Unravelling Confounding Sources in a Complex Vapour Intrusion Scenario

A Case Study of an SSDS-Retrofitted Former Manufacturing Facility

TERRAPEX

Toronto Vapour Intrusion Conference
May 5, 2026

ABOUT ME…

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- Licensed professional engineer and designated “Consulting Engineer” in Ontario
- Recognized as a “Qualified Person” for the submission of Records of Site Condition (a.k.a. a “QP_{ESA}”) and Risk Assessments (a.k.a. a “QP_{RA}”) by the Ontario Ministry of the Environment, Conservation and Parks
- More than 30 years of experience in the environmental engineering consulting industry

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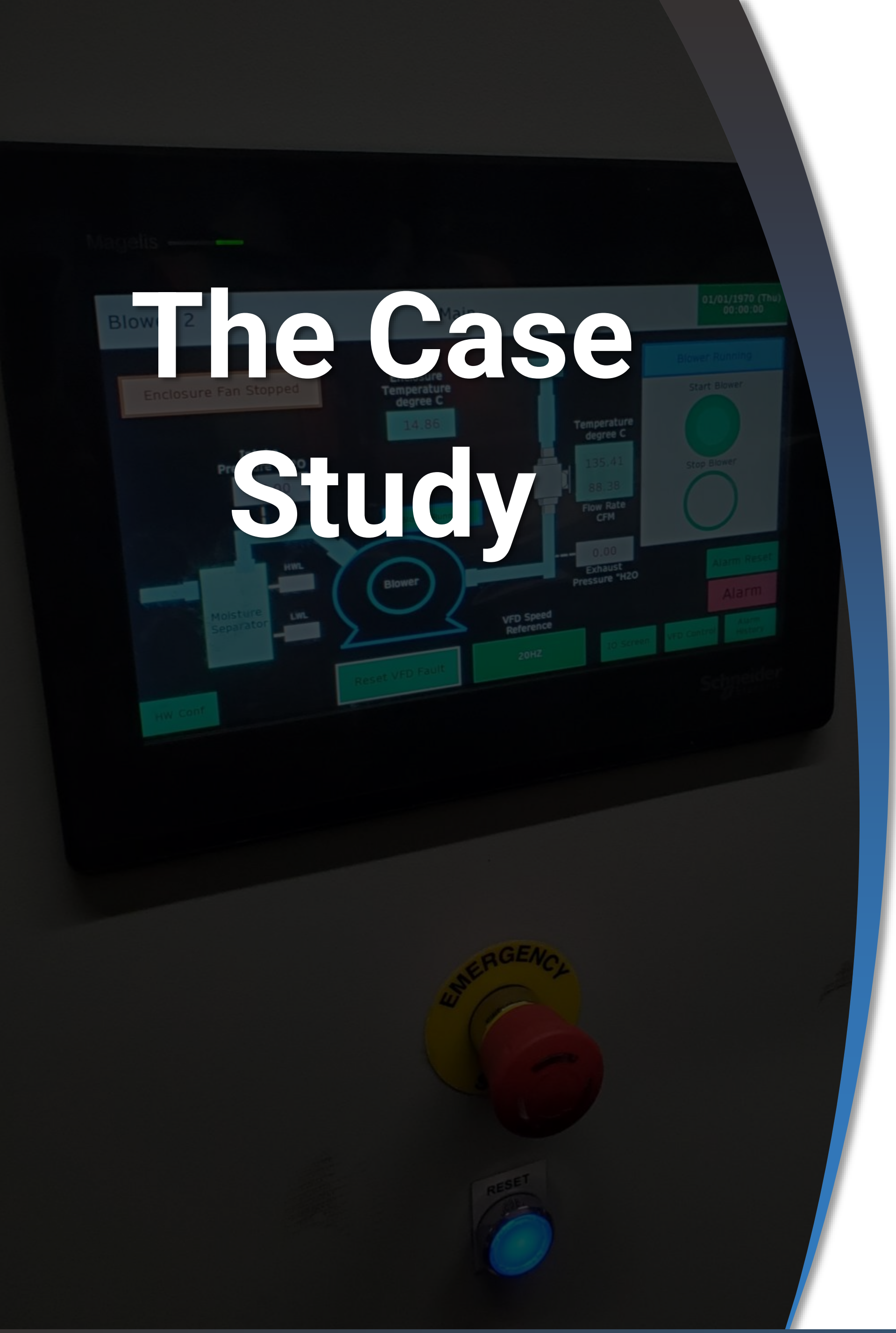

The Case Study

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BACKGROUND

- A former manufacturing facility in southwestern Ontario (currently being using as a logistics centre by the tenant) was retrofitted with a SSDS
- Contaminants of concern: TCE and its degradation products
- Successful installation of the SSDS was a condition for closing of a Purchase and Sale Agreement (PSA)
- Purchaser was acquiring the property for investment purposes and did not have any intention of changing the use of the property (or the tenant, in the short term)
- The PSA required the Seller to conduct indoor air sampling, compare the results to targets based on MECP “Health Based Indoor Air Criteria”, and demonstrate that the SSDS was successfully mitigating unacceptable vapour intrusion risks

