



Vapor intrusion mitigation systems – is a parking garage enough?

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Agenda

- 1 Guidance review
- 2 Garage design styles
- 3 Garage operation
- 4 Example calculations for vapor intrusion evaluation



Guidance review

26 states mention VI mitigation in guidance or state program documents.



Fewer address/mention parking garages as a mitigation design technique.



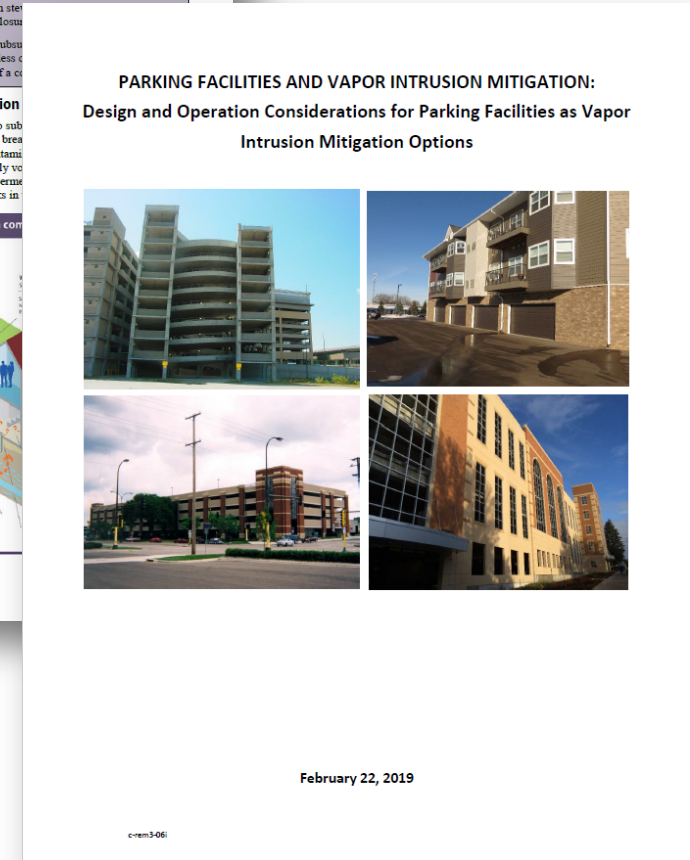
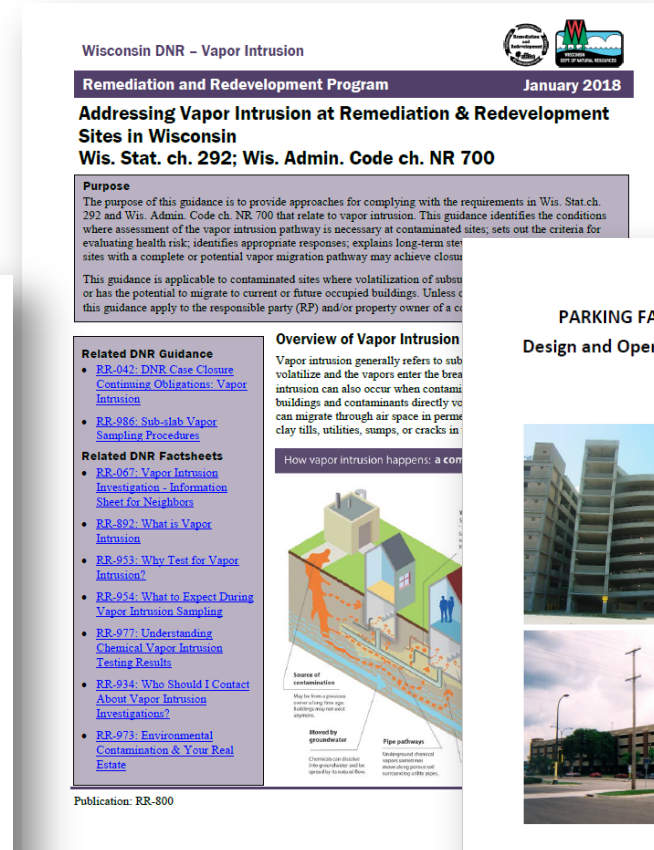
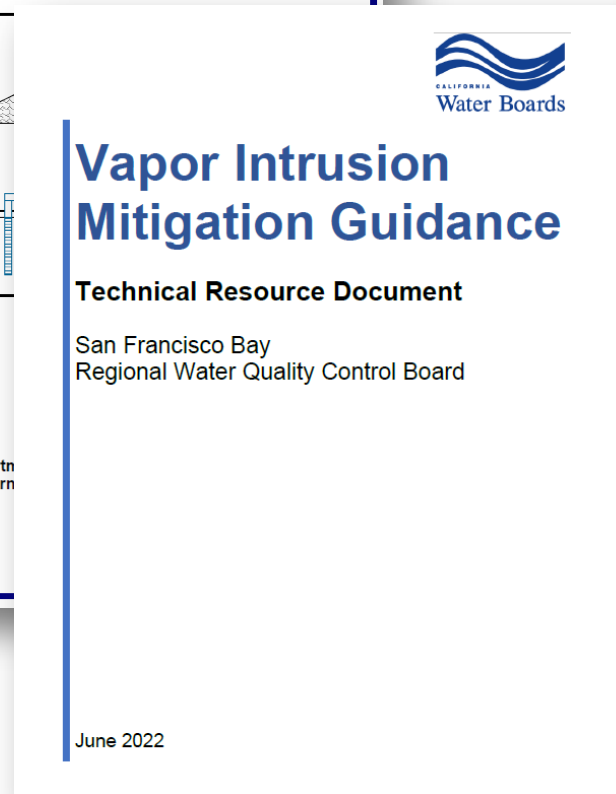
Even fewer provide details clarifying and discussing parking garages as potential mitigation.

