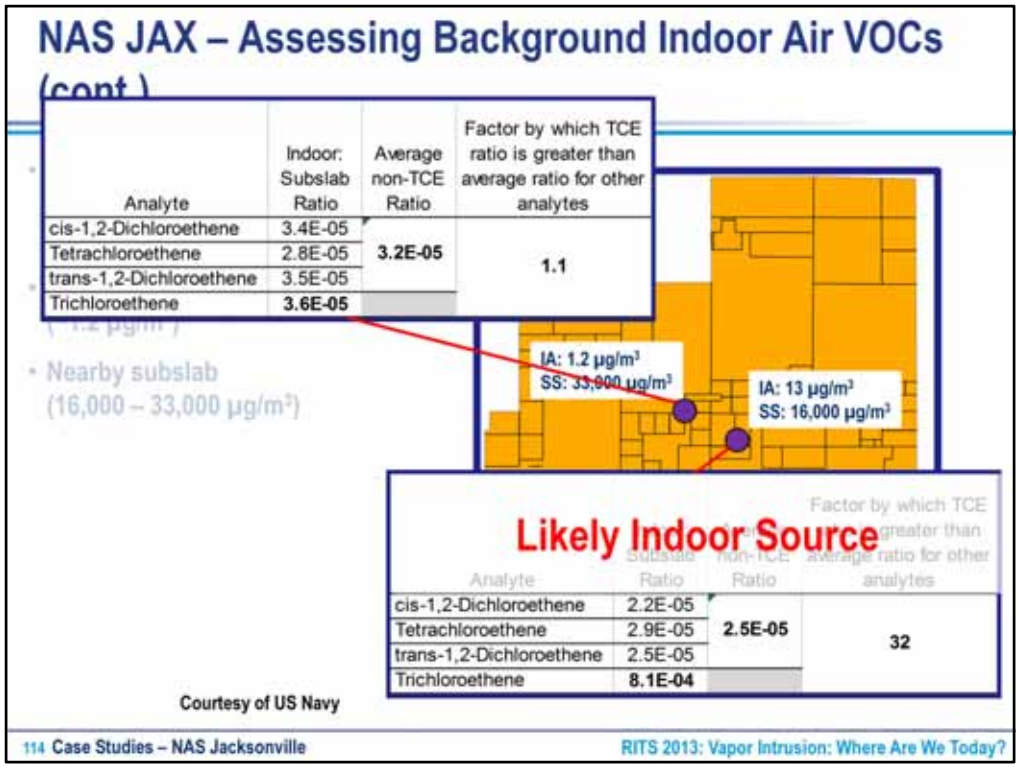
Using the ratio method I described earlier, we looked at the indoor to subslab ratios for the 4 cVOCs listed in the left column. As you can see in the 2nd column, the ratios of cisDCE, PCE, and trans-DCE in the office with the lower indoor air TCE level were all very similar. Not only were the ratios similar for these 3 cVOCs, but the ratio for TCE was also similar.



Analyte	Indoor: Subslab Ratio	Average non-TCE Ratio	Factor by which TCE ratio is greater than average ratio for other analytes
cis-1,2-Dichloroethene	3.4E-05	3.2E-05	1.1
Tetrachloroethene	2.8E-05		
trans-1,2-Dichloroethene	3.5E-05		
Trichloroethene	**3.6E-05**		

Analyte	Indoor: Subslab Ratio	Average non-TCE Ratio	Factor by which TCE ratio is greater than average ratio for other analytes
cis-1,2-Dichloroethene	2.2E-05	2.5E-05	32
Tetrachloroethene	2.9E-05		
trans-1,2-Dichloroethene	2.5E-05		
Trichloroethene	**8.1E-04**		

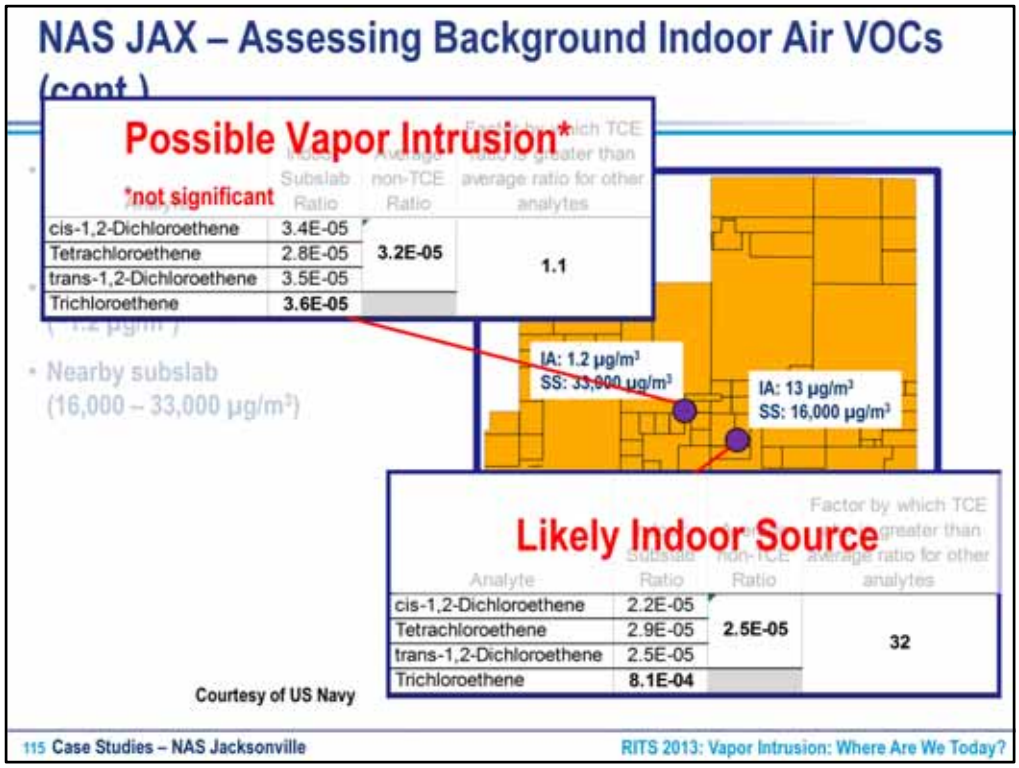
Contrast that with what was observed in the office with higher TCE indoor air concentrations. The ratios of cisDCE, PCE, and transDCE were once again similar to each other, but in this case, the ratio of TCE was more than an order of magnitude different.