Indoor Air Sampling

Indoor Air Sampling Results

Parameter	HBIAC-based indoor air target (µg/m3)	Observed Concentrations	
		min. value (µg/m3)	max. value (µg/m3)
Dichloroethylene, 1,1-	118	< 0.198	< 0.198
Dichloroethylene, 1,2-cis-	42.9	< 0.198	< 0.198
Dichloroethylene, 1,2-trans-	42.9	< 0.396	< 0.396
Trichloroethylene	0.871	< 0.269	**1.63**
Vinyl Chloride	0.406	< 0.0511	< 0.0511

Indoor air target based on MECP "Health Based Indoor Air Criteria" for an industrial building and a source allocation adjustment for a non-potable groundwater exposure scenario

Indoor air sampling identified TCE concentrations in excess of the established indoor air target


PANIC TIME

Taking a structured approach to (apparent) failure assessment

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STEP ONE

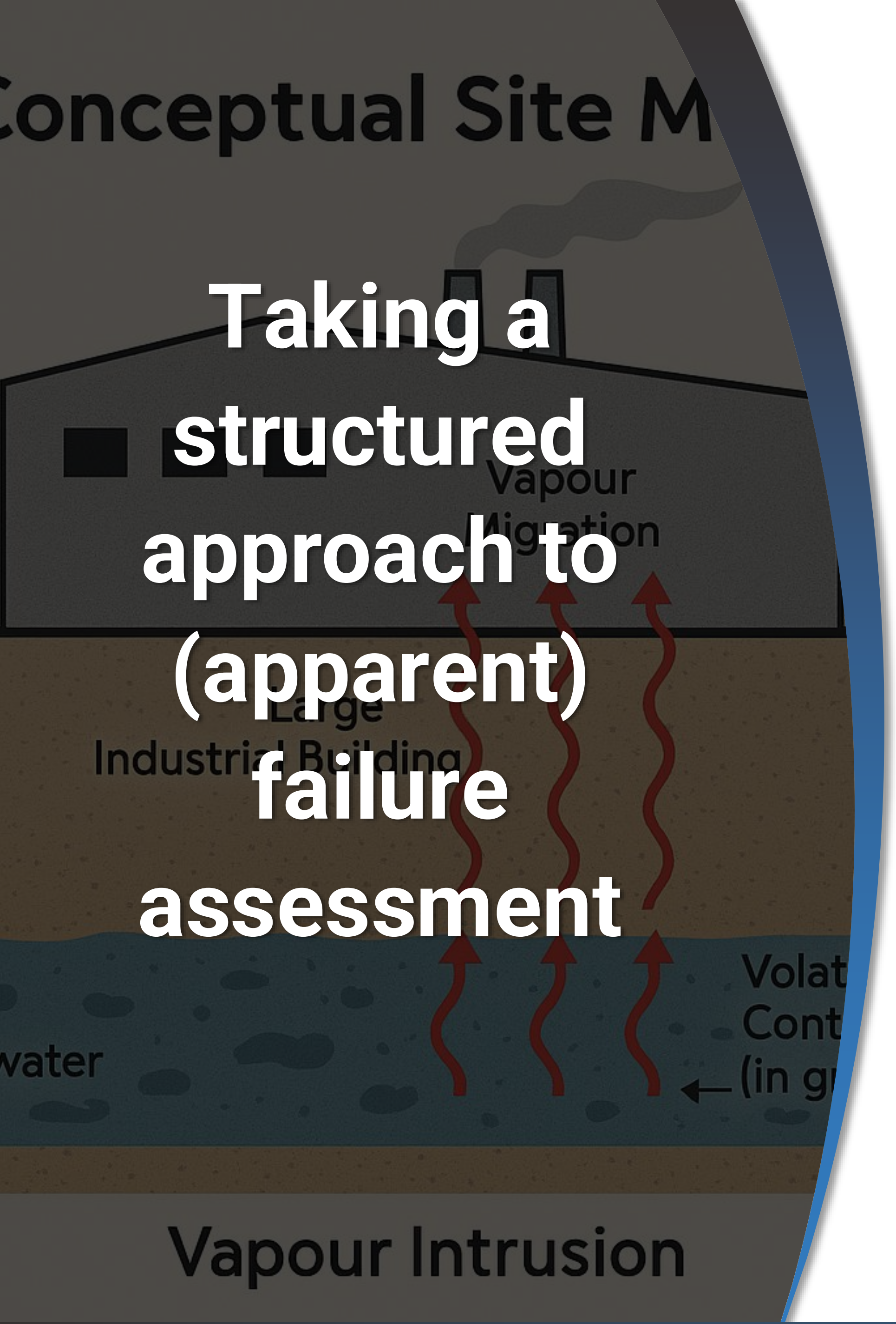
Confirm there actually is a problem

Laboratory results aren’t sacrosanct, and the presence of parameters of concern within indoor air isn’t necessarily an indication of vapour intrusion

Have confirmatory samples been collected?

Has the potential presence of confounding sources been accounted for?

Is the evaluation criteria appropriate / correct?



