Introduction

Radon Control in Schools

Key Messages

1. Effective radon control depends on understanding of radon entry mechanisms
2. More than 25 years of experience of successfully:
   A. Reducing radon in schools
      1) Facility managers are a key team member
      2) Thorough diagnostics saves money
      3) Consultants and contractors need to be trained, and eventually certified, for school building mitigation
   B. Preventing radon problems in new schools is straight forward
3. National standards offer essential guidance

Radon Concentrations in U.S. Schools (EPA, 1993 *National School Radon Survey*, Washington, DC: U.S. EPA)

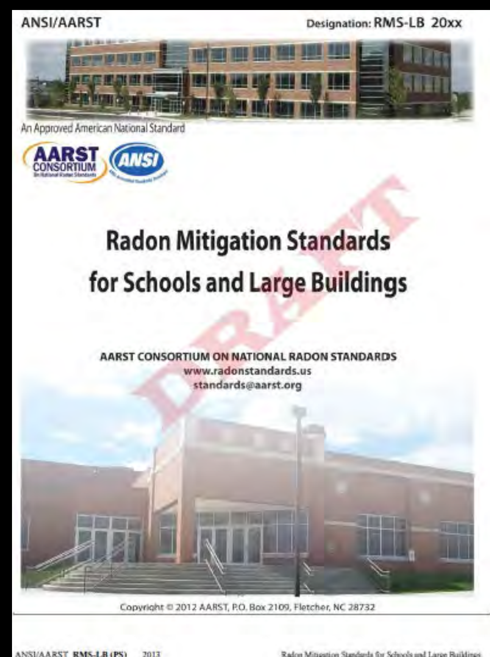
Radon Concentration	Ground Contacted Classrooms	EPA Radon Potential Zone	Percent of Classrooms ≥ 4 pCi/L	Ground Contacted Classrooms ≥ 4 pCi/L	Percent Schools ≥ 4 pCi/L
0-2 pCi/L	***91%***	***High***	***6.8%***	***None***	***80.7%***
2-4 pCi/L	6.3%	Medium	2.7%	**1 or 2**	**9.9%**
4+ pCi/L	**2.7%**	Low	0.8	**3 to 5**	**4.2%**
				6 or more	**5.1%**

Radon Mitigation Standards

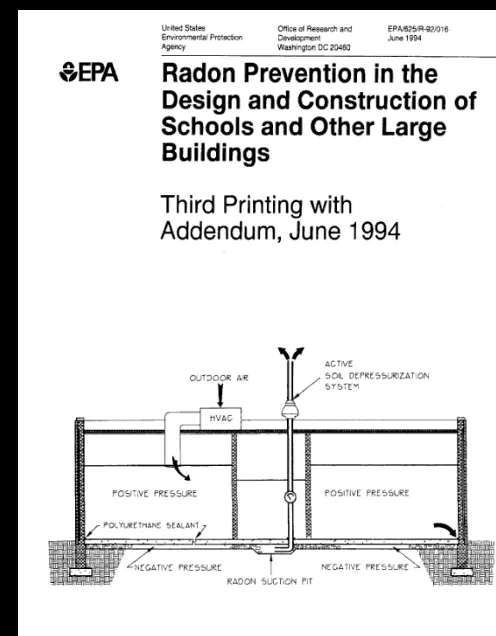
#1. Iowa is a regulatory state

#2. Iowa's regs and rules are influenced by national standards, e.g.

U.S. EPA, 1994



ANSI/AARST, forthcoming



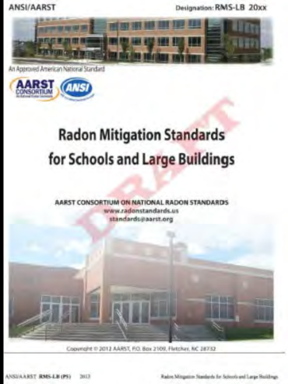
U.S. EPA, 1994

US EPA Reducing Rn in Schools Guidance

1.0 Introduction
2.0 Indoor Environment
3.0 Correcting Rn Problems
4.0 HVAC Restoration
5.0 Retest Radon
6.0 Detailed Investigation
7.0 Design and Implementation of Mitigation
- **7.1 Active Soil Depressurization (ASD)**
- **7.2 Pressurization**
- **7.3 Dilution**

8.0 Post-Mitigation Testing
9.0 Long-Term Radon Management
10.0 Special Considerations

ANSI/AARST Rn Mitigation Standard


ANSI/AARST Designation: RMS-LB 20xx

An Approved American National Standard

AARST CONSORTIUM ANSI

DRAFT

Radon Mitigation Standards
for Schools and Large Buildings

AARST CONSORTIUM ON NATIONAL RADON STANDARDS
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ANSI/AARST RMS-LB (PS) 2012 Radon Mitigation Standards for Schools and Large Buildings

1.0 Scope

2.0 Significance of Use

3.0 Qualified Contractors

4.0 General Practices

5.0 System Design

6.0 Building Investigation

7.0 ASD System Installation

- 7.1 Suction Points
- 7.2 Piping (ducts)
- 7.3 Pipe Sizing
- 7.4 Exhaust Discharge
- 7.5 Fan Installation

8.0 Sealing

9.0 Required for All Systems

- 9.1 OM&M