Analyte	Indoor: Subslab Ratio	Average non-TCE Ratio	Factor by which TCE ratio is greater than average ratio for other analytes
cis-1,2-Dichloroethene	3.4E-05	3.2E-05	1.1
Tetrachloroethene	2.8E-05		
trans-1,2-Dichloroethene	3.5E-05		
Trichloroethene	**3.6E-05**		

Analyte	Indoor: Subslab Ratio	Average non-TCE Ratio	Factor by which TCE ratio is greater than average ratio for other analytes
cis-1,2-Dichloroethene	2.2E-05	2.5E-05	32
Tetrachloroethene	2.9E-05		
trans-1,2-Dichloroethene	2.5E-05		
Trichloroethene	**8.1E-04**		

... providing relatively strong evidence for an indoor source in the office on the right, and....



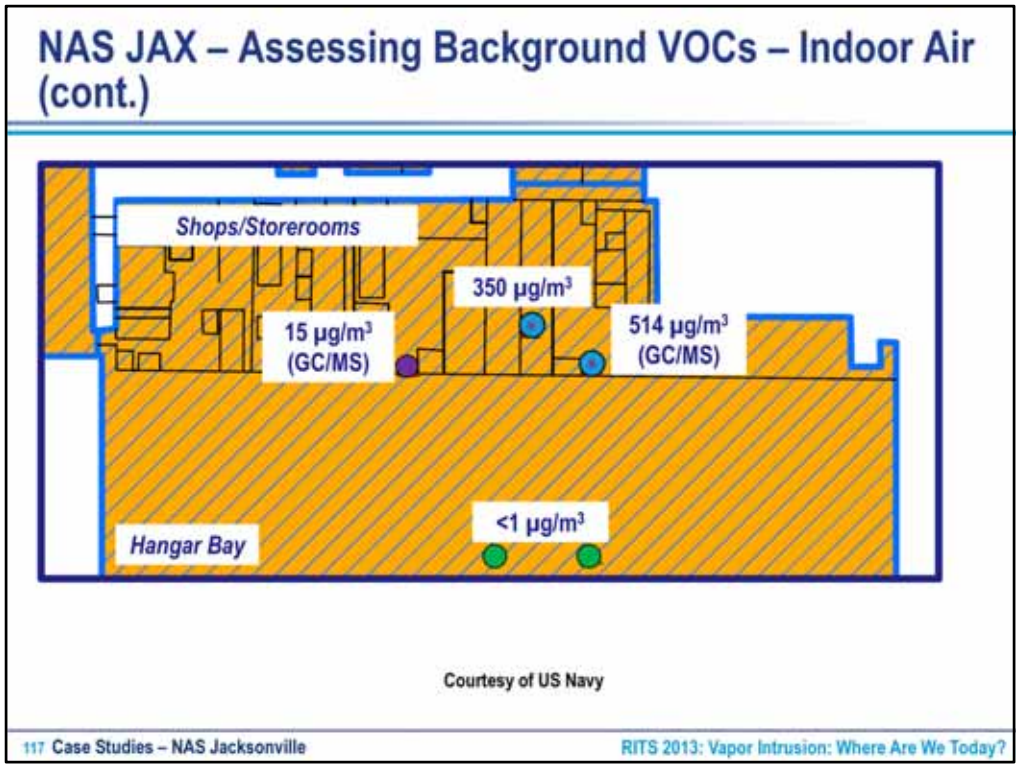
...evidence of possible vapor intrusion that was not significant in the office on the left.

NAS JAX – Assessing Background VOCs – Indoor Air (cont.)

- *trans*-1,2-DCE (350 µg/m^3 by TO-15) above indoor air screening level (260 µg/m^3)
- No subslab data
- Collected portable GC/MS indoor data

116 Case Studies – NAS Jacksonville RITS 2013: Vapor Intrusion: Where Are We Today?

I also want to show you an example of using the portable GC/MS instrument to assess background VOCs. Trans-1,2-DCE was detected slightly above its indoor air SL in a sample collected from the industrial building shown here.