Example states with some details provided

- Michigan (EGLE) – “...VI risks in underground parking garages are typically **lower than the risks** or concerns posed from **carbon monoxide** and automobile fuel vapors, which are necessarily addressed through the use of mechanical ventilation...**additional documentation** may be required to show that the risk for VI has been adequately addressed...**ventilation rate** and **design** for the structure be **documented** and included as part of the assessment...”
- DC (DOEE) – “...new construction where the **lowest level** of a building may be used solely for vehicle **parking**, DOEE will consider requests to use only an approved PVI barrier without the incorporation of sub-slab depressurization...**air exchange rates** for the parking level should be **provided to DOEE** in support of the request...an **environmental covenant** would be required which limits human occupation on the lowest level of the building.”

Example states with more details provided

- Minnesota
- Wisconsin
- California



Example states with more detail provided

Minnesota

- What is it (above-ground open air vs enclosed parking garage)
- Specific garage design upgrades/considerations for VI mitigation use
- Published study on design and operating considerations for parking garages used for VI mitigation

Wisconsin

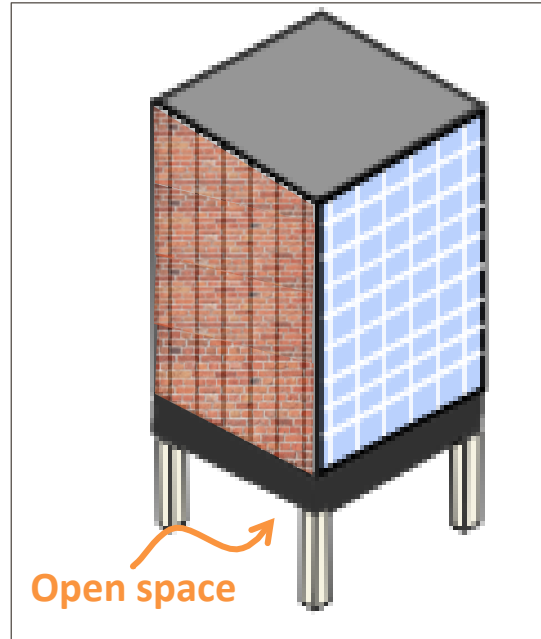
- How mitigation via parking garage works
- Key design elements
- Design guidelines/considerations
 - Sealing elevator pits/other connections to occupied spaces
 - Air exchange rates and pressure control between spaces
 - Documentation of ventilation system specifications
 - Commissioning and decommissioning guidelines
 - Project example

California

- Factors to consider
 - Garage occupancy
 - Ventilation
 - O&M over time
 - Garage depth
 - Elevators, stairwells, and internal parking offices
- Sealing of potential vapor conduits between spaces
- Performance monitoring recommendations for ongoing O&M

VI mitigation via building design

- Building construction less susceptible to VI
 - Open-air ground floor buildings, tuck-under parking, open-air garages



- Open-air crawlspace is not the same as an open-air ground floor; a crawlspace does not necessarily break all potential VI pathways
- Elevators, stairwells, and parking offices still need to be considered

VI mitigation via building design (continued)

- Building construction less susceptible to VI
 - Enclosed/underground ventilated parking garages