Taking a structured approach to (apparent) failure assessment

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STEP TWO

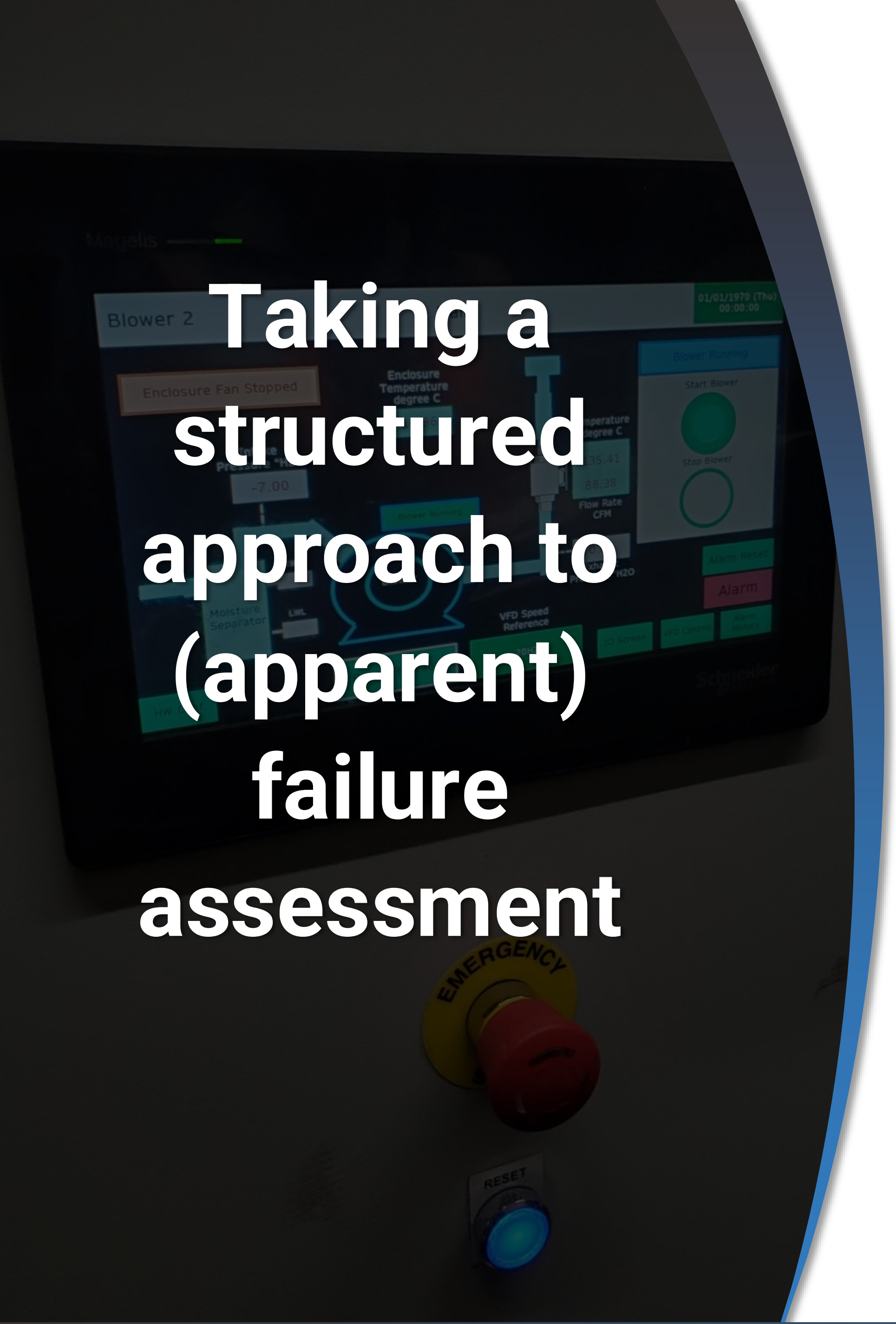
Is the Conceptual Site Model flawed?

The SSDS may be doing exactly what it was designed to do, but it's trying to solve the wrong problem

Was there adequate characterization of contaminant distribution, mass, and flux?

Were potential temporal/seasonal changes in subsurface conditions appropriately accounted for?

Are there (previously unrecognized) offsite sources contributing to onsite vapour intrusion?