These are the results I showed earlier, where the maximum concentration was detected at this location on the right of this figure. The progressively lower concentrations as we moved away provided suggestive evidence of an indoor source.

NAS JAX – Assessing Background VOCs – Indoor Air (cont.)

Key Point

- Background sources can influence indoor air results
- Apply background evaluation methods during VI assessment (Navy Background VI Guidance)

118 Case Studies – NAS Jacksonville

RITS 2013: Vapor Intrusion: Where Are We Today?

A subsequent focused building survey identified an indoor source of *trans*-1,2-DCE in a nearby work area.

NAS JAX – Bonus Findings

- 37 manufactured soil gas probes
- Installation time < 10 min/probe
- Simultaneous leak checking
  - Helium (SOP)
  - Water dam (emerging)
- No leaks detected with either method

Key Point Manufactured subslab probes & water dam leak checks are efficient and effective alternatives to current methods

119 Case Studies – NAS Jacksonville RITS 2013: Vapor Intrusion: Where Are We Today?

One of the bonus findings in the NAS JAX investigation is related to the use of a new manufactured subslab soil gas probe, call the Vapor Pin. Rather than using grout to install a traditional probe, this is a subslab probe with a silicone seal that is quickly installed with a mallet in less than 10 minutes. We compared the traditional helium leak checking method shown in this picture on the left with the water-dam method recommended by the manufacturer. No leaks were detected with either method. These results supported the conclusion that manufactured subslab probes and the water-dam leak check are efficient and effective alternatives to the current methods.

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120 RITS 2013: Vapor Intrusion: Where Are We Today?

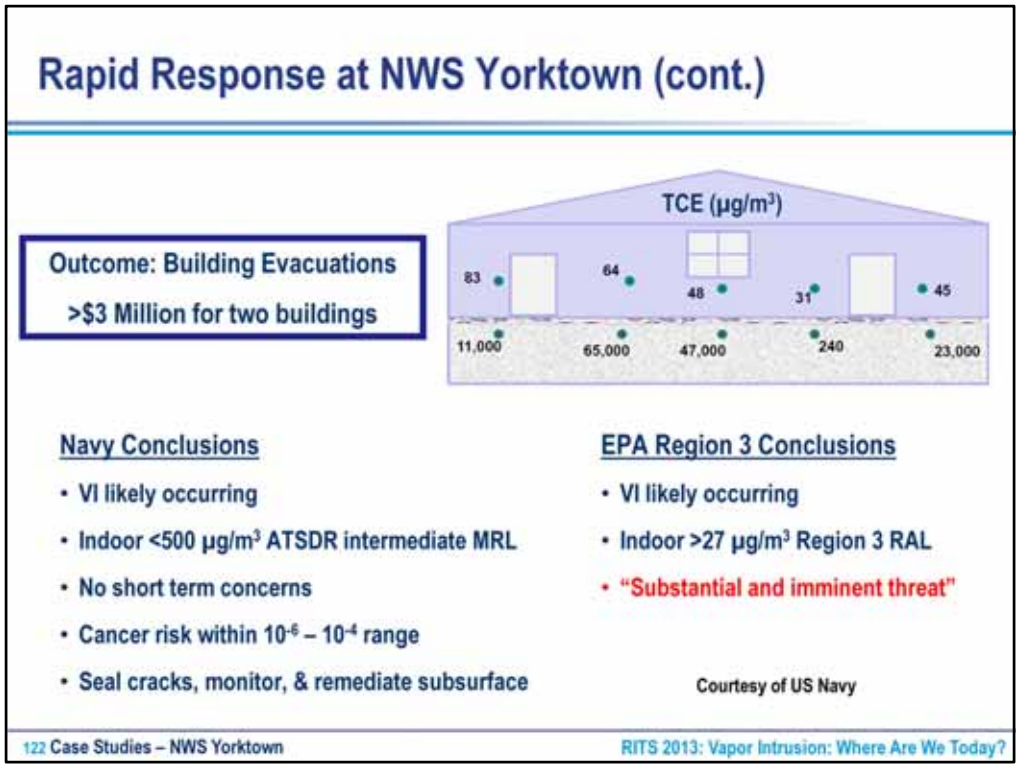
The second case study I want to highlight is for a site at Naval Weapons Station Yorktown where the Navy had to deal with the rapid response issue.