Enclosed parking garage — points of vapor entry

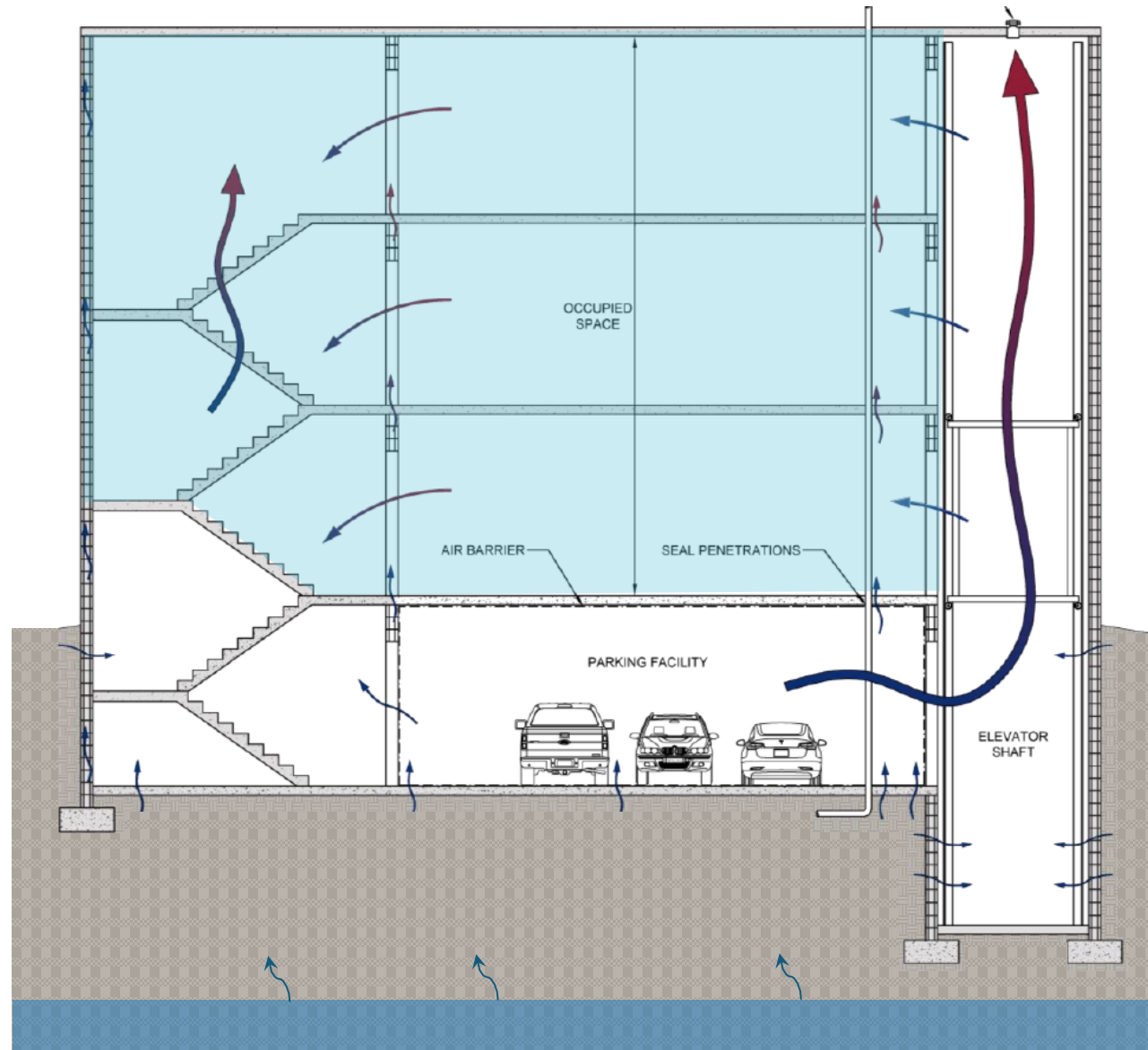


Figure Modified from
MPCA Parking Facilities and Vapor Intrusion Mitigation

Factors to consider

- VI conceptual site model (CSM)
- Remediation via construction
- Presence (or potential future presence) of occupied areas within the parking garage
- Vapor transport pathways (elevators, stair wells, utility chases)
- Groundwater management
- Type and operation of the garage ventilation system and pressure differential targets
- Applicable building codes



Parking garage construction

- Greater ventilation (and negative differential pressure) relative to overlying enclosed occupied spaces
- Accessory areas (e.g., guard shacks, attendant offices) – positive pressure compared to garage space
- Air barriers required on all six surfaces
- Sealants used for utility penetrations, doors, windows, lighting fixtures, etc.
- Wall construction – concrete block vs. poured concrete



Parking garage ventilation

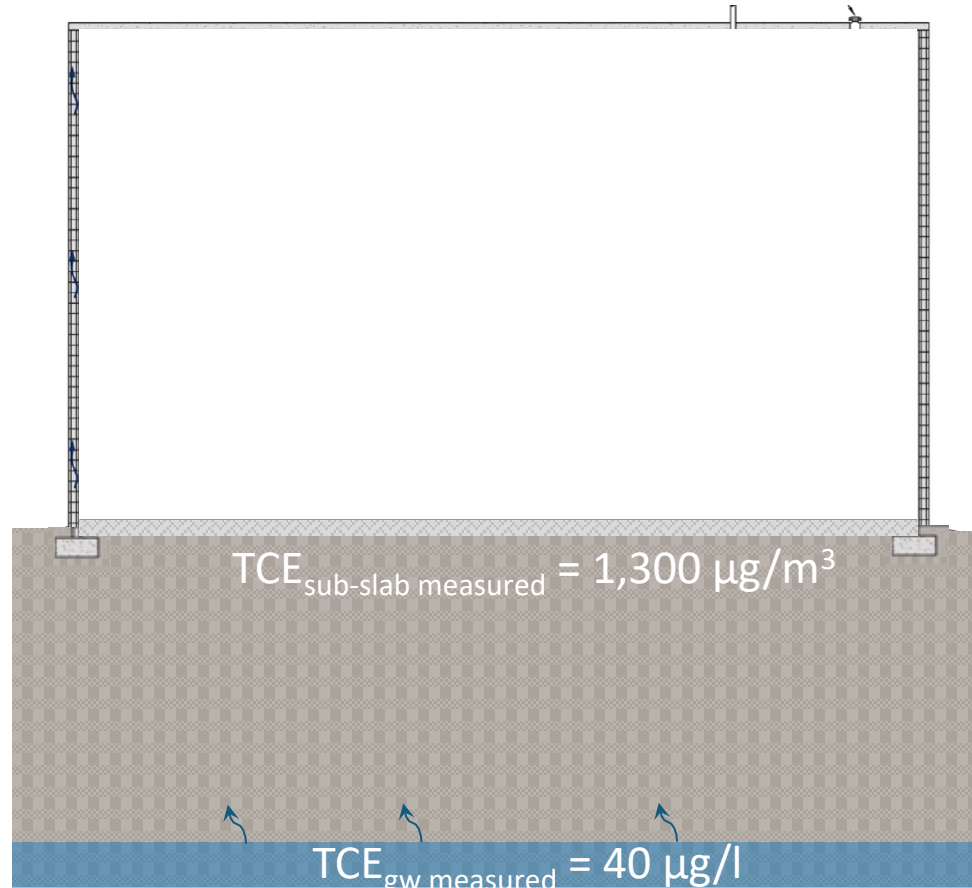
- Typical code:
Target - 0.75 cfm per ft² (~5 ACH)
Minimum - 0.05 cfm per ft² (~0.33 ACH)
- Carbon monoxide typical target:
low-level alarm = 25-35 ppm
- Example typical screening level:
TCE = 8.8 µg/m³ = 0.0016 ppm*
- Backup power planning
- Total ventilation may include both natural and mechanical ventilation

