Vapor Intrusion and Groundwater Contamination Sensor Needs

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Presented to the 2018 IEEE International Conference workshop on Wireless for Space and Extreme Environments bringing together investigators from the National Aeronautics and Space Administration (NASA), the Canadian Space Agency (CSA), the European Space Agency (ESA), and other space agencies, along with aerospace and space defense industries and academic researchers, in an effort to understand and solve the emerging problems facing wireless sensing and communication in space and related extreme environments in association with the Marshall Space Flight Center, Huntsville, Alabama

Abstract

Vapor Intrusion and Groundwater Sensor Needs

Vapor intrusion is an urgent EPA human health concern where low-level, potentially carcinogenic, contaminants migrate through soil and into occupied buildings. Mitigation involves depressurizing beneath the basement floor to prevent vapors from entering the building. Economical sensors are needed to monitor pressure differentials between ambient indoor air and sub-slap air. Economical sensors are also needed to detect ambient indoor air containing perchloroethylene (PCE) and trichloroethylene (TCE). Also of interest are benzene, 1,3,5-trimethylbenzene and 2,4,6-trimethylbenzene.

Monitoring of contaminated groundwater is an ongoing EPA health concern. Remote, wireless sensors are needed in permanent monitoring wells. Additionally, investigations cost thousands of dollars to drill temporary soil borings to collect one-time water samples. The borings are sealed per health code requirements the same-day. To significantly increase the benefit of these temporary borings, permanent sensors are needed to be inserted into the borings prior to sealing to continuously detect contaminants; and to a lesser extent, to detect groundwater flow direction, groundwater elevation, ph, and / or temperature. Primary contaminants of concern are benzene, perchloroethylene (PCE) and trichloroethylene (TCE). Sensors need to be able to withstand vehicular traffic running over the sealed borings.

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Groundwater Contamination

Sensor Needs

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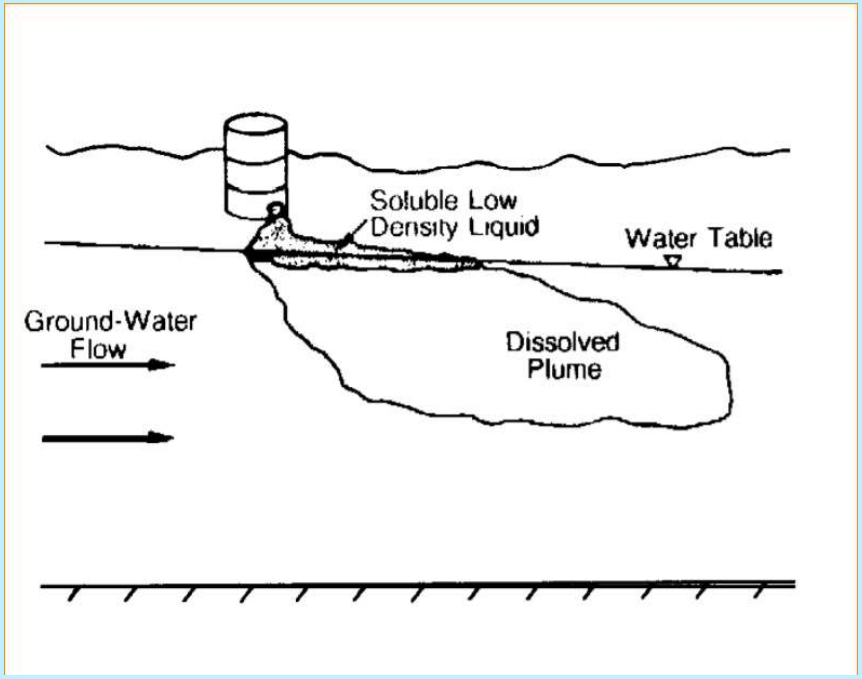
Groundwater Contamination

Groundwater aquifers are typically sandy soil formations saturated with water.

Groundwater flows horizontally generally following topography.

Petroleum or solvents are the most common types of contaminants.



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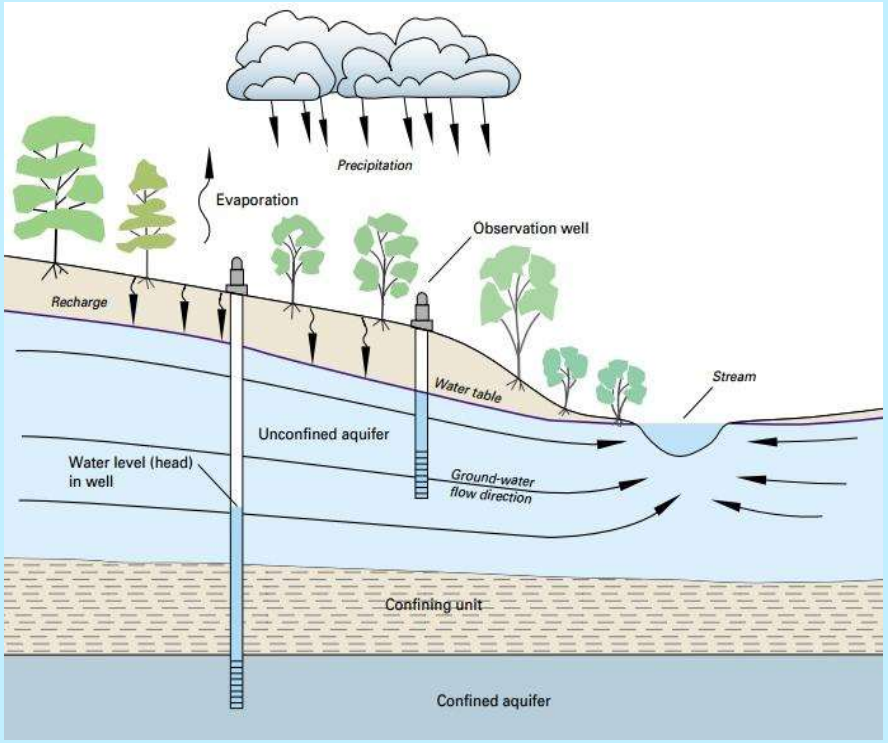
Groundwater Dynamics

Have been studied and understood since the 1800's

Monitoring wells are used to gather data

Monitoring wells assess contamination trends



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Monitoring Wells

At-Grade
Monitoring Well

Above-Grade
Monitoring Well

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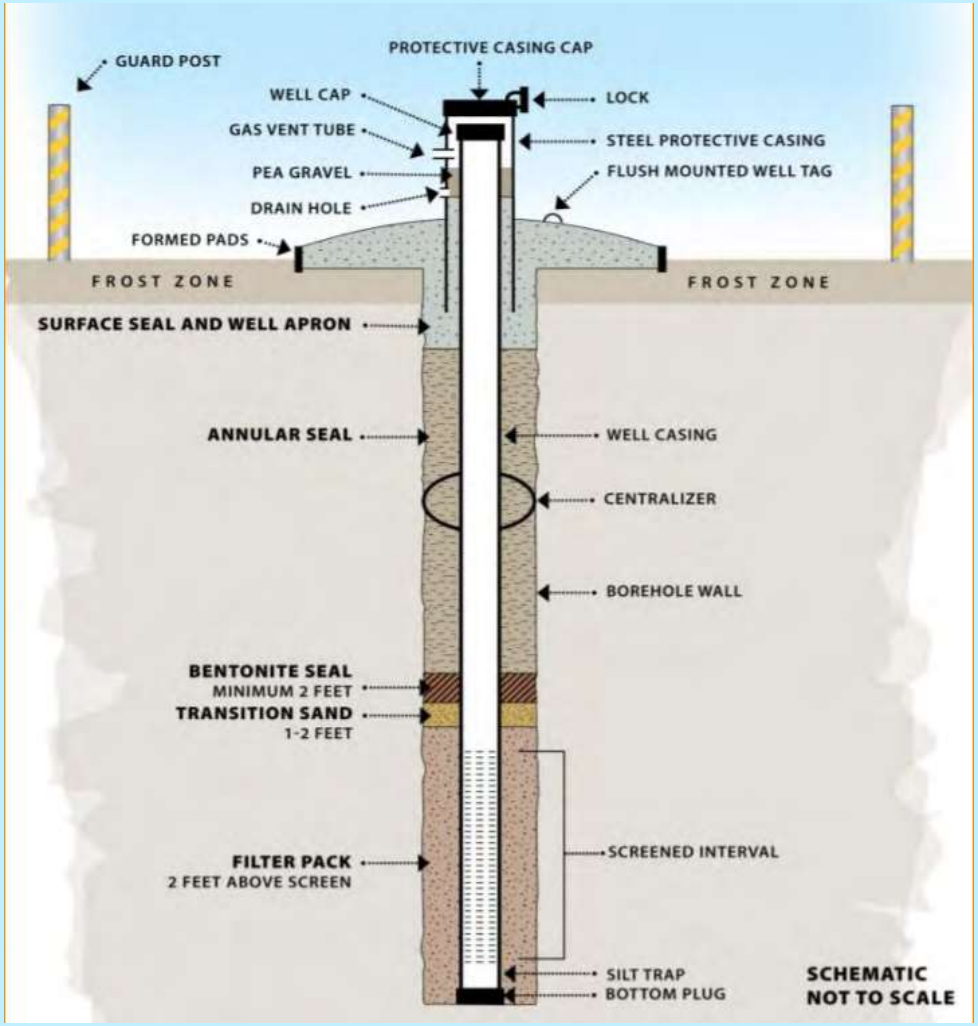
Typical Monitoring Well



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Monitoring Well Equipment

Water Samples are needed for:

- Analysis of volatile organic compounds
* Groundwater Elevation
* Temperature
* pH
* Reduction / Oxidation Potential
* Conductivity
* Dissolved Oxygen