Taking a structured approach to (apparent) failure assessment

STEP THREE

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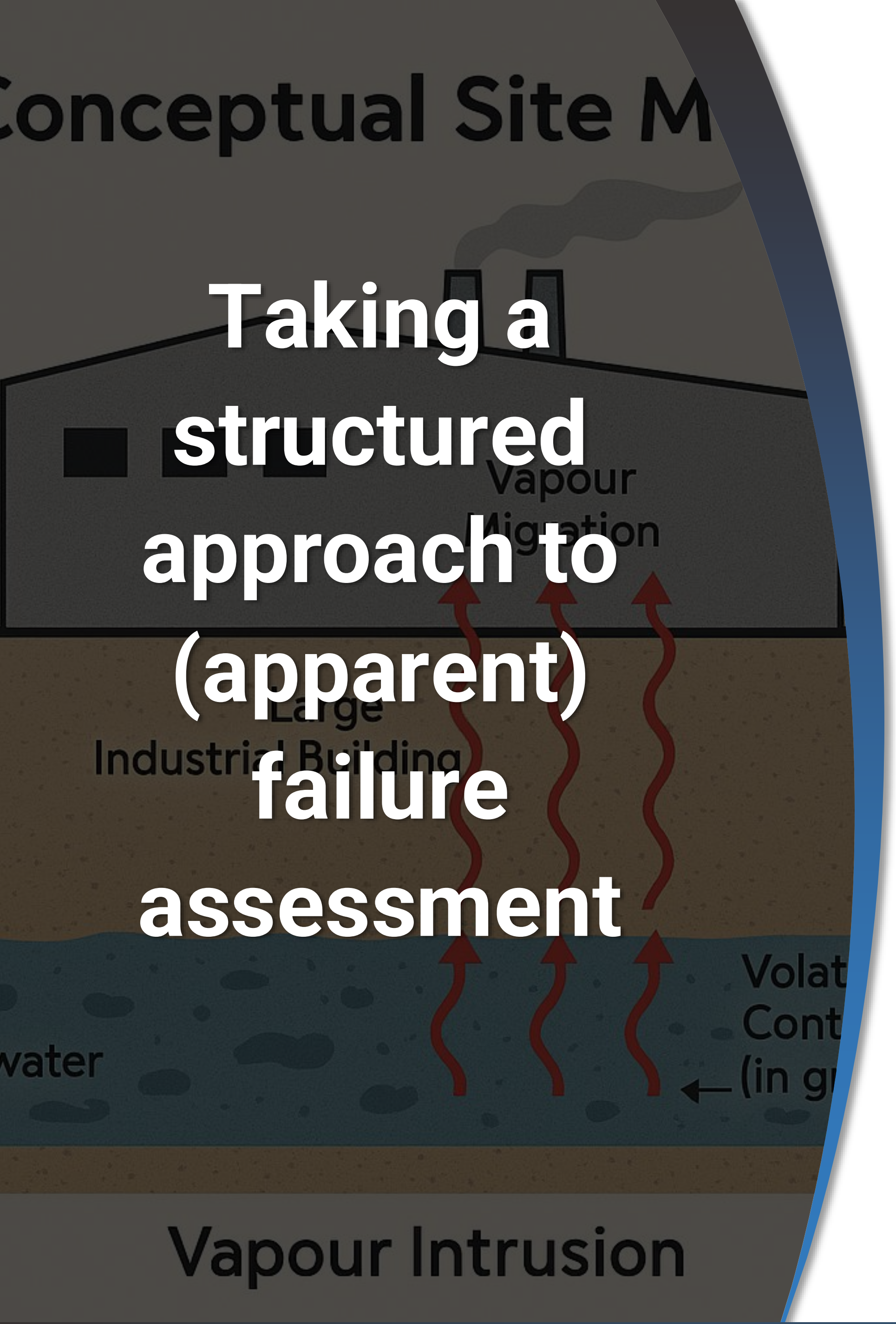
Is the SSDS the "source"?

Confirm captured vapours are not (directly or indirectly) being introduced to the indoor environment

Is the SSDS piping system intact?

Are vapour discharges suitably distant from building windows and fresh air intakes?

Are backdrafts drawing vapours into the building environment?



Taking a structured approach to (apparent) failure assessment

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STEP FOUR

Is the Pressure Field Extension Inadequate?

The SSDS may not be achieving the radius of influence at each extraction point anticipated by the system design

Are there too few suction points (excessive spacing between extraction locations) and were the extraction fans properly sized??

Is the sub-slab granular base heterogeneous, or are there subsurface obstructions impeding air flow?

Has the system been properly maintained?

Taking a structured approach to (apparent) failure assessment

STEP FIVE

Is slab or building leakage overwhelming the system?

Short-circuiting can result in indoor air (as opposed to sub-slab vapours) being captured by the SSDS

Were cracks and joints in the floor slab adequately sealed?

Have sumps and utility penetrations in the floor slab been sealed?

Is the building HVAC system creating pressure gradients that compete with (or even reverse) SSDS effectiveness?

Assessment Findings

- Concentrations of TCE within indoor air did exceed MECP "Health Based Indoor Air Criteria" for an industrial setting
- None of the materials stored inside the building were identified as potential confounding sources of TCE
- No issues with either the CSM or the SSDS design were identified
- No evidence that captured SSDS vapours were being introduced (directly or indirectly) into the building interior
- While accessible cracks, joints, utility penetrations, and other breaks in the floor slab had been sealed as part of the SSDS installation, **ongoing logistic centre operations had precluded inspections of some areas of the floor slab**
- **no efforts had been made to seal the entirety of the building floor slab**

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Next steps:

It’s clearly the floor slab that’s the problem, right?