Rapid Response at NWS Yorktown

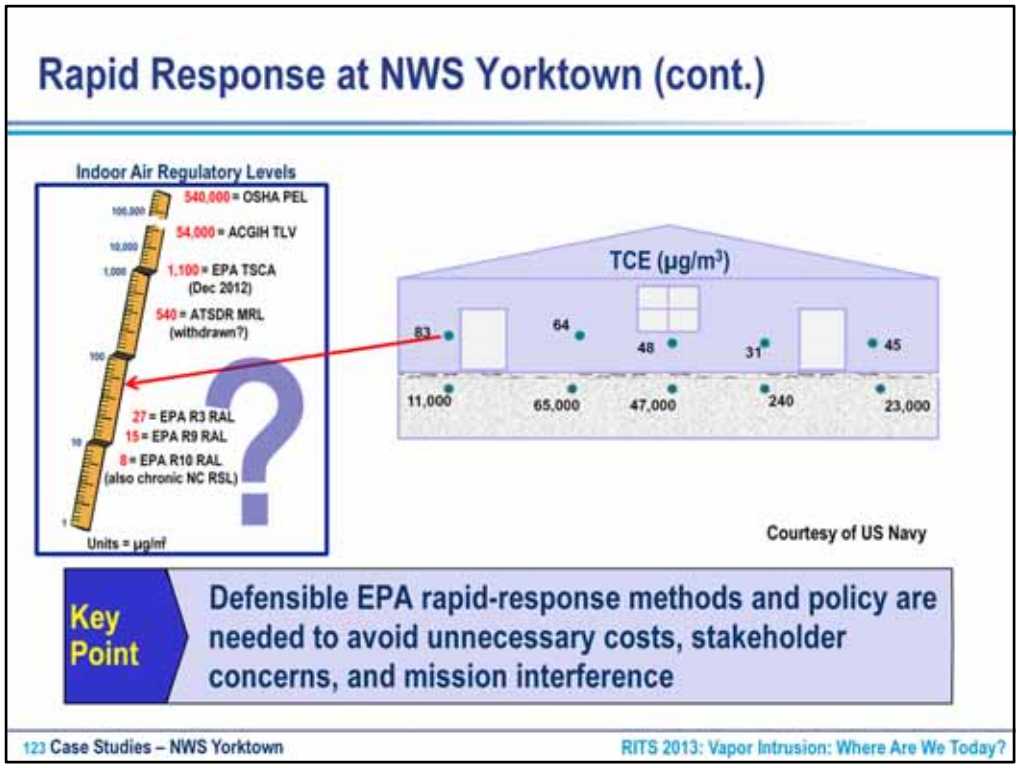
- Groundwater and soil TCE sources
- 2012 VI investigation

121 Case Studies – NWS Yorktown RITS 2013: Vapor Intrusion: Where Are We Today?

The Case Study building was located over relatively strong GW and soil TCE sources, with shallow GW concentrations up to 5,000 ug/L.



Subslab and indoor TCE results in ug/m3 are shown on the figure, with subslab concentrations up to 65,000 ug/m3 and a maximum indoor air concentration of approximately 80 ug/m3. The Navy's conclusions were that VI likely was occurring, but that there were no short-term exposure concentrations. They recommended sealing cracks as quickly reasonable, continue monitoring, and remediate the subsurface. EPA Region 3 also concluded that VI was likely occurring, but since concentrations exceeded a "ad hoc" RAL of 27 ug/m3 that they derived, it posed a substantial and imminent threat. The outcome was that two buildings were evacuated, costing the Navy >$3M, which also impacted a critical defense mission.



Remember this ruler and the wide range of TCE RALs I showed you earlier? The key point for this particular hot topic is that defensible EPA rapid-response methods and policy are needed to avoid unnecessary costs, stakeholder concerns, and mission interference.

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124 RITS 2013: Vapor Intrusion: Where Are We Today?

The 3rd and final case study is a mitigation example for a building at MCB Camp Lejeune.

MCIEAST-MCB Camp Lejeune – Background

- ~236 sq. mi. in Onslow County, North Carolina
- ~150,000 military, retirees, and civilian personnel
- Sand or silt with sand/clay lenses
- Depth to groundwater = 0 – 22 ft bgs

Courtesy of US Navy

125 Case Studies – MCIEAST-MCB Camp Lejeune RITS 2013: Vapor Intrusion: Where Are We Today?

MCB Camp Lejeune is located in NC and is home to ~150,000 personnel. GW is shallow and the vadose zone is primarily sand or silt.

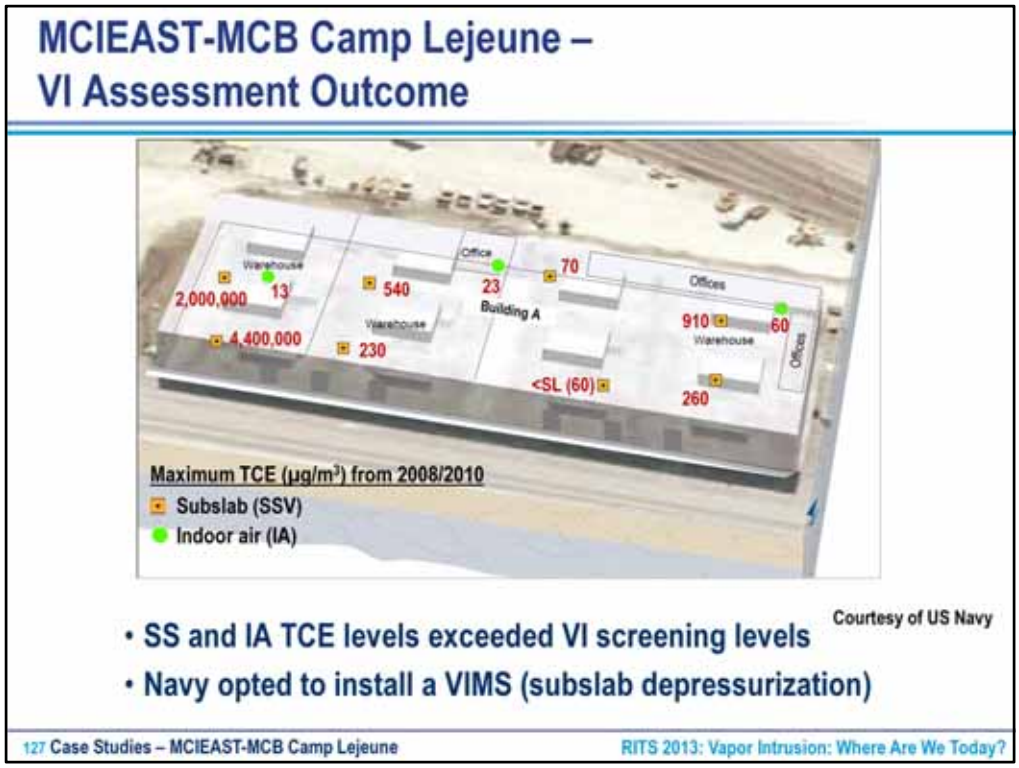
Notes:
Highest potential for VI? sand
Because the base is so large, 6 study areas defined geographically
Groundwater 0-22 ft bgs in surficial aquifer, several deeper aquifers underlying