Mechanical Ventilation Options

1. Full time: ACH constant
2. Demand-based ventilation:
 - turns on with CO/NO₂ trigger
 - min. ACH, increases with CO/NO₂ trigger

Thought exercise – Is the parking garage a sufficient barrier?

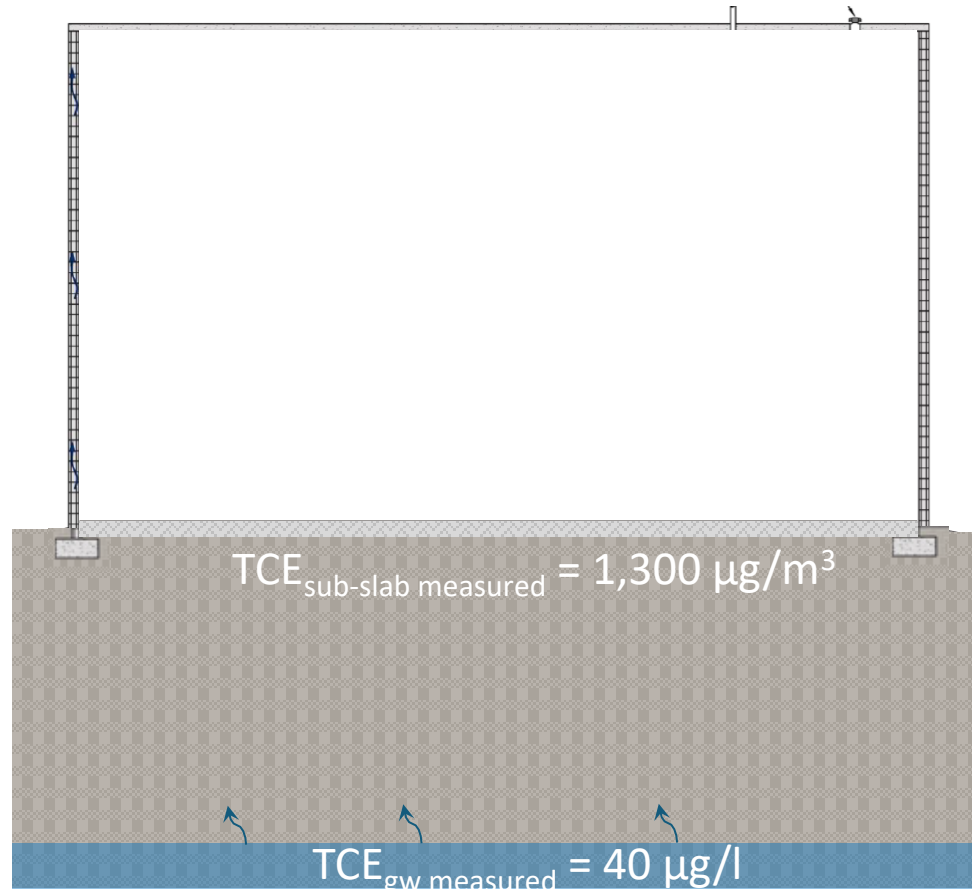
Original Property (to be demo'd)