* Sensors for these items exist

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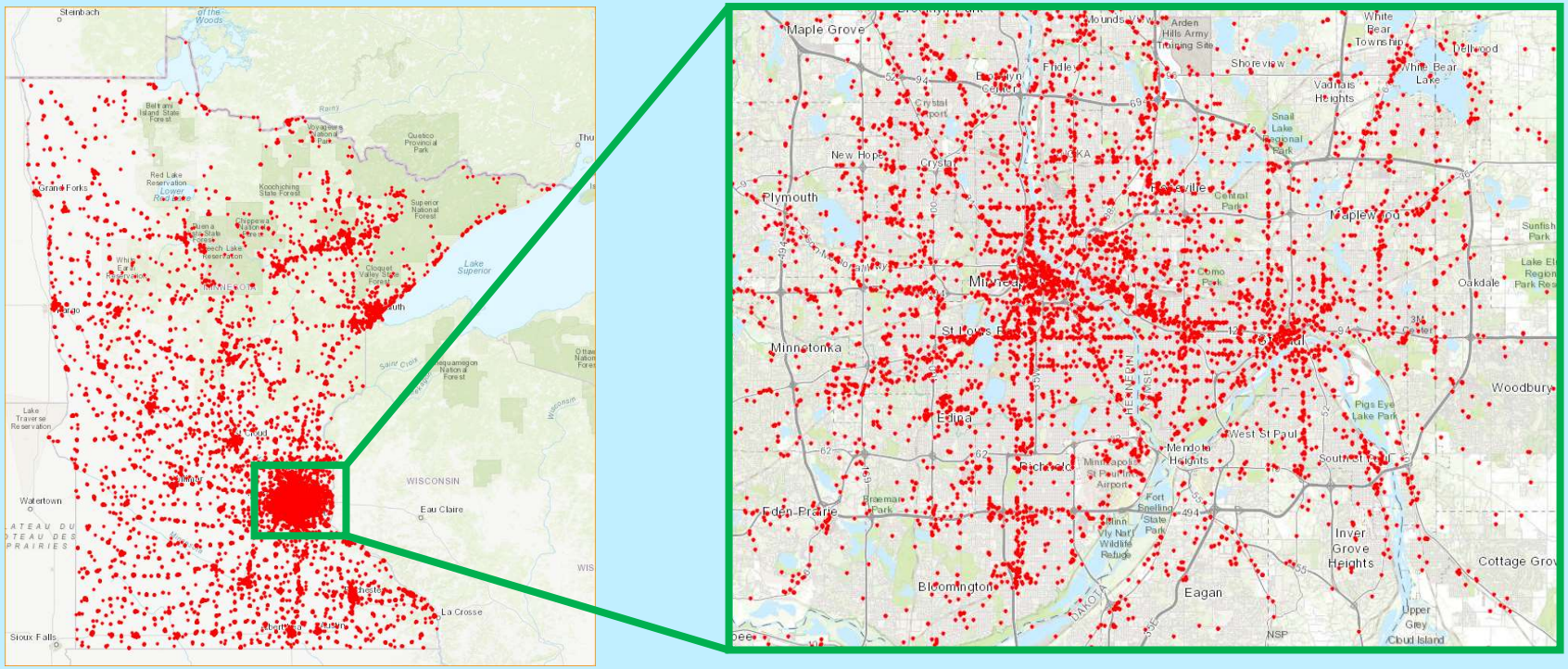
Minnesota Leaking Tank Sites
20,000 +



Travel Time and to all these sites is Expensive.
Remote, Wireless Sensing makes Sense!

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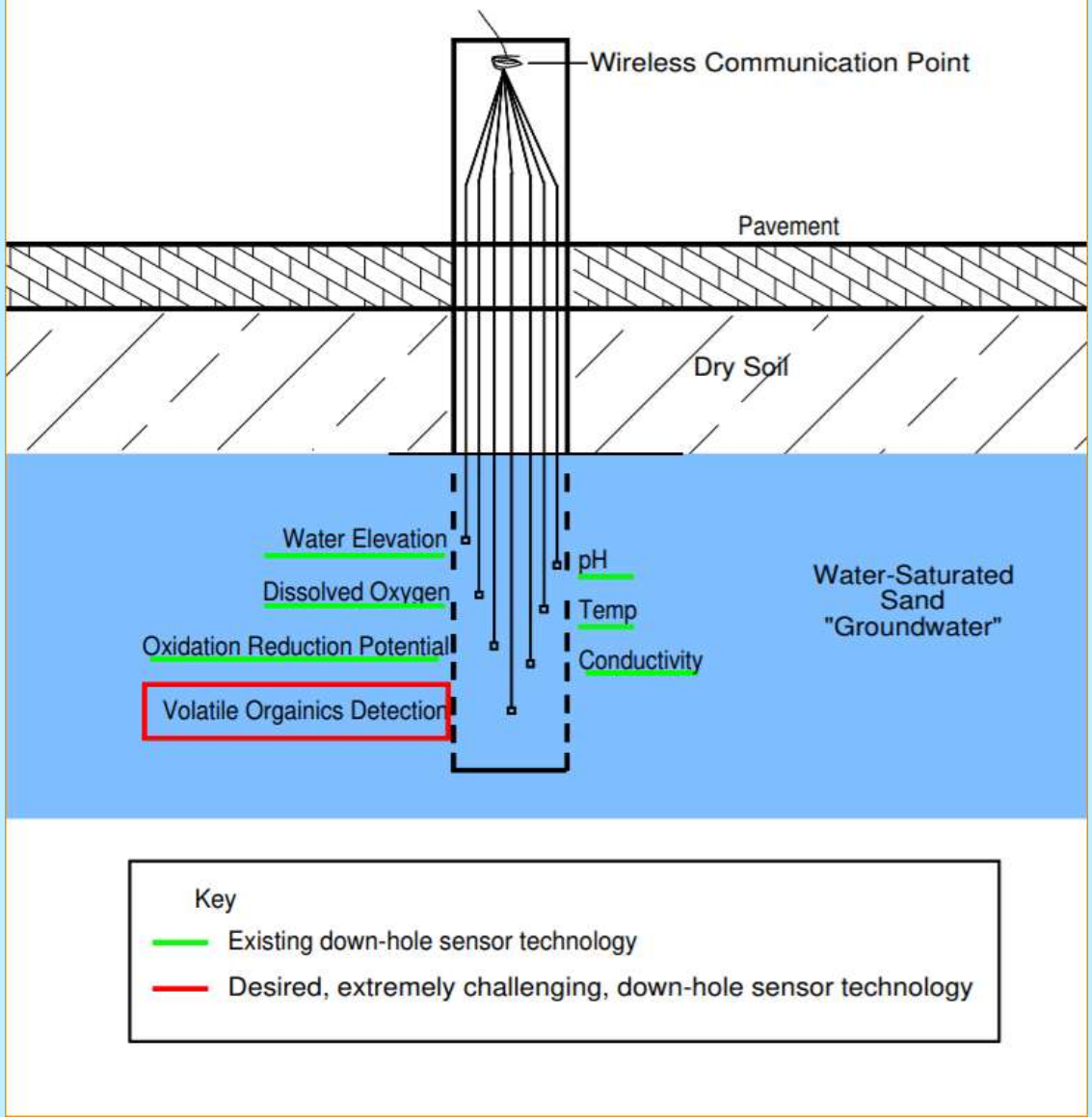
Desired Sensors
Above-Grade Monitoring Well
Schematic



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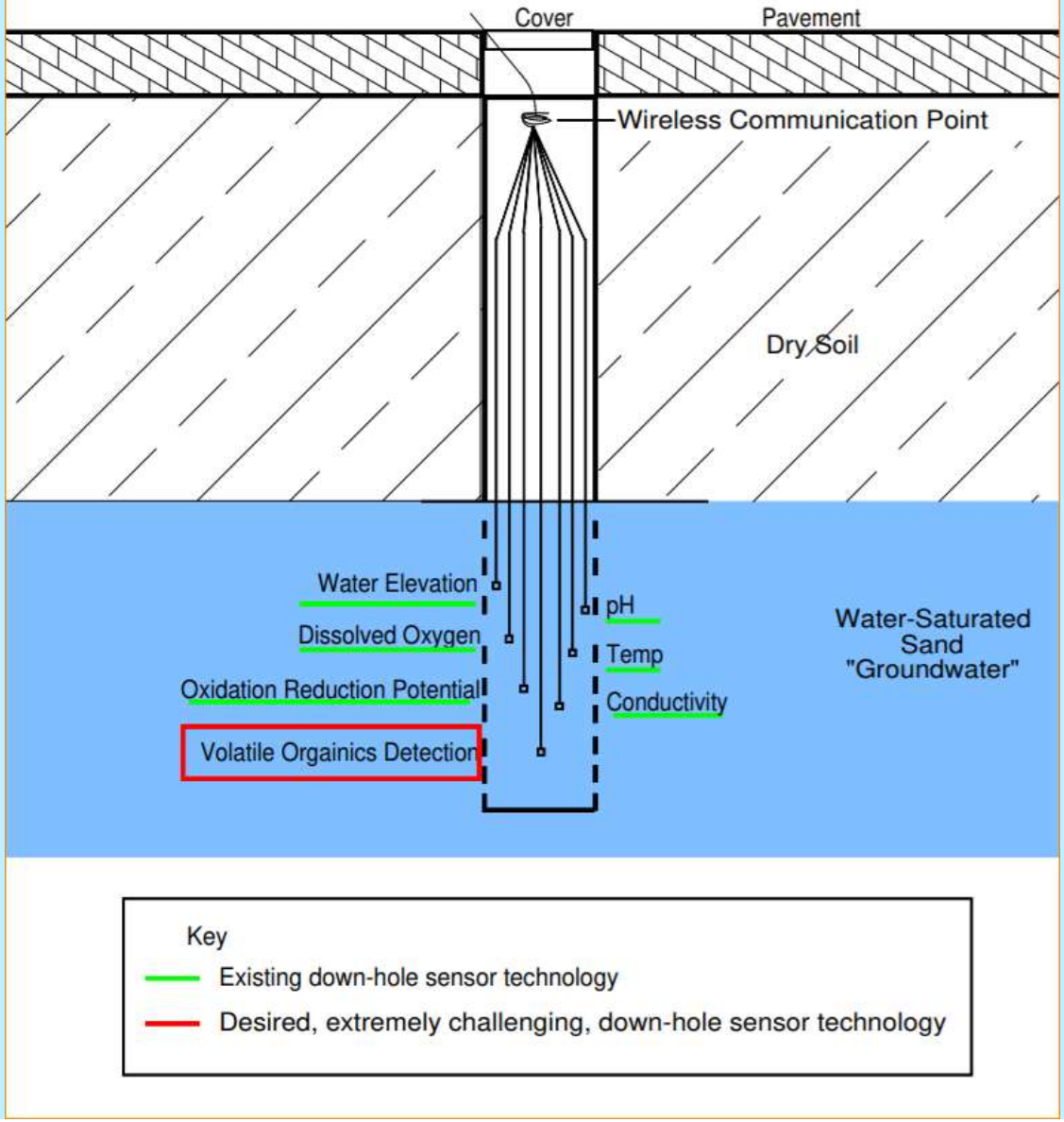
Desired Sensors
At-Grade / Geoprobe Monitoring Well
Schematic