MCIEAST-MCB Camp Lejeune – VIMS

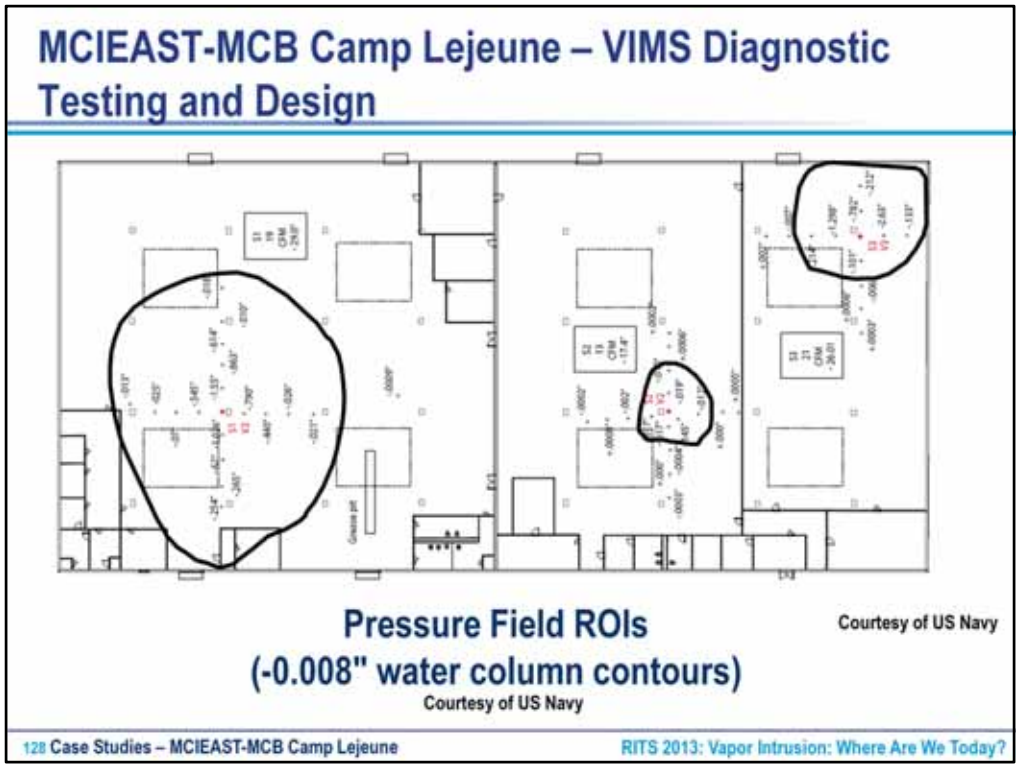
- Single story equipment storage brick warehouse with several offices, 72,000ft^2
  - Three sections (auto repair, tent storage, and misc. storage)
- Thick concrete foundation
  - Pile-type formation built in 1940s
- ~5 workers spend most of time in air conditioned offices