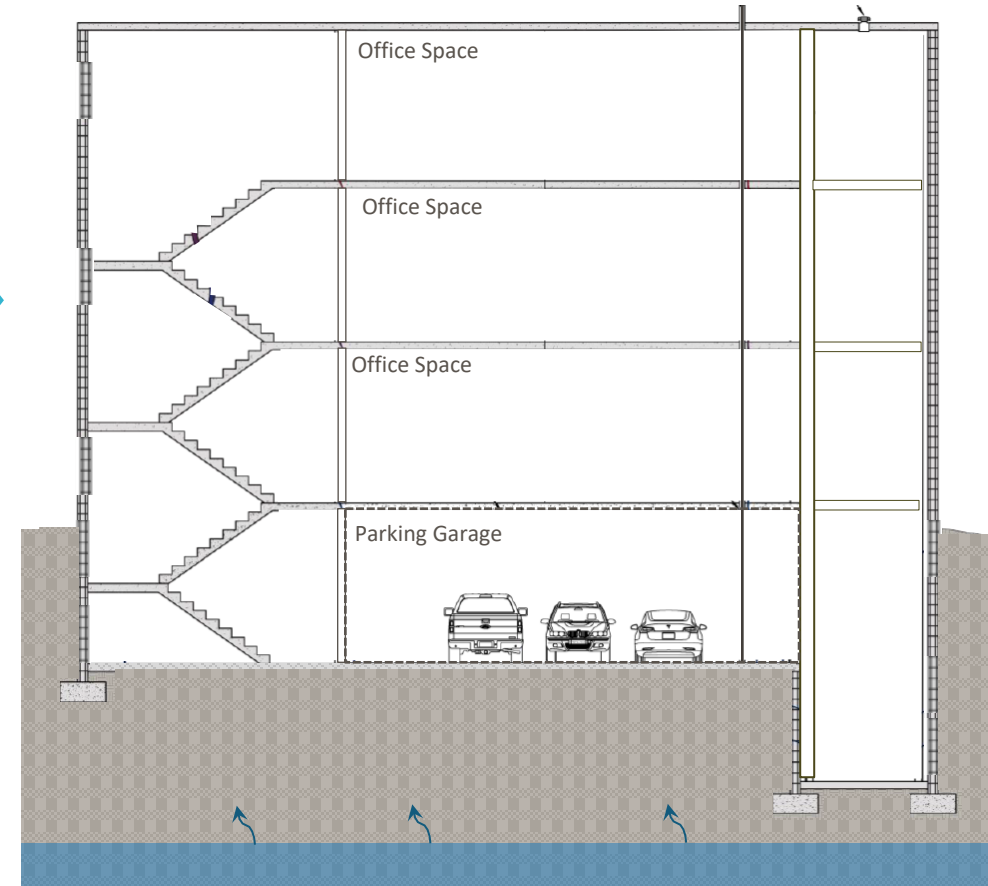
- Site with limited impacts
 - Groundwater source
 - Sampled groundwater concentration – TCE @ $40 \mu\text{g}/\text{l}$,
 - Sampled sub-slab concentration – TCE @ $1,300 \mu\text{g}/\text{m}^3$
- New construction – demo current building
- Parking garage to go one level below grade
- Office space on ground floor and above parking garage

Thought exercise – Is the parking garage a sufficient barrier?

Original Property (to be demo'd)



Envisioned Redeveloped Property



Thought exercise – Is the parking garage a sufficient barrier?

Site Data (TCE)	
C_{gw} (measured)	40 ($\mu\text{g/l}$)
C_{sg} (measured)	1,300 $\mu\text{g/m}^3$
Estimated Data	
C_{sg} (est)	17,000 $\mu\text{g/m}^3$
C_{ia} garage (est range)	1.3 – 17 $\mu\text{g/m}^3$
C_{ia} occupied (est range)	0.13 – 1.7 $\mu\text{g/m}^3$

→ 1. $C_{sg(est.)} = H * C_{gw}$ where H

→ 2. $C_{ia(est.)} = C_{sg} \times \alpha$ where $\alpha = 0.001$

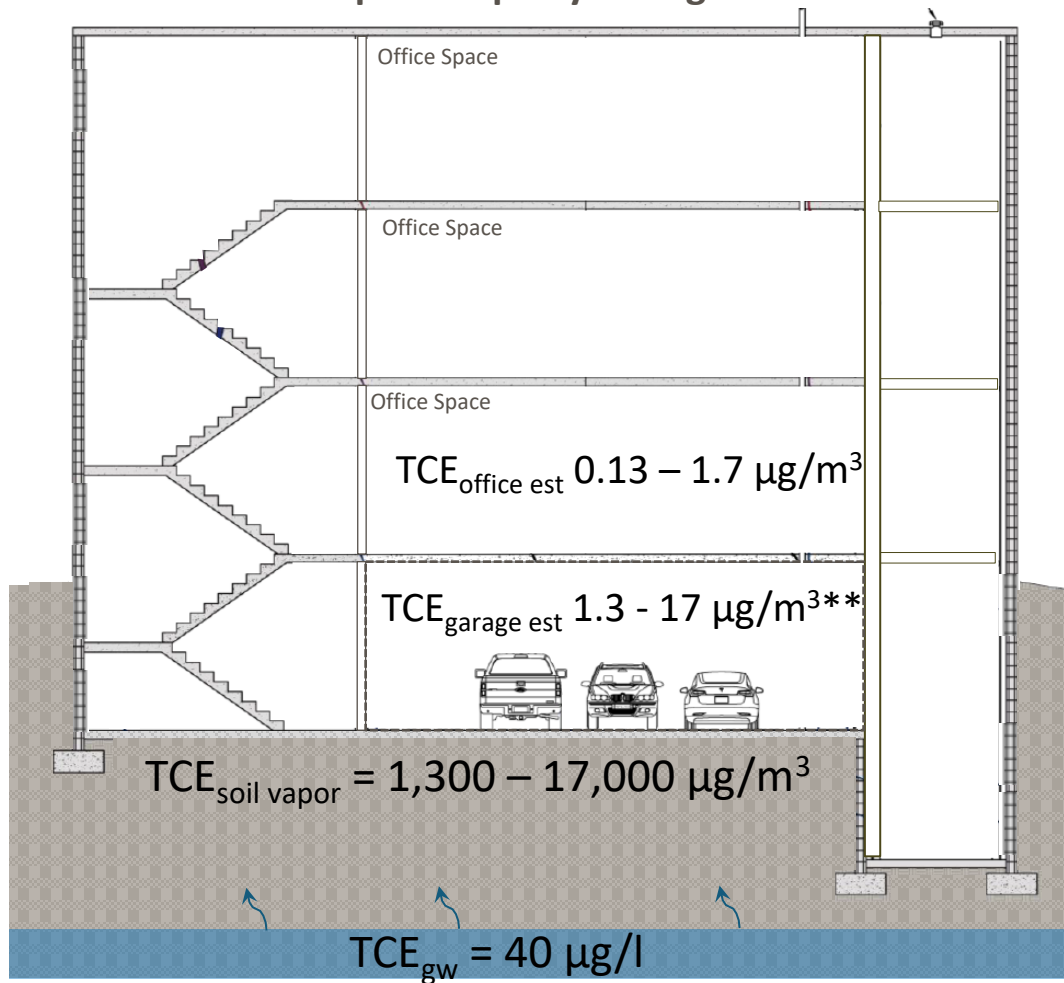
→ Assume 10% (0.1) leakage across air barrier (note: $VISL = 3.0 - 8$).