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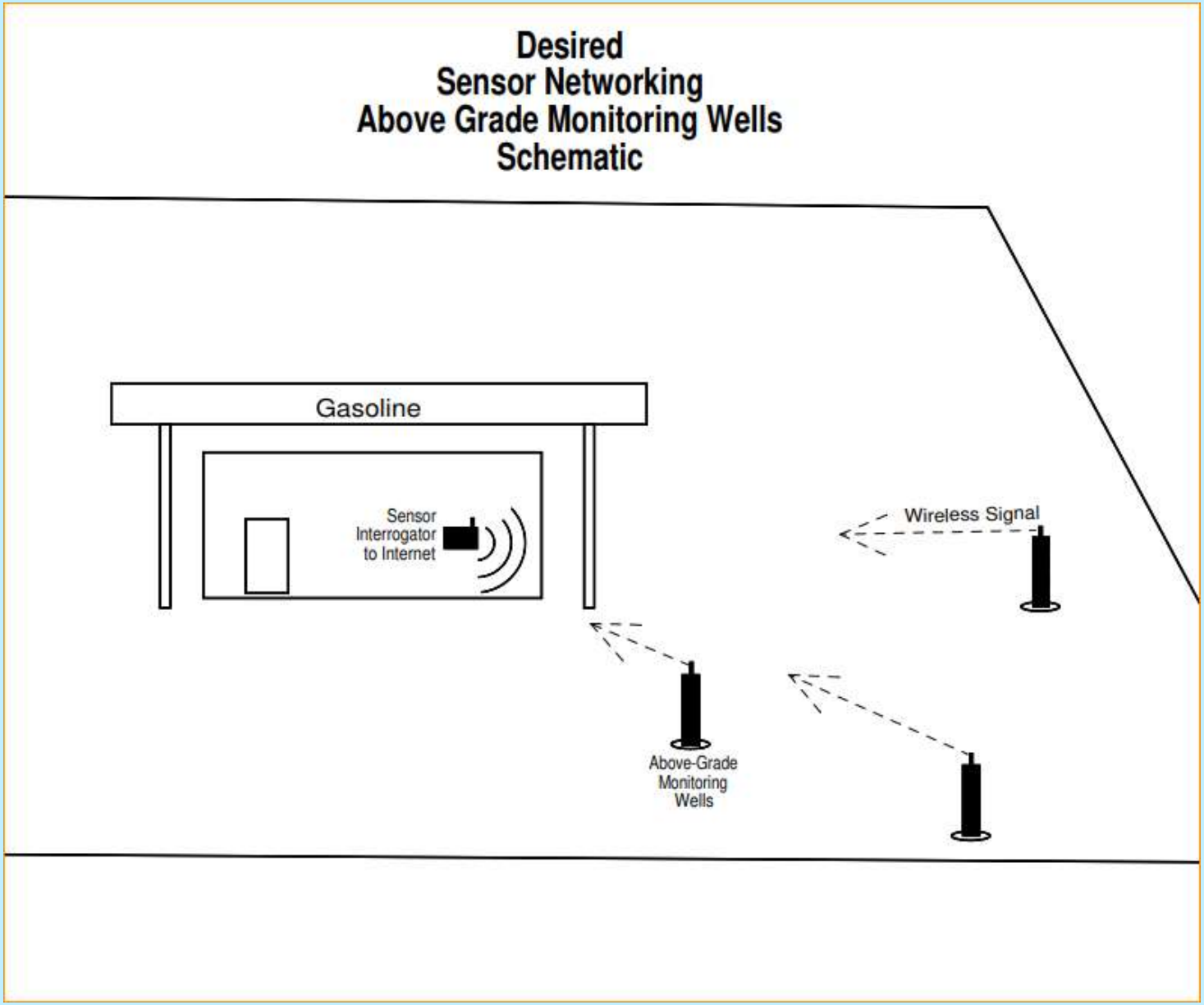
Desired Sensor Networking Above Grade Monitoring Wells Schematic



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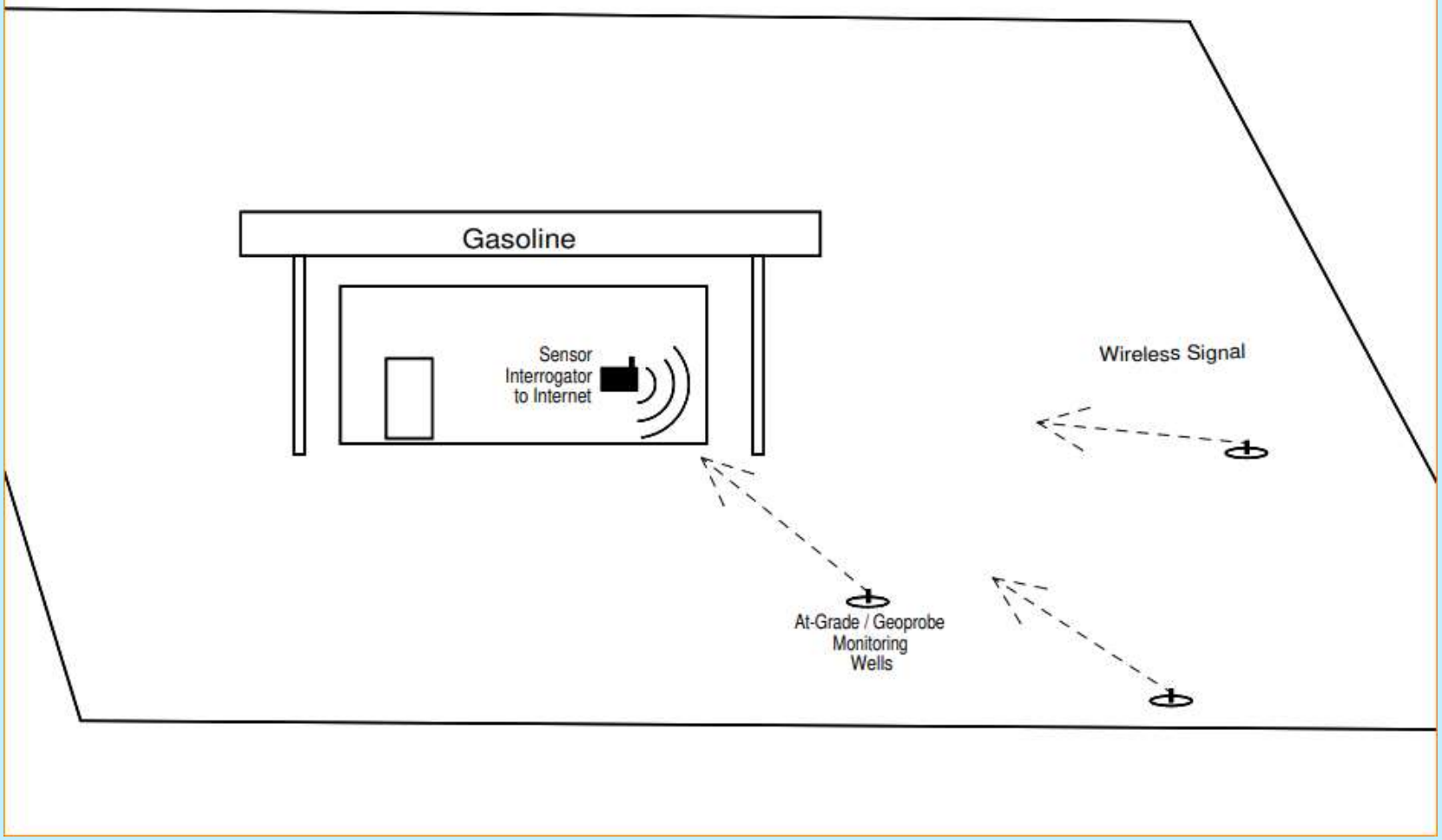
Desired
Sensor Networking
At-Grade / Geoprobe Monitoring Wells
Schematic



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Specific Needs:

GROUNDWATER MONITORING

Aqueous Chemical Sensors in Monitoring Wells

Submerged in water; daily sample rate; range approx. 100 feet; resolution +/- 5%

- Benzene 3 ug/L
- Tetrachloroethylene (PERC or PCE) 4 ug/L
- Trichloroethylene (TCE) 0.4 ug/L
- When able: Volatile Organic Compound list (60+ chemicals)

Wireless Connectivity

Wirelessly Connect data from monitoring wells to internet

- Chemical Analyses
- Groundwater Elevation
- Temperature
- pH
- Reduction / Oxidation Potential
- Conductivity
- Dissolved Oxygen

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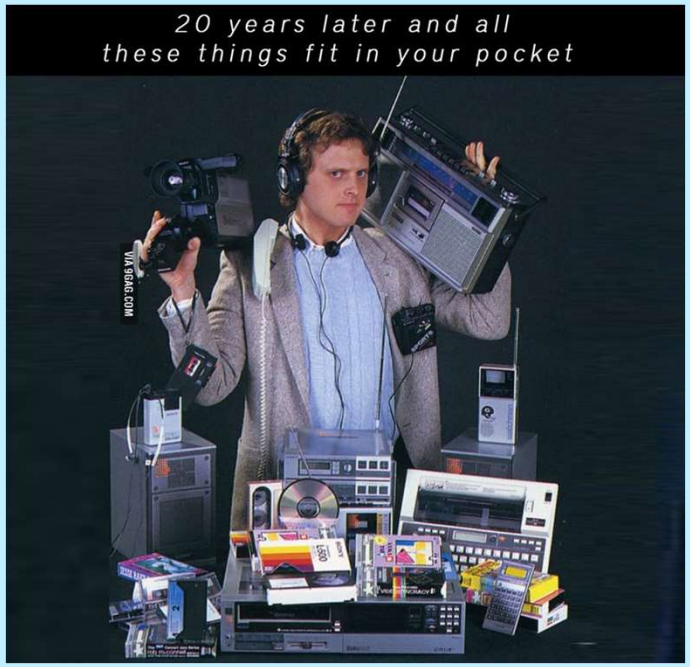

Replaced with:

To be Replaced with:

??