126 Case Studies – MCIEAST-MCB Camp Lejeune RITS 2013: Vapor Intrusion: Where Are We Today?

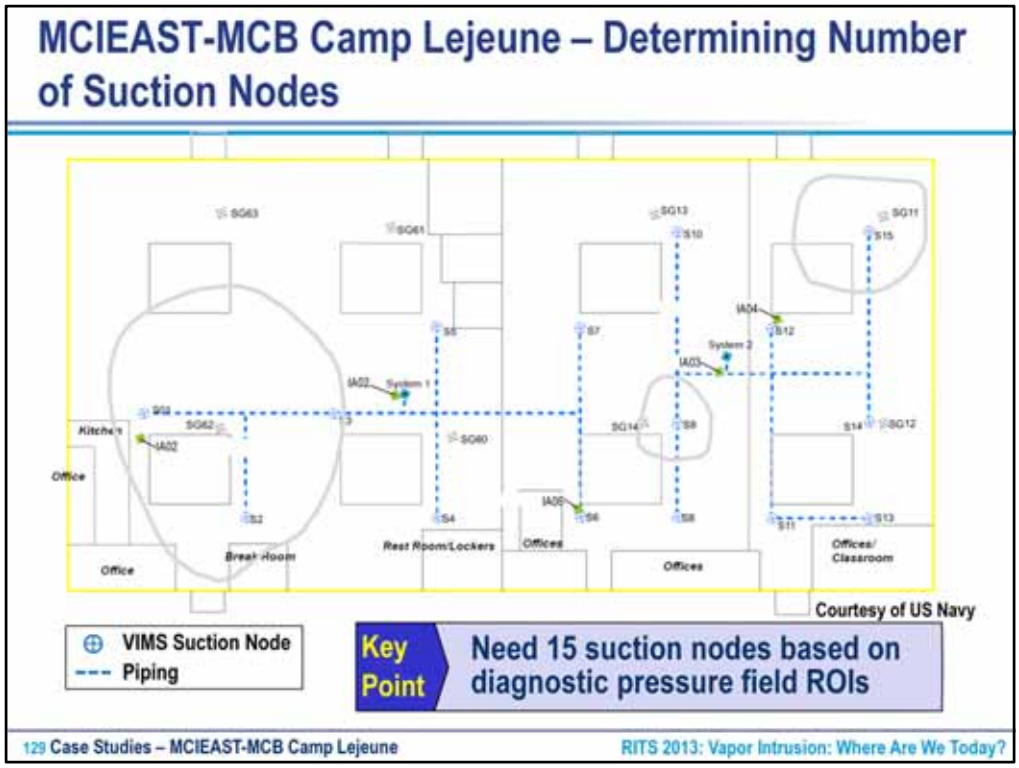
The building of interest is a single story equipment storage brick warehouse with several offices. The foundation is thick concrete and ~5 workers spend most of their time in the air conditioned offices.



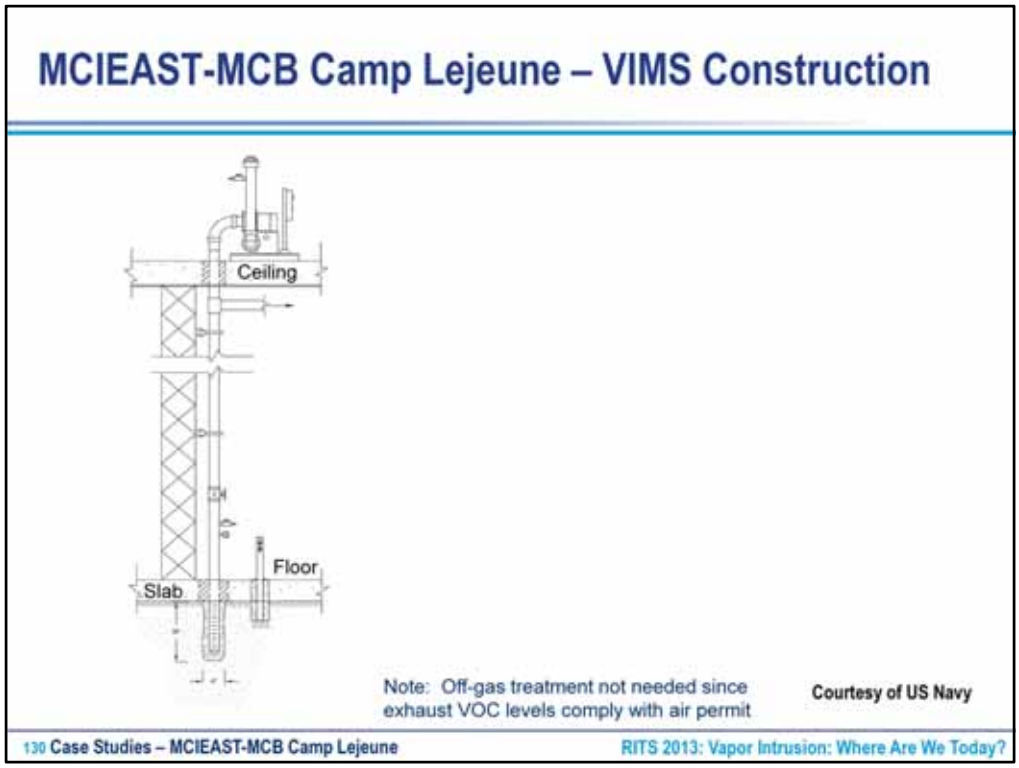
Subslab and indoor air TCE levels exceeded VI SLs and the concentrations are shown on this figure, with the orange symbols showing the subslab results and the green circles representing indoor air sample locations. The Navy opted to install a subslab depressurization mitigation system.