Key Points:

- $C_{sg(est)}$ conservative. Assumes no attenuation from GW to slab of building and fully mixed.
- $\alpha = 0.001$ based on empirical studies of buildings, conservative to use in a parking garage.
- Leakage of 0.1 is conservative assuming air barrier between parking and occupied spaces and ventilation in parking garage are per code.

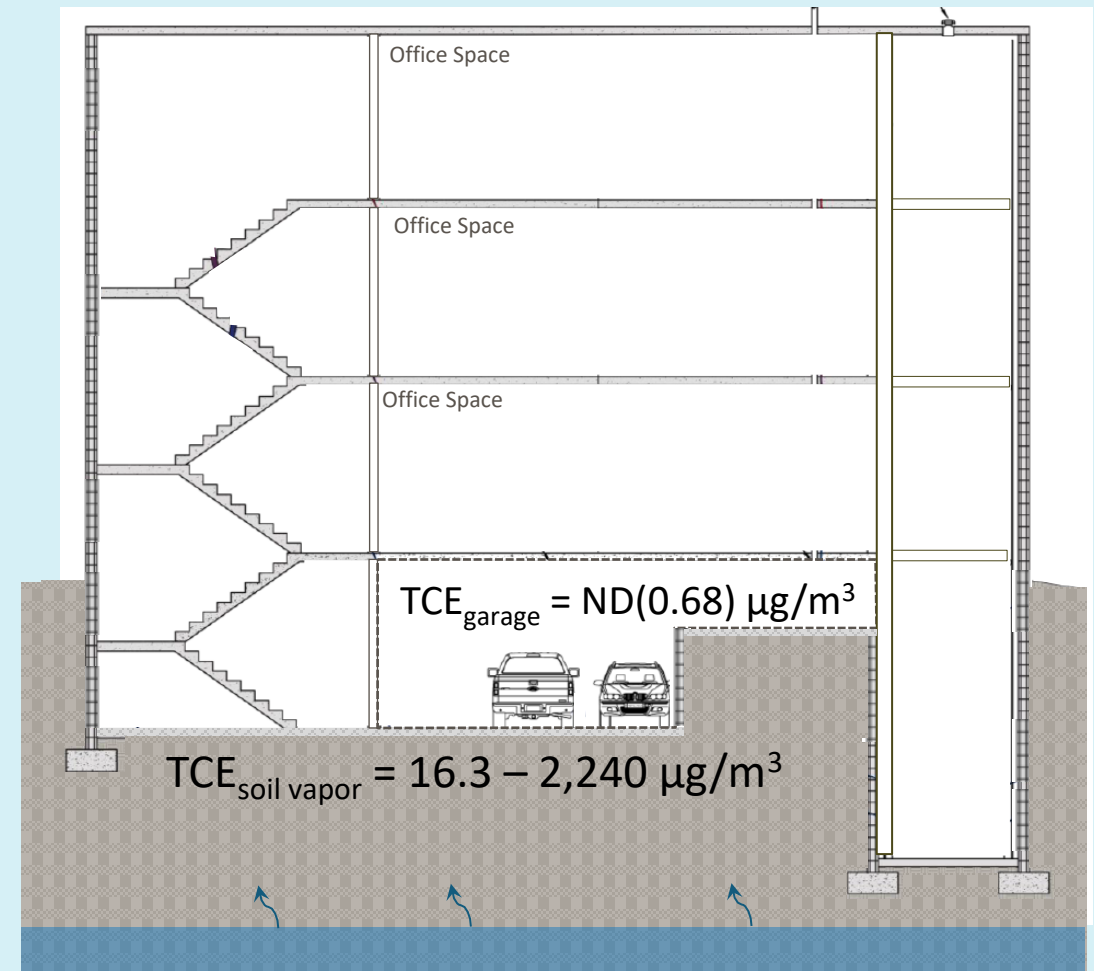
Thought exercise – Is the parking garage a sufficient barrier?