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Vapor Intrusion

Sensor Needs

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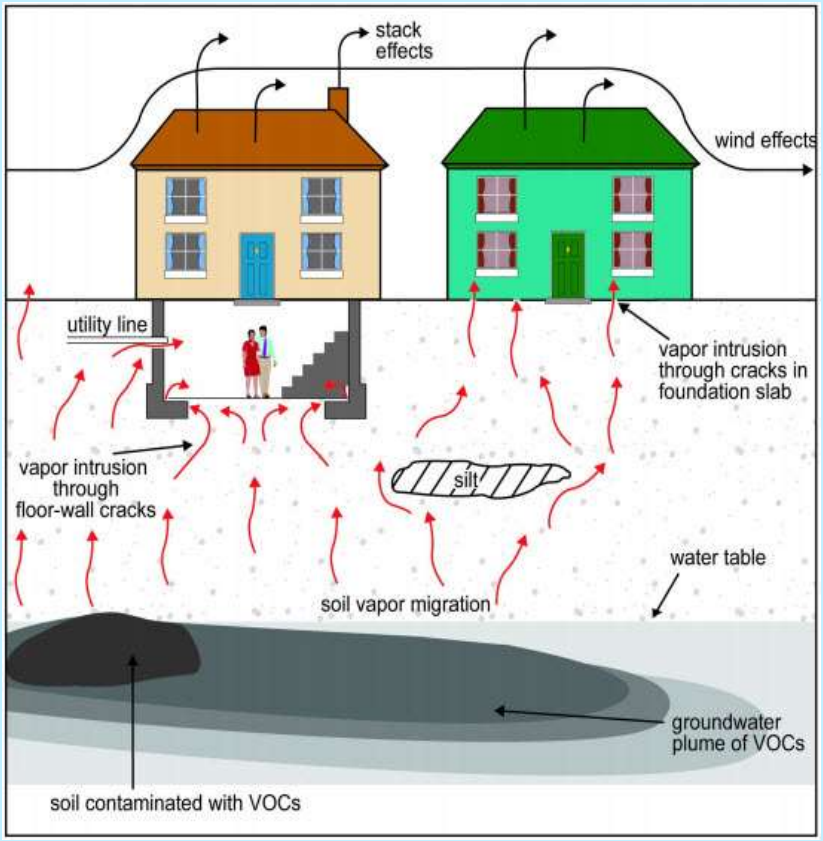
Vapor Intrusion is Relatively New and an EPA Hot Issue

Vapor Intrusion

Vapor intrusion occurs when vapor-forming chemicals migrate from a subsurface source into an overlying building -- similar to radon gas seeping into homes.

Hazardous Cleaning solvents were cheap and everywhere

Vapors are drawn into lower-pressure buildings



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Best Management Practices for Vapor Intrusion

"Continuing adjustments on a Pathway that Continues to Emerge"

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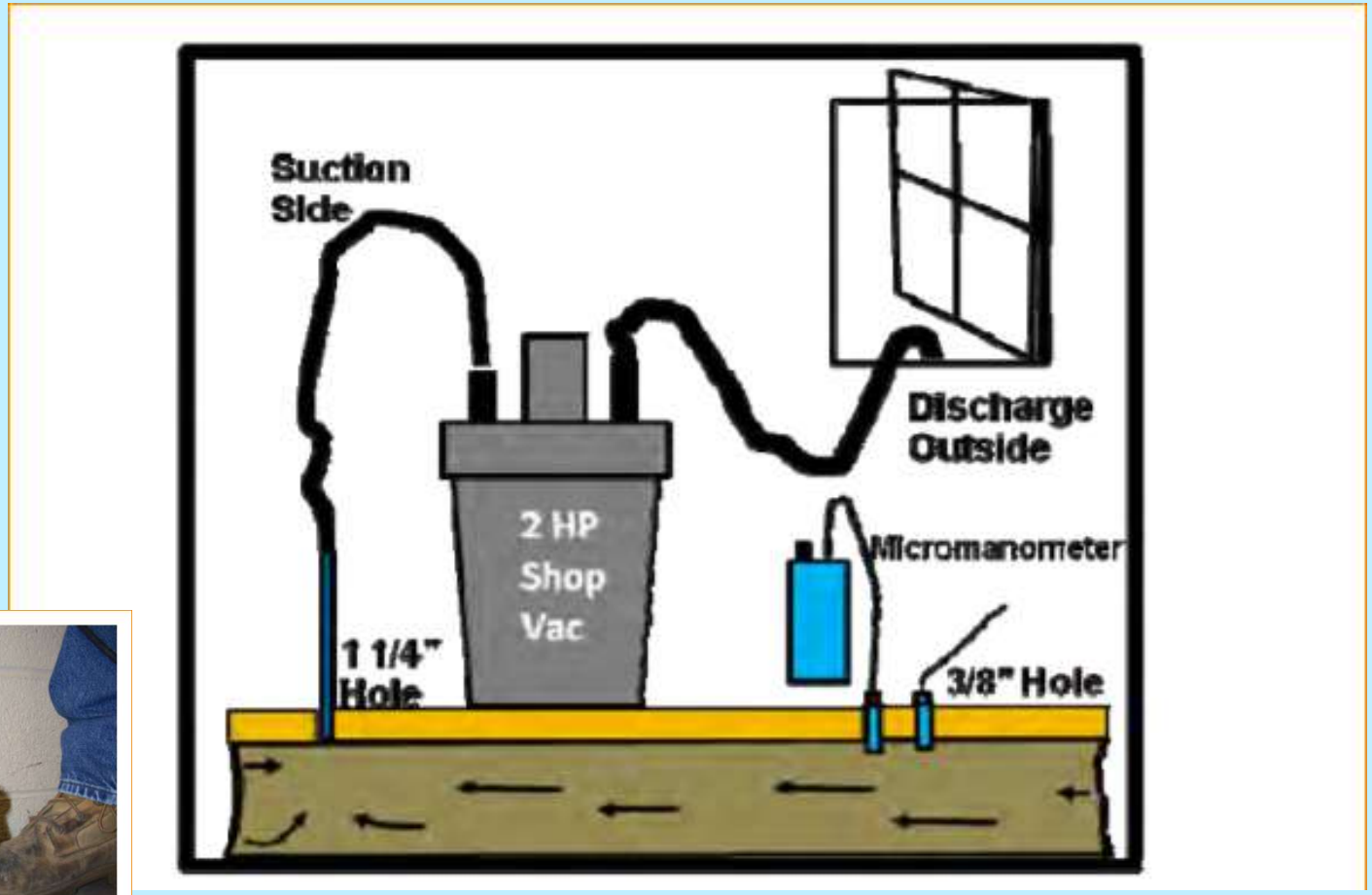
For residential homes, sub-slab depressurization mitigation works well.
Pilot testing is required to ensure sub-slab air flow.
Schematic air flow communication test shown below:



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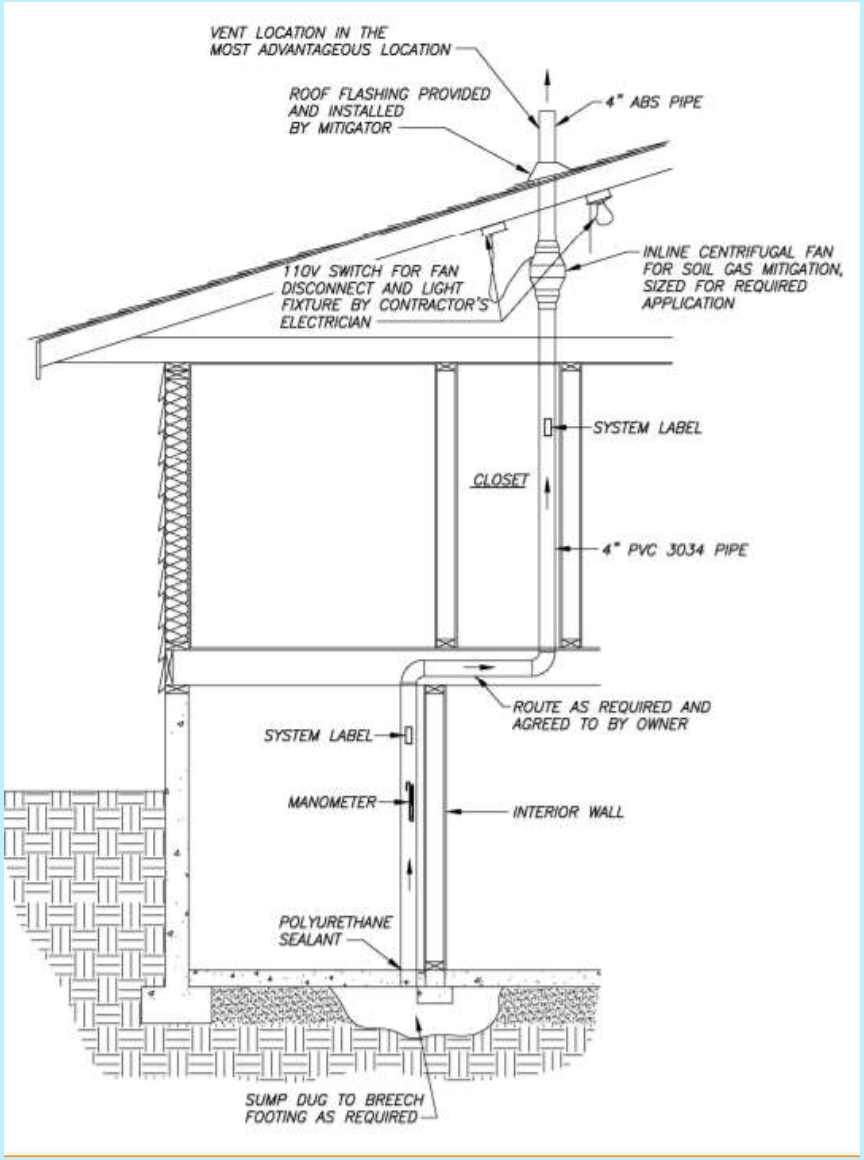
Vapor Intrusion followed same mitigation standards as those for Radon:

- Seal Floor Cracks
- Sub-slab depressurization



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For existing larger commercial buildings, Sub-slab depressurization becomes more complicated Pilot Test Results Below:

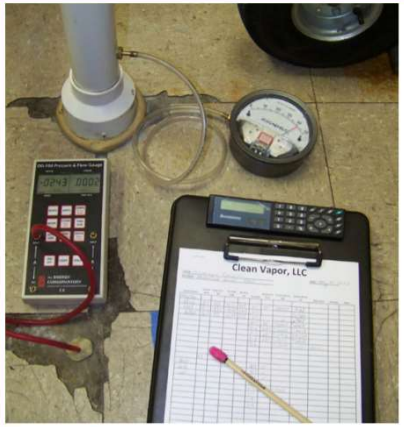
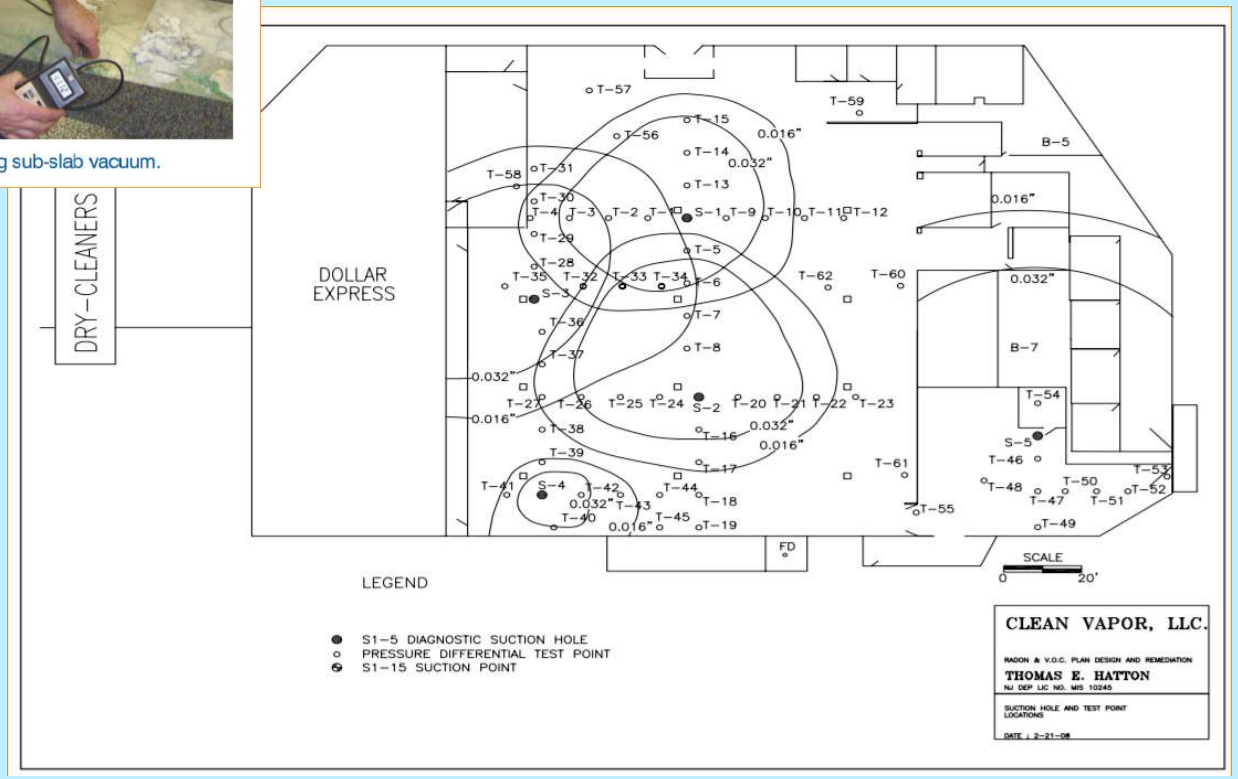


Figure 4. Static vacuum test.

Figure 5. Measuring sub-slab vacuum.



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Resulting Design Below:

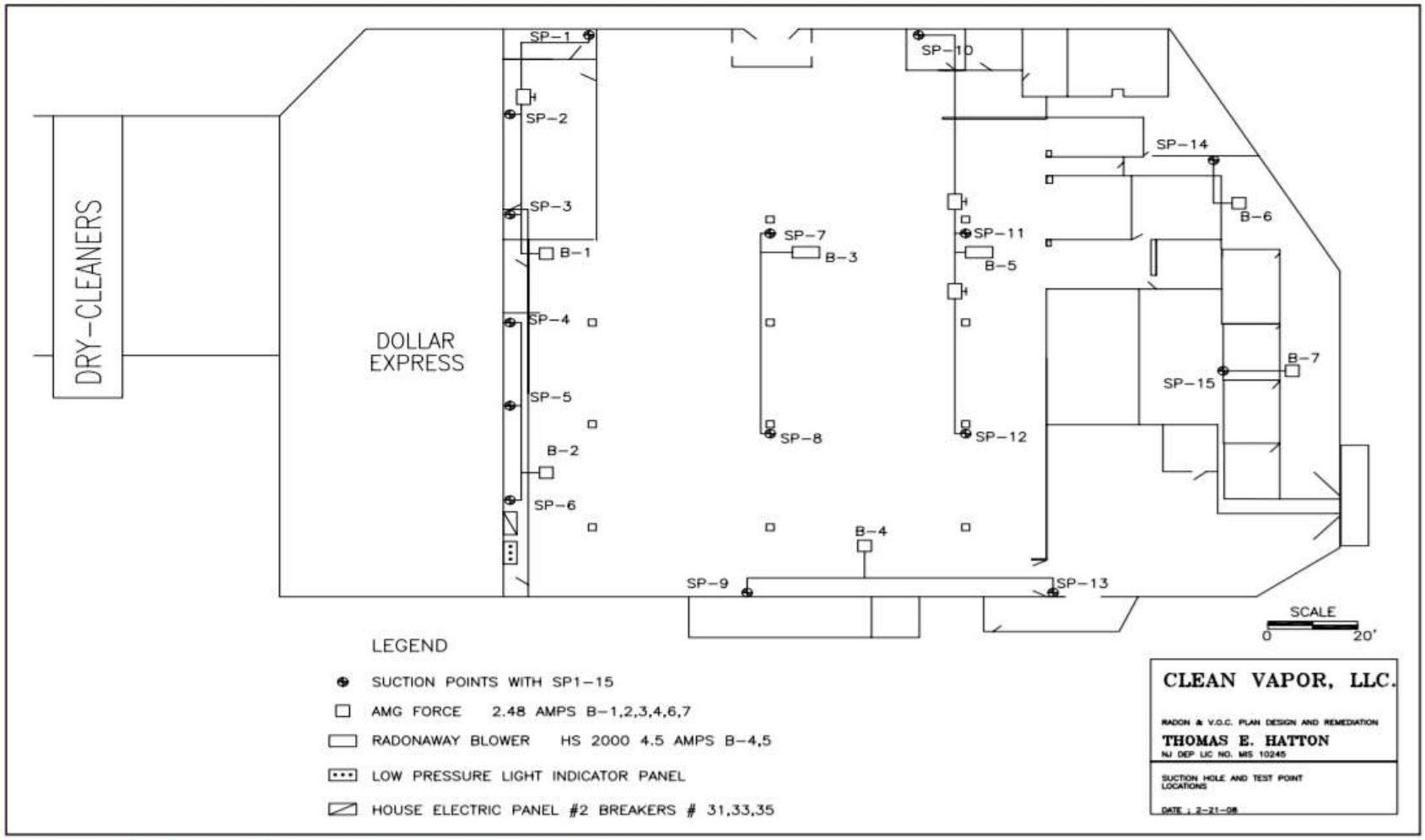

Figure 11. Blower and suction point design.

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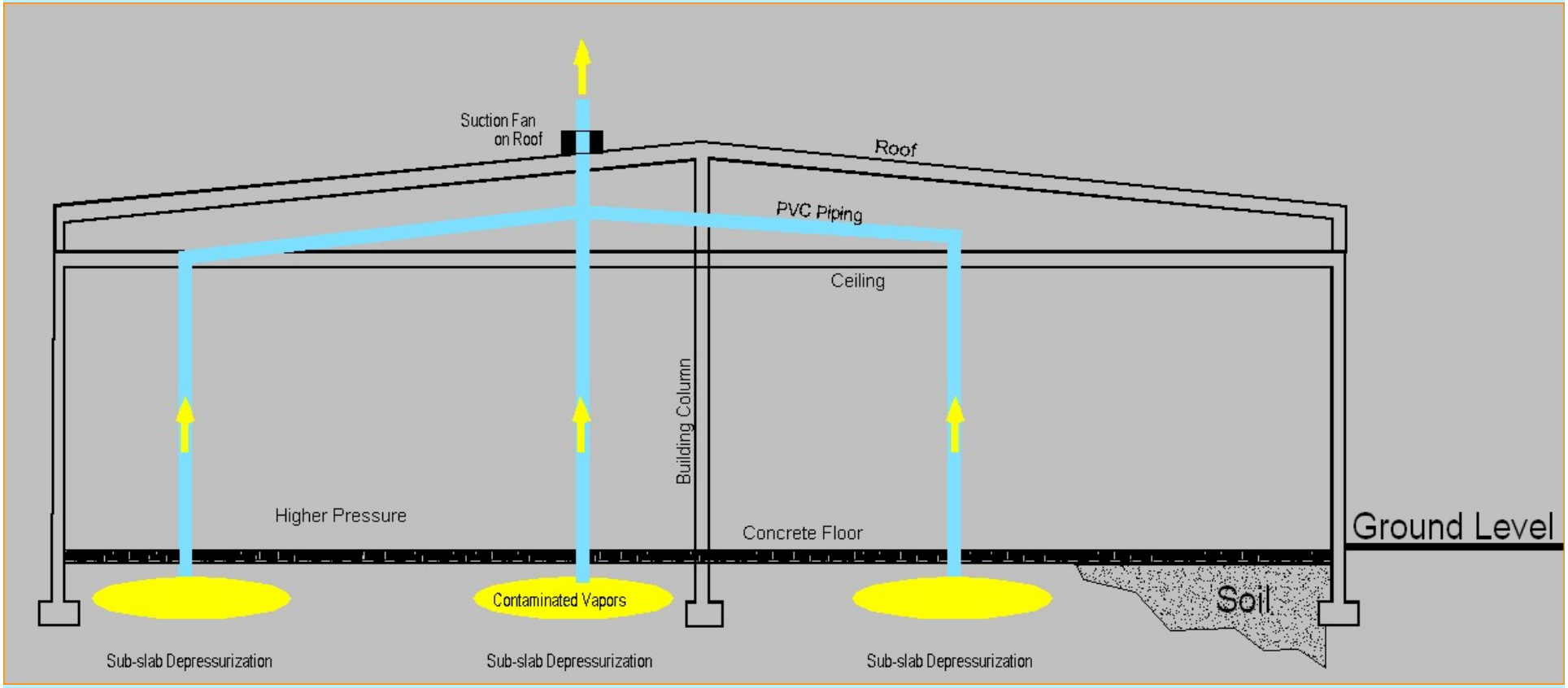
Existing Building or New Building Schematic
Current Practice
Sub-slab Depressurization System