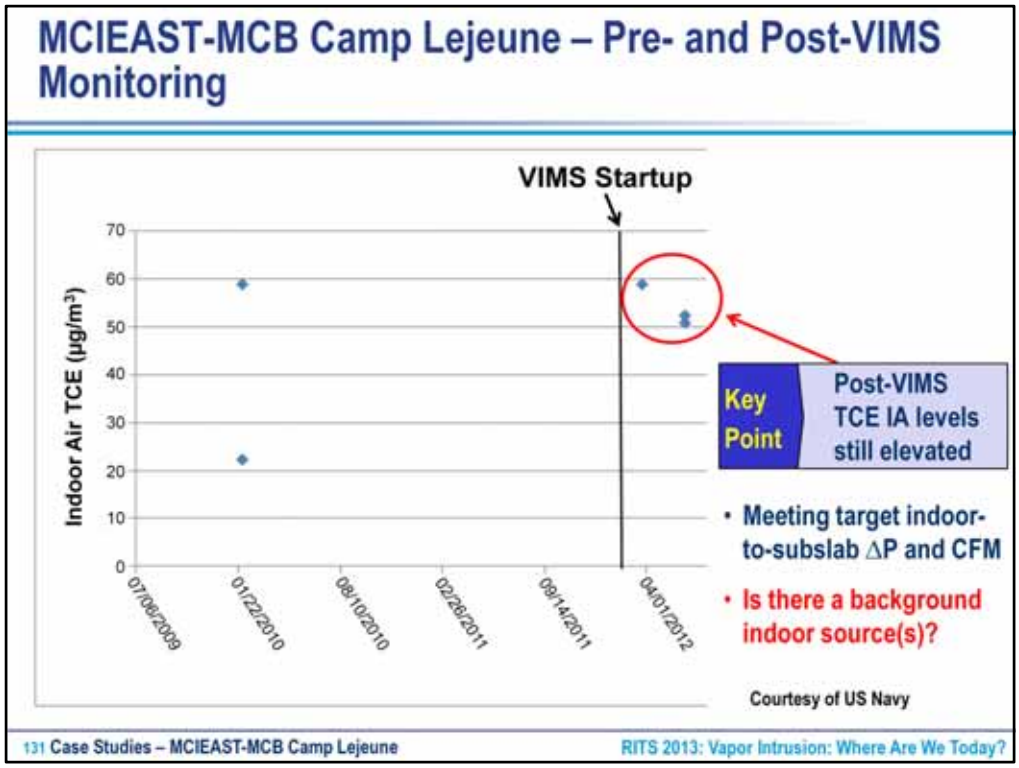
The three diagnostic test locations are shown on this figure, with the contour lines representing the target water column pressure contour of -0.008 inches of water.



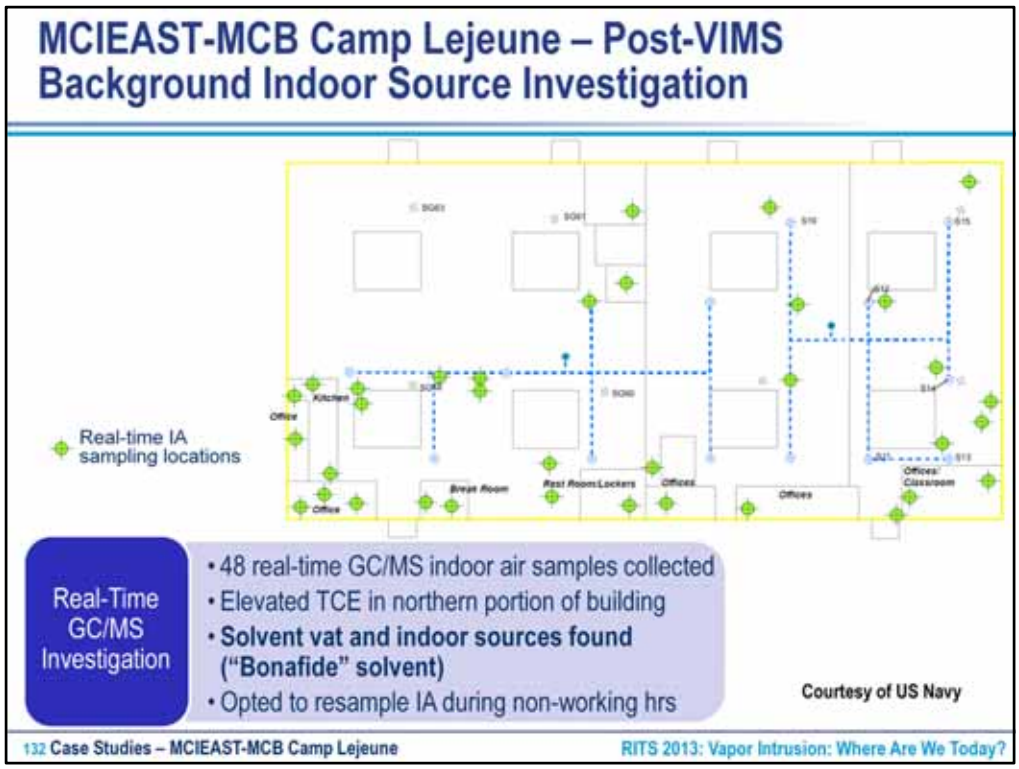
The diagnostic pressure field ROI results indicated a need for 15 suction nodes. The locations of these suctions nodes were selected to insure overlap of the pressure fields, biased somewhat towards the regularly occupied portion of the building.