Redeveloped Property Thought Exercise

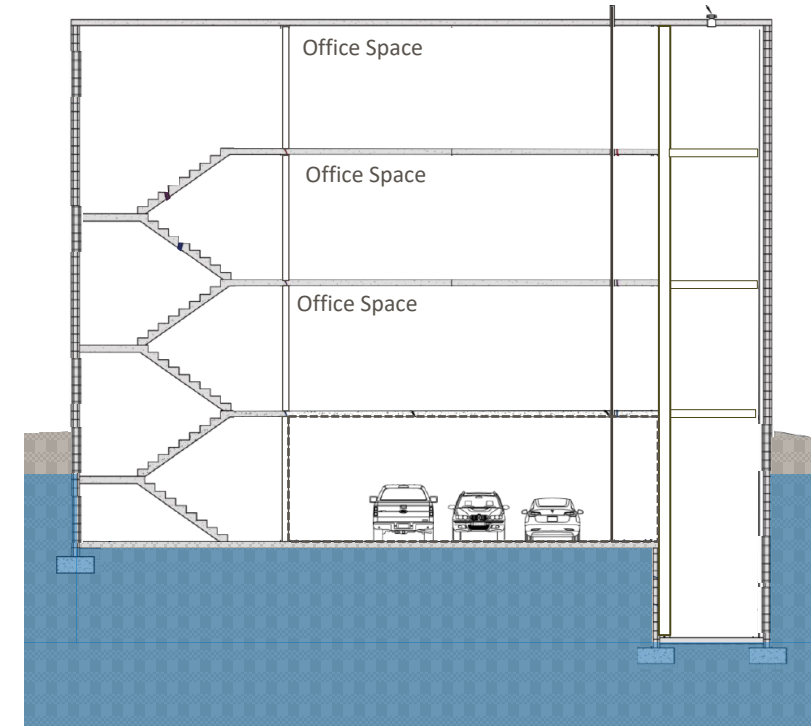
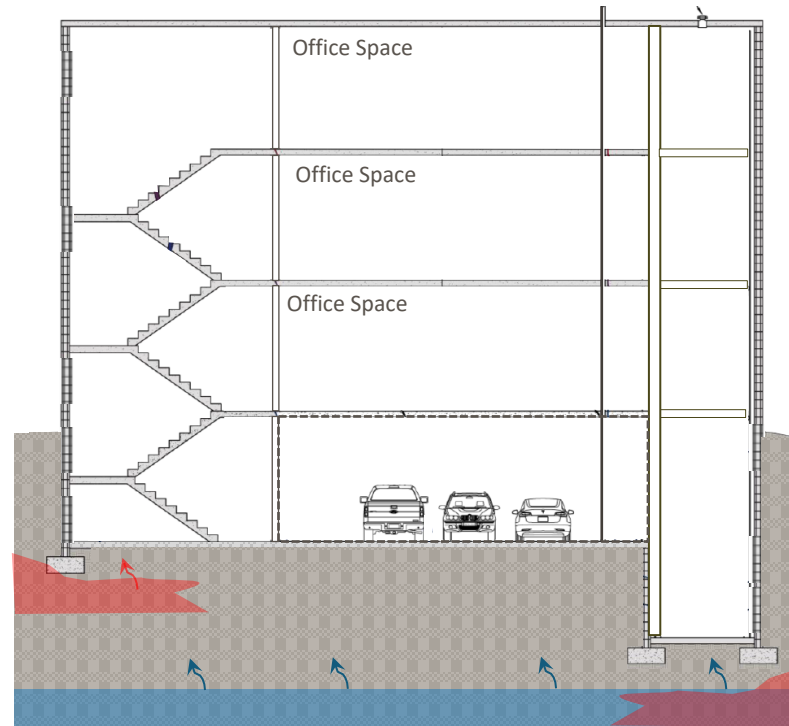
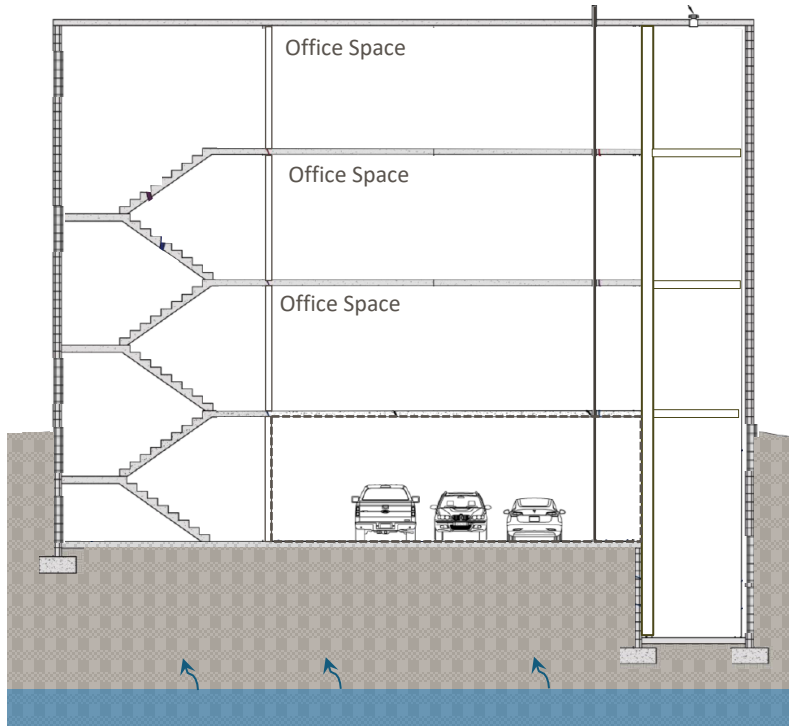