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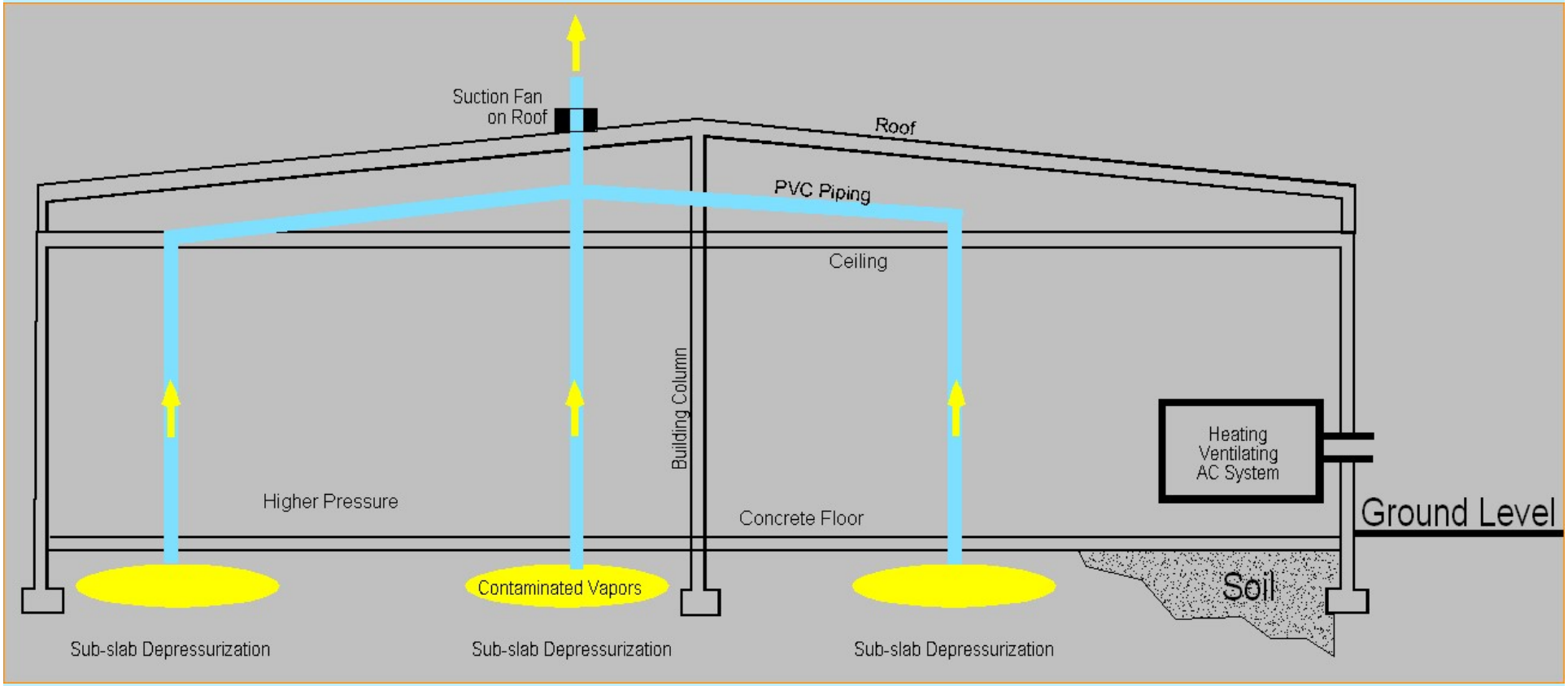
Existing Building or New Building Schematic
Current Practice
Sub-slab Depressurization System
Showing HVAC System



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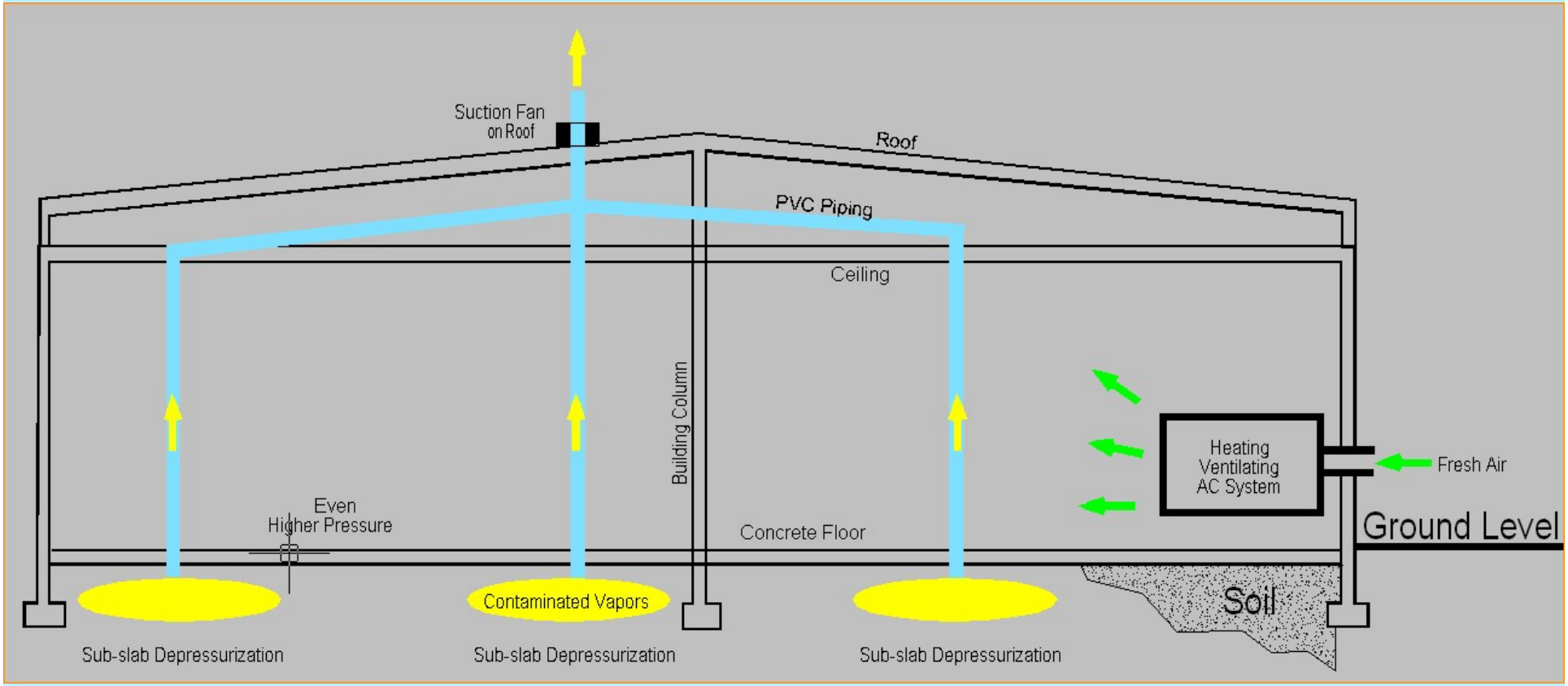
Existing Building or New Building Schematic
Current Practice
Sub-slab Depressurization System
Showing HVAC System On



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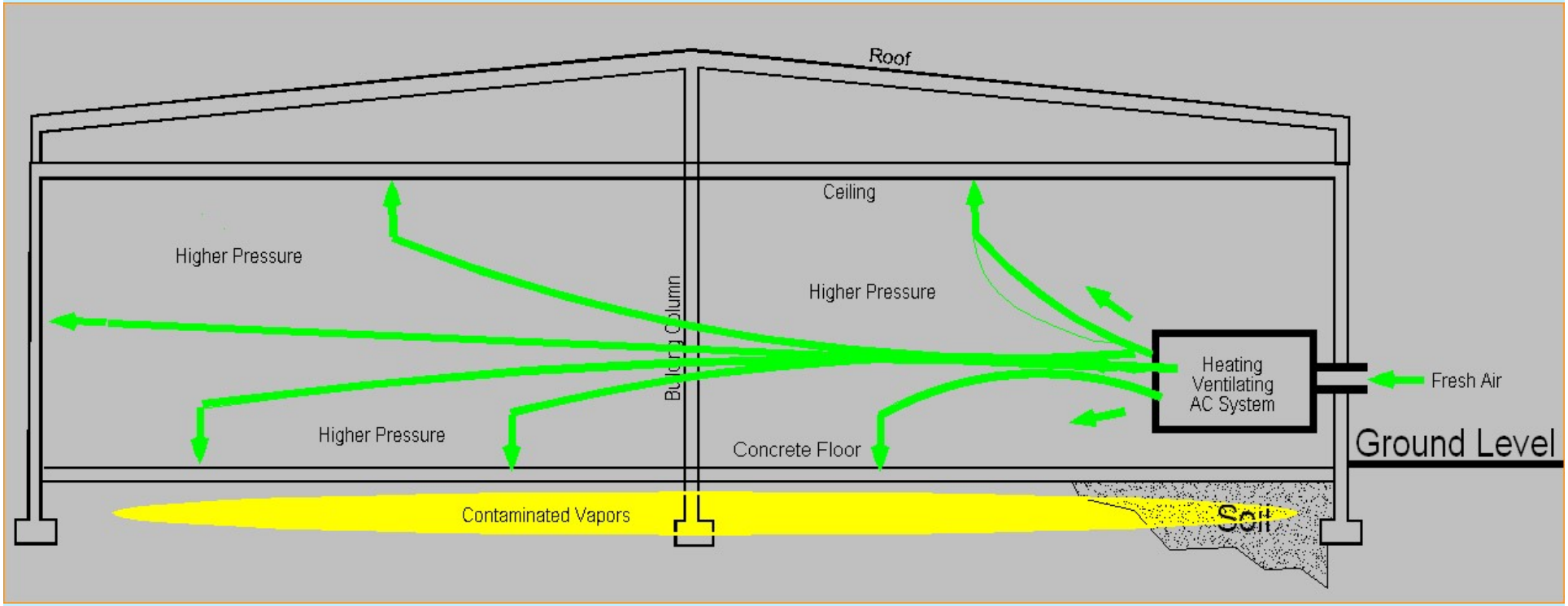
Alternate?
Showing HVAC System On
(keep windows closed!)