Our analysis isn’t yet complete…

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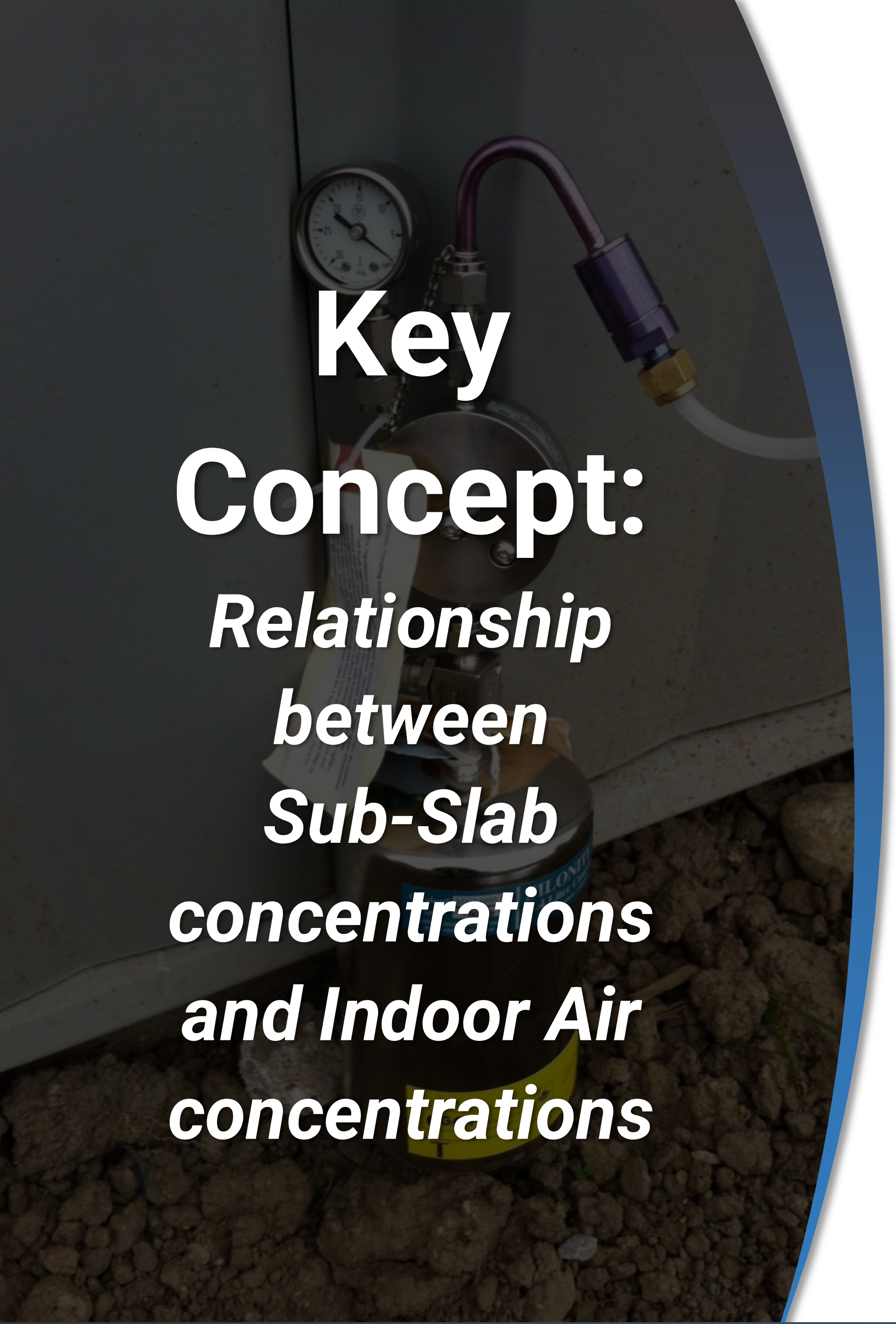
AT ISSUE

The SSDS design accounted for the absence of a seal on the floor slab!

The presence of parameters of concern within indoor air isn’t necessarily an indication of vapour intrusion

- More practically, sealing the floor slab would incur considerable expense and significantly inconvenience the building tenant
- While the Seller was willing to initiate a work plan to seal the floor slab, they wanted assurances it was absolutely necessary before starting



Key Concept:

Relationship between Sub-Slab concentrations and Indoor Air concentrations

THE SIMPLE MATH

$$C_{IA} = \alpha \cdot C_{SS}$$

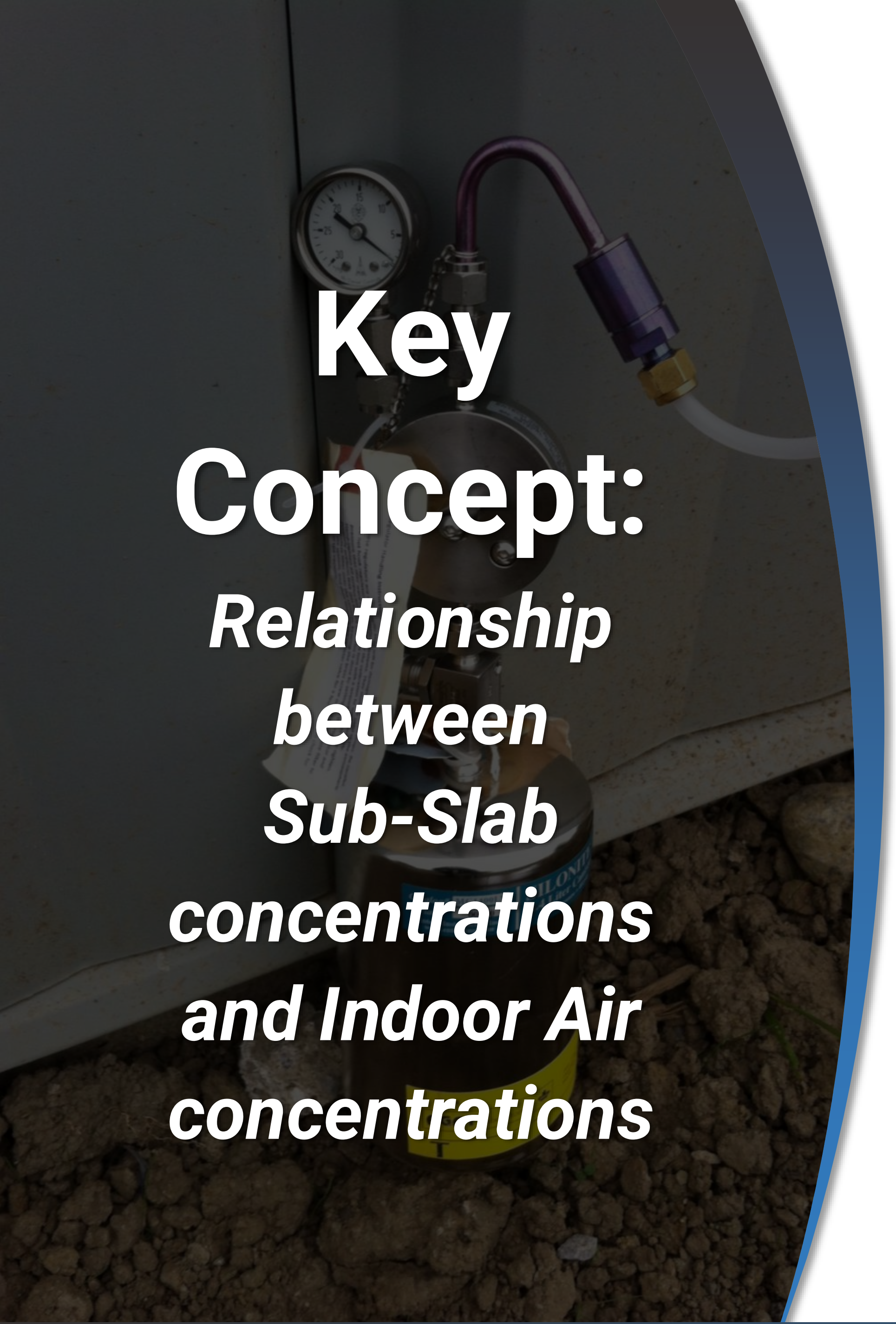
Where,

$C_{IA} = contaminant\ concentration\ in\ indoor\ air$

$\alpha = vapour\ intrusion\ attenuation\ coefficient$

$C_{SS} = contaminant\ concentration\ in\ sub\text{-}slab\ vapour$

The implication of this equation is that, <u>all other things being equal</u>, a reduction in sub-slab vapour concentrations of a contaminant will result in a proportional decrease in the indoor air concentrations of that contaminant.



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Relationship between Sub-Slab concentrations and Indoor Air concentrations