** Has not taken into account garage ventilation which will dilute this value

Real Site: Redeveloped Property



Conceptual site models to consider



Parking garage mitigation options

Above the water table

- Mitigation via garage design – no additional VI-specific mitigation
- VOC vapor membrane
- Passive venting (with or without VOC membrane) – full/partial
- Active system (with or without VOC VI membrane) – full/partial

Below the water table

- Mitigation via garage design – no additional VI-specific mitigation
- Waterproofing membrane with VOC-specific resistivity
- Ventilation of an underdrain system

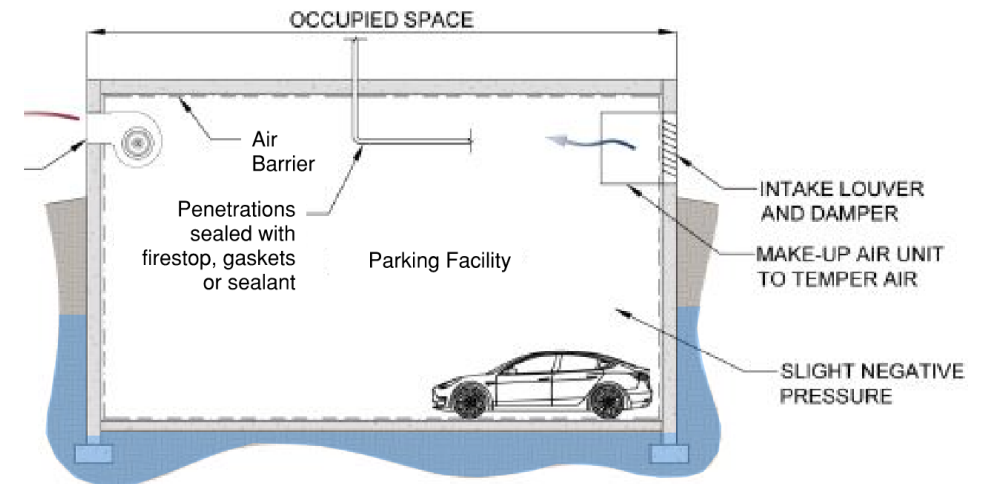
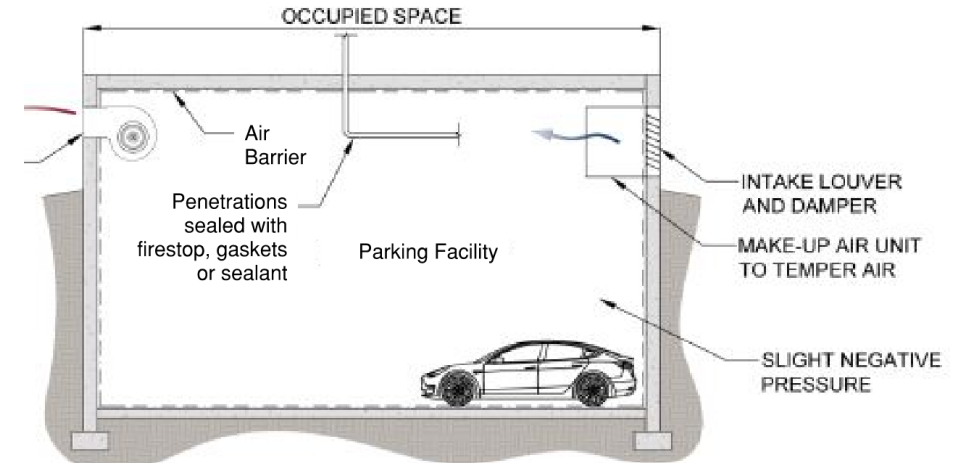


Figure Modified from MPCA Parking Facilities and Vapor Intrusion Mitigation

Closing thoughts

- Potential for VI is greatly reduced by building designs that incorporate parking garages
- Understanding why this works is important:
 - To confirm it will work with your site's conditions and your site's parking garage operation plans
 - To address areas that may need additional consideration (e.g., elevator banks, stairs, parking attendant offices)
 - To provide documentation to stakeholders
- More empirical data would be interesting!



References

- California Department of Toxic Substances Control – Vapor Intrusion Mitigation Advisory (October 2011)
- Minnesota Pollution Control Agency – Parking Facilities and VI Mitigation: Design and Operation Considerations for Parking Facilities as VI Mitigation Options (February 2019)
- San Francisco Bay Regional Water Quality Control Board – VI Mitigation Guidance (June 2022)
 - Section 2C Mitigation by Building Design and Function
- Wisconsin Dept. of Natural Resources – VI Guidance
 - Table 8F, Appendix C
- Local/International building codes – ex. 2021 International Mechanical Code Section 404
- Reduction of Environmental Tobacco Smoke Transfer in Minnesota Multifamily Buildings Using Air Sealing and Ventilation Treatments. Center for Energy and the Environment. November 2004.



Questions?

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