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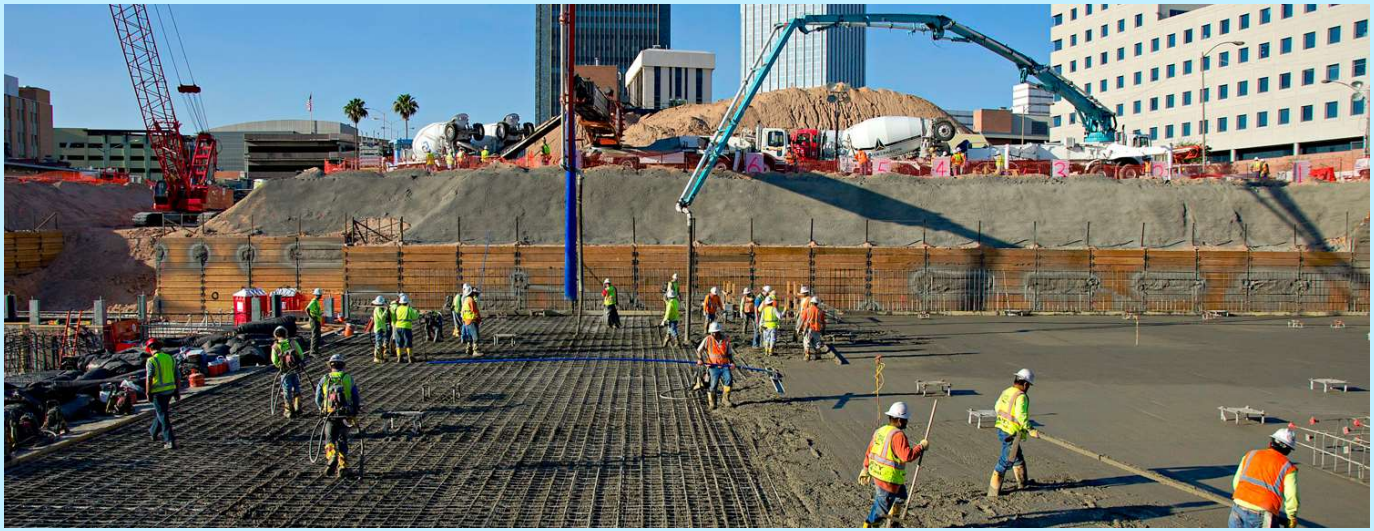
Sub-Slab Depressurization becomes more Complicated on Larger Footprint Buildings



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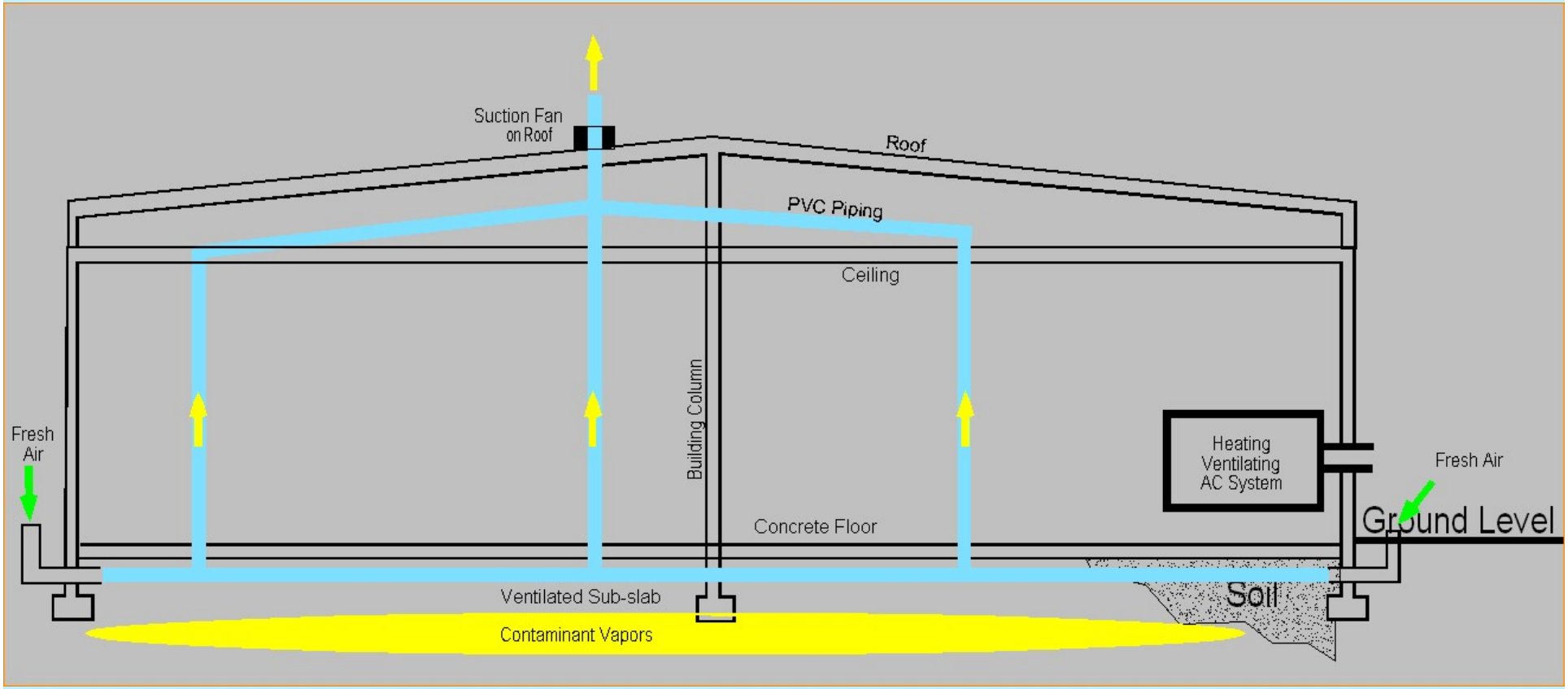
New Building
Alternate-1
Sub-Slab VENTILATION System



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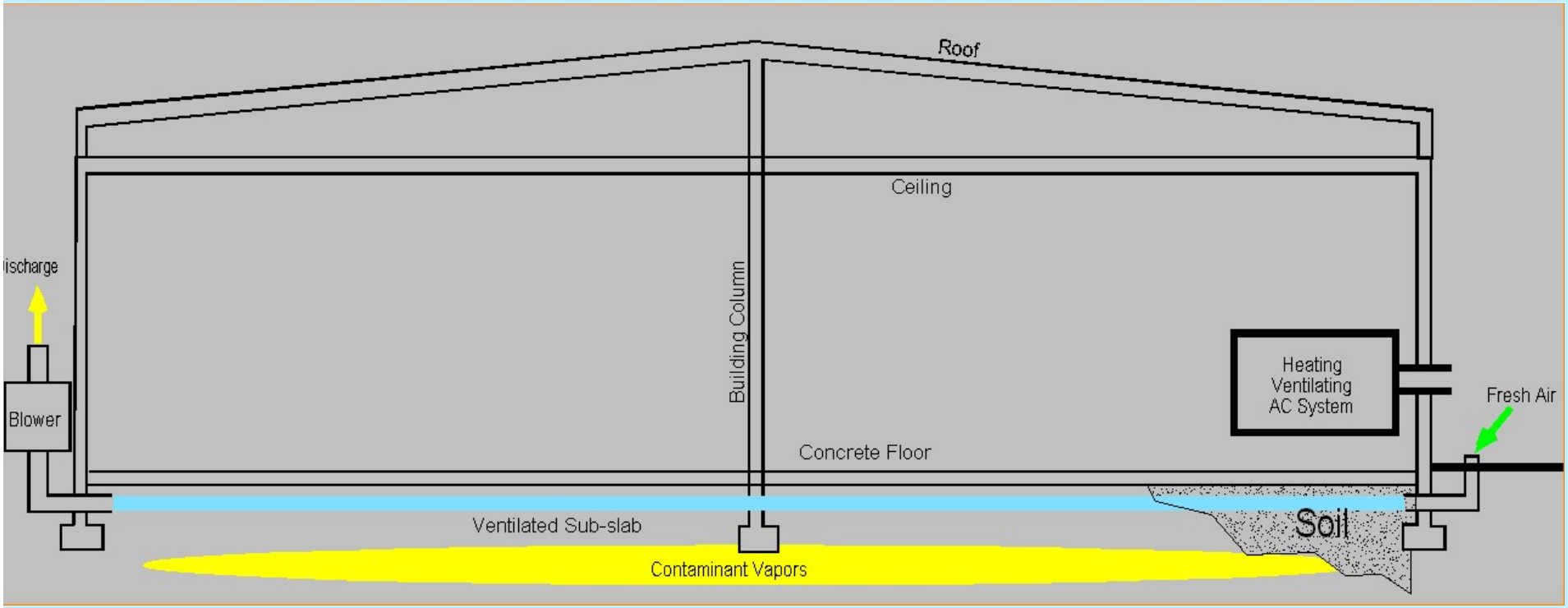
New Building
Alternate-2
Sub-Slab VENTILATION System