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NOT-SO SIMPLE…

$$\alpha = \frac{Q_{flux}}{Q_{flux} + Q_{vent}}$$

Q_{flux} = *effective contaminant flux from soil into building*

Q_{vent} = *building ventilation flow rate*

$$Q_{vent} = AER \cdot V_b$$

AER = *building air exchange rate*

V_b = *building volume*

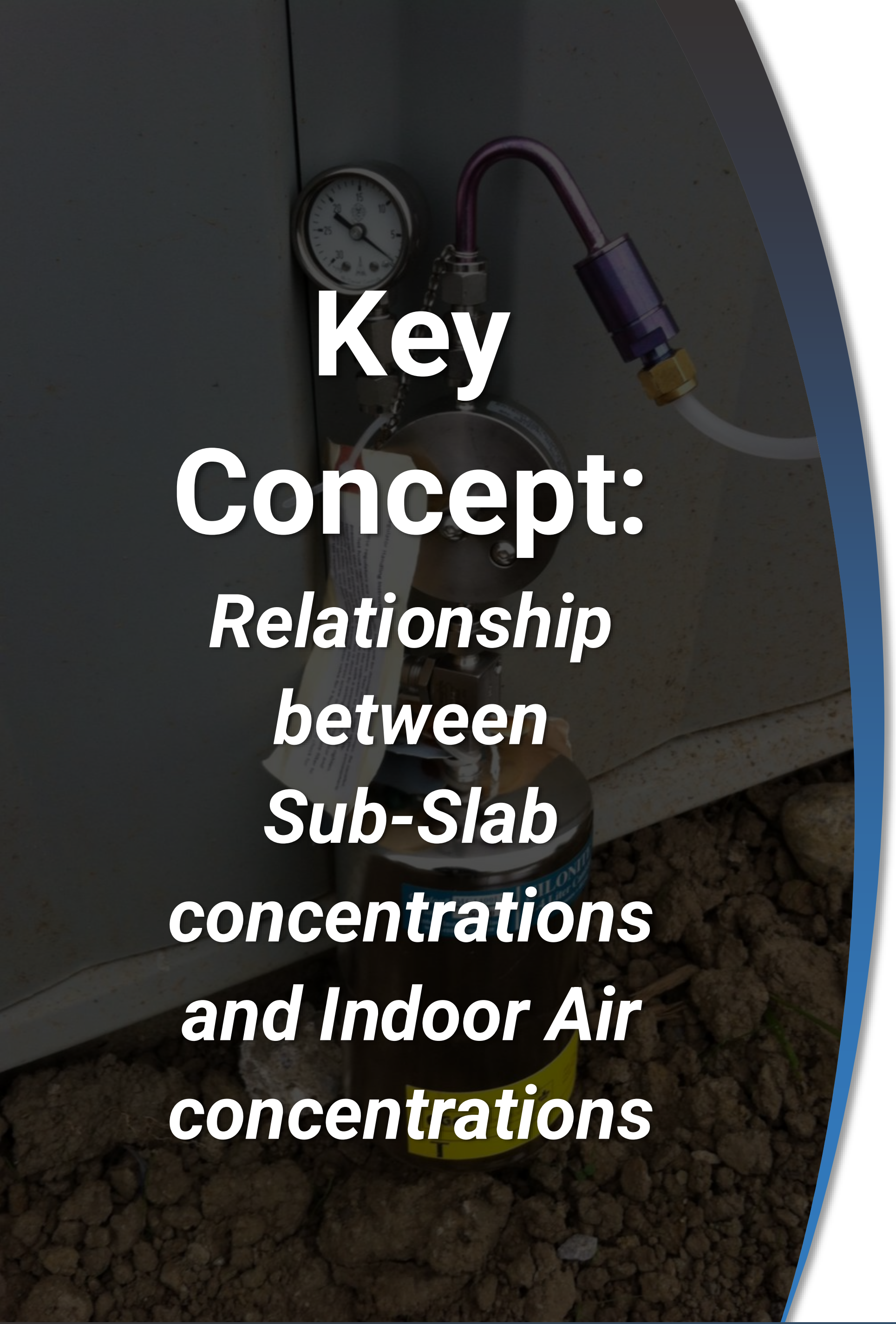
Q_{vent} is constant

for a large building, we can assume AER would essentially be unaffected by the operation of a SSDS

$$Q_{flux} = \frac{A_{crack} \cdot D_{air}}{L_{crack}} + Q_S$$

diffusion component

advection component



Key Concept:

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NOT-SO SIMPLE…

$$Q_{flux} = \frac{A_{crack} \cdot D_{air}}{L_{crack}} + Q_S$$

- A_{crack} = *effective crack area, floor slab*
- L_{crack} = *crack thickness*
- D_{air} = *molecular diffusion coefficient in air*

These parameters are constant so the diffusion component of Q_{flux} is constant

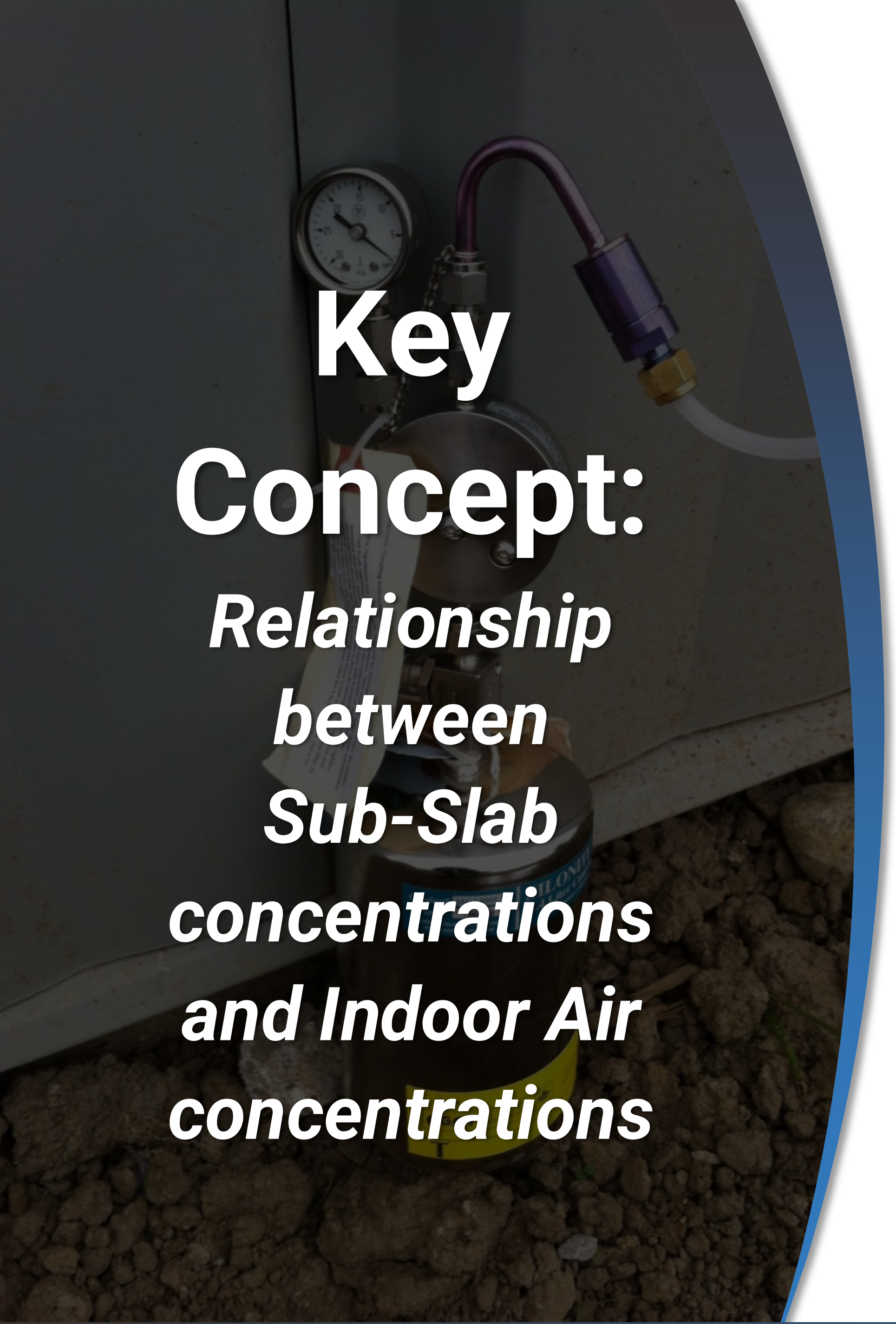
$$Q_s = \frac{k_{air} \cdot A_f}{\mu_{air}} \cdot \frac{\Delta P}{L_{crack}}$$