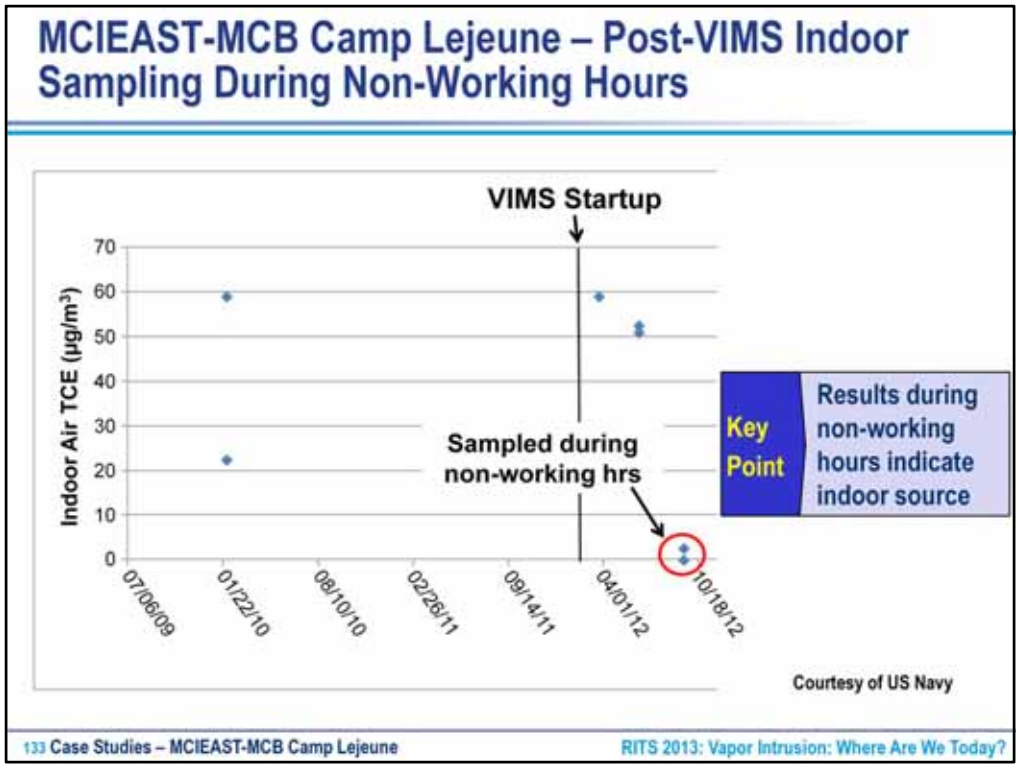
The piping was installed as shown on this design diagram and the pictures on the right, with the fans being installed in the attic space. Off-gas treatment was not needed since exhaust VOC levels complied with the Base air permit.



This figure shows the indoor air concentrations pre- and post-VIMS. Notice that the post-VIMS TCE IA levels were still elevated, even though indoor-to-subslab pressure differential and air flow targets were being achieved. This raised the question as to whether there was an indoor source of TCE.



A post-VIMS background indoor source investigation was performed using the portable GC/MS field instrument. 48 real-time GC/MS indoor air samples were collected at the locations shown with the green symbols on this figure. TCE concentrations were elevated in the northern portion of the building. A solvent vat and corresponding solvent containing TCE was found. A picture of the solvent vat is shown on the bottom right of this slide. Resampling the IA during non-working hours with the VIMS running was recommended.



As you can see on this figure, TCE indoor concentrations dropped significantly during non-working hours, which provided additional and relatively strong evidence of an indoor source... highlighting the importance of identifying background sources.

Presentation Overview

- Introduction
- Review of Key Vapor Intrusion (VI) Concepts
- Update on Recent or Expected VI Guidance Documents
- Current/Upcoming Challenges, Hot Topics, and Solutions
- Case Studies
- ▶ Summary

134 RITS 2013: Vapor Intrusion: Where Are We Today?

In summary.....

Summary

- Navy 2012 Data Call confirmed VI investigations continue to be a priority
- There continues to be significant variability in regulatory VI guidance
  - VI 5-Yr Review OSWER Directive (Dec 2012)
  - EPA updated VI guidance (cVOC & pVOC) expected in 2013
- Consider VI factors and fundamental truths when conducting MLE VI evaluations
- Current regulatory focus and uncertainty about VI rapid responses
- Understanding VI challenges, hot topics, and solutions can improve assessments
  - Examples: Achieving consistency, spatial/temporal variability, building prioritization, background vapor sources, and designing/installing/monitoring VIMS
- Emerging methods can provide better data, increased efficiency, and cost-savings
- Navy industrial buildings are different than residential buildings

Vapor Intrusion – "Where are We Going?"

- Updated EPA (2013?) VI and ITRC pVI guidance
- More real-time data and dynamic work plans
- Longer duration indoor air sampling
- Scientifically defensible approach to RALs
- Improved systematic site/building prioritization
- Systematic/quantitative building prioritization & decision frameworks
- More sophisticated collection and use of building characteristics data
- Improved understanding of industrial buildings
- More effective, cheaper, and sustainable VIMS
- Element of Hazardous Ranking System (HRS) and National Priority Listing (NPL)

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