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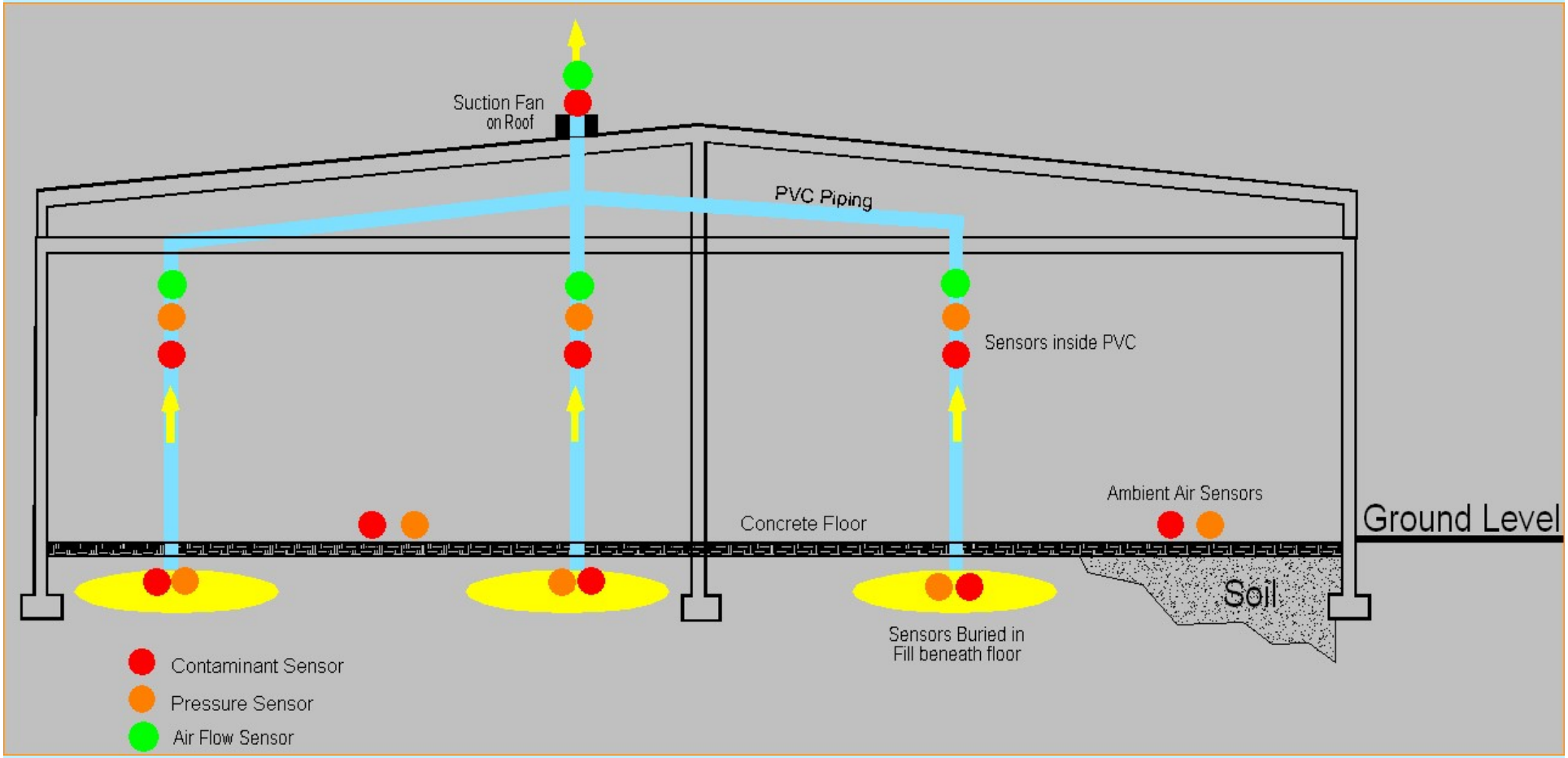
Vapor Intrusion
Where Can We Use Sensors?

In EXISTING, NEW, MITIGATED and NON-MITIGATED buildings
Install with minimal damage (i.e., minimize holes in the floor)



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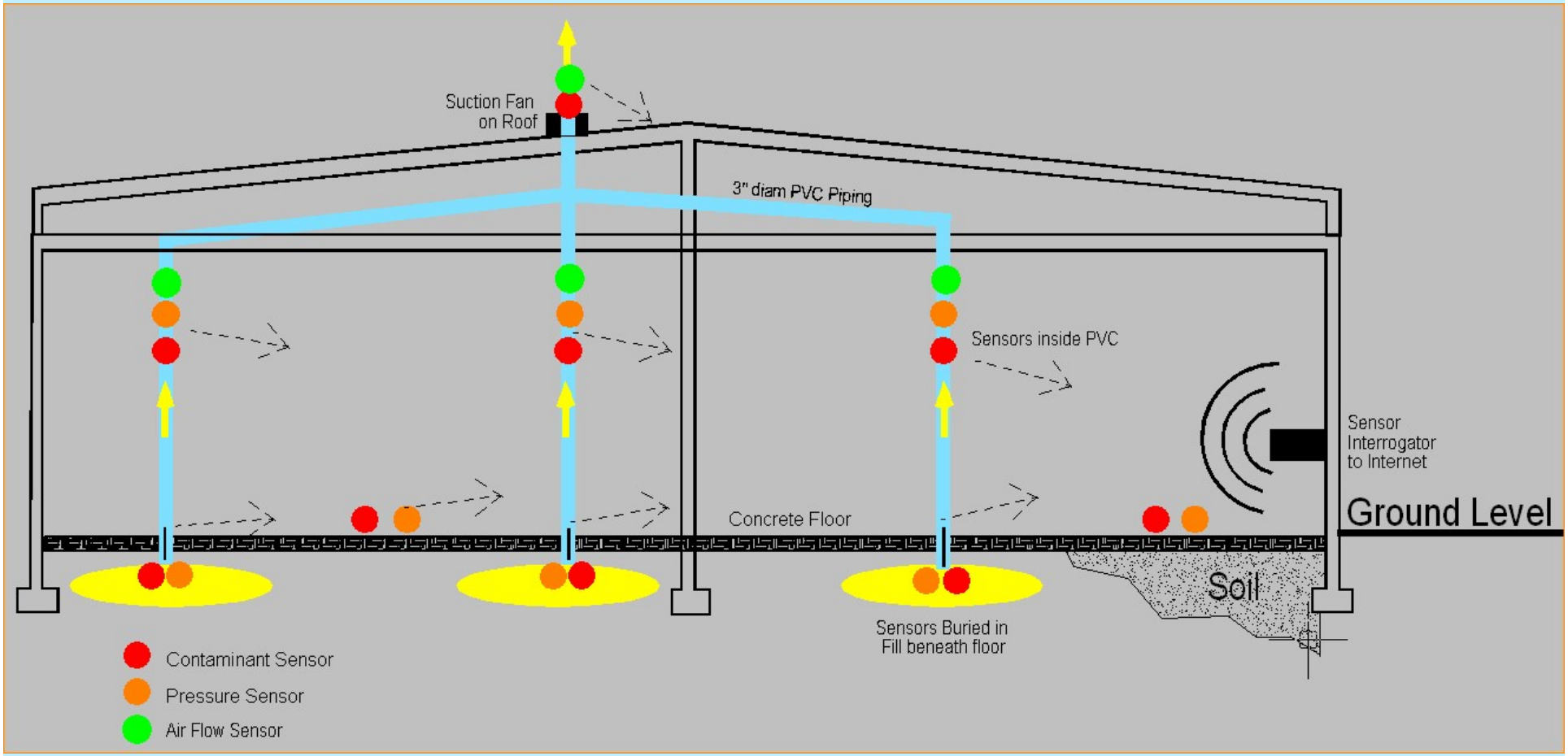
Desired Sensor Networking Schematic



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Specific Needs:

VAPOR INTRUSION

Vapor Chemical Sensors

Common atmospheric pressures; daily sample rate; range approx. 100 feet; resolution +/- 5%

- TCE (trichloroethylene) 2.1 ug/m3
- PCE (perchloroethylene) 3.4 ug/m3
- Benzene 4.6 ug/m3
- of lesser urgency, 1,2,4 Trimethylbenzene 63 ug/m3
- of lesser urgency, 1,3,5 Trimethylbenzene 63 ug/m3
- When able: Volatile Organic Compound list (60+ chemicals)

Air Sensors

Common atmospheric pressures; daily sample rate; range approx. 100 feet; resolution +/- 5%; rugged enough to be placed below a floor slab; compact enough to fit through a 1" hole drilled into an existing concrete slab

- Pressure Sensor, +/- 0.25 pascals
- Air flow Sensor, 10-100 cfm

Wireless Connectivity

- Wirelessly Connect vapor data from inside a building to internet

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Other Needs

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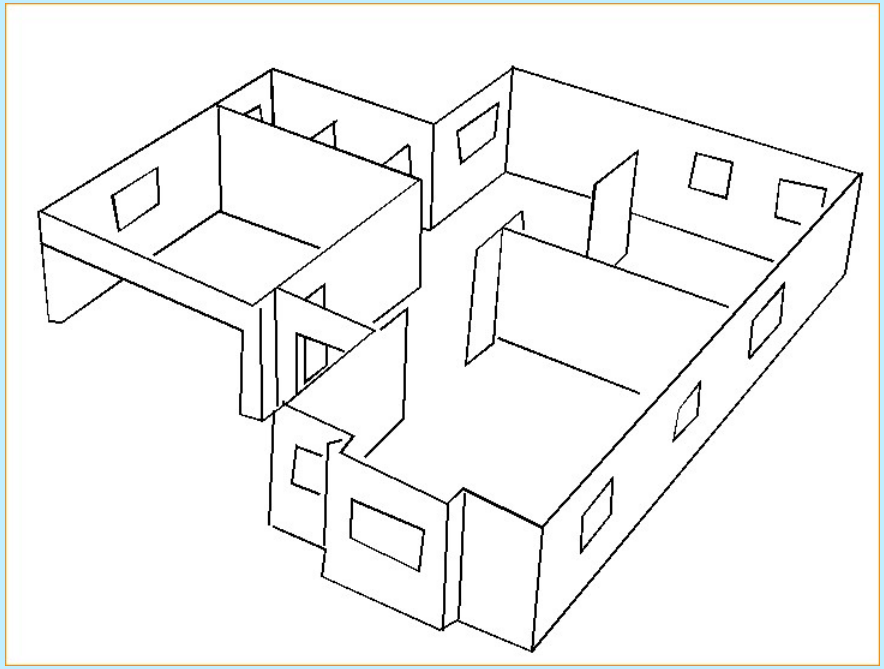
Sensors Needed to Locate Walls to create Computer Aided Drawing



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Research Needed!

University /Other
Vapor Intrusion Research Topics:

- Pressure Flow Dynamics Beneath Buildings
- Chemical Vapor Flow Dynamics Beneath Buildings
- Pressure Interactions of Mitigation System with HVAC System
- Contaminant dynamics over time beneath buildings
- Air and contaminant movement with different soil types and moisture
- Assess the number of sub-slab vapor and pressure sensors required to accurately characterize vapor dynamics
- Many more studies needed…

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Thank you for attending

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