- k_{air} = *air permeability of soil*
- A_f = *foundation area in contact with soil*
- μ_{air} = *dynamic viscosity of air*

ΔP = *pressure differential* $(P_{soil} - P_{indoors})$

These parameters (and L_{crack}) are also constant

With a SSDS operating, ΔP becomes smaller and so the advective component of Q_{flux} becomes smaller, meaning Q_{flux} itself becomes smaller



Key Concept:

Relationship between Sub-Slab concentrations and Indoor Air concentrations

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NOT-SO SIMPLE…

$$\alpha = \frac{Q_{flux}}{Q_{flux} + Q_{vent}}$$

With a SSDS operating, Q_{flux} becomes smaller while Q_{vent} is unchanged, meaning that α becomes smaller.

If our complex set of equations predicts that with a SSDS operating α becomes smaller, assuming α is constant means we can use the "simple" mathematical relationship between sub-slab concentrations and indoor air concentrations as a conservative evaluation.

$$C_{IA} = \alpha \cdot C_{SS}$$

PRE-SSDS INSTALLATION

INDOOR AIR

Trichloroethylene within Indoor Air Samples

Sampling Location	HBIAC-based indoor air target (µg/m3)	Max. Observed Concentration (µg/m3)	Required Reduction
IA-03	0.871	**0.963**	9.6%
IA-05		**4.71**	81.5%
IA-11		**3.91**	77.7%
IA-17		**2.28**	61.8%

Note: only selected data is presented

*Presuming that TCE within indoor air was resulting solely from the intrusion of contaminant vapours beneath the floor slab, **an 82% reduction in sub-slab vapours** would be expected to reduce indoor air concentrations to MECP Health Based Indoor Air Criteria levels*

POST-SSDS INSTALLATION

SUB-SLAB VAPOUR

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Trichloroethylene within Sub-Slab Vapour Samples

Sampling Location	Sub-Slab Criterion (µg/m³)	Max. Observed Concetrations		Apparent Reduction (%)
		pre-SSDS (µg/m³)	post-SSDS (µg/m³)	
VP-03	218	189	26.1	86
VP-05		3,960	73.9	98
VP-11		29,400	122	100
VP-15		12,800	234	98
VP-16		1,170	122	90

Note: only selected data is presented

With the SSDS in operation, sub-slab vapour concentration have been reduced sufficiently ***to reduce TCE concentrations within indoor air to be less than MECP Health Based Indoor Air Criteria levels****.*

The SSDS is achieving its performance objectives?!?

Problem formulation

- No issues with either the CSM or the design, installation, or maintenance of the SSDS system were identified
- No evidence that the SSDS isn't capturing TCE vapours beneath the floor slab of the building
- No evidence that captured TCE vapours were being introduced (directly or indirectly) into the building interior
- None of the materials stored inside the building were identified as potential confounding sources of TCE
- **BUT concentrations of TCE within indoor air were exceeding MECP "Health Based Indoor Air Criteria"**

So what's going on?

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“When you have eliminated the impossible, whatever remains, however improbable, must be the truth.”

Sir Arthur Conan Doyle, *The Fate of the Evangeline*, 1885

- Historical activity associated with the former manufacturing facility had resulted in numerous spills of TCE-based solvents onto concrete surfaces
- Subsequent analytical testing of concrete cores recovered from the building slab in solvent use, handling, and storage areas revealed detectable concentrations of TCE within the cement matrix

Key Takeaways

- Troubleshooting apparent failures of SSDS installations requires a methodical, structured, engineering-based approach
- Contaminant vapours can arise from many different sources
- MECP “Health Based Indoor Air Criteria” are NOT total concentration standards / criteria

Thank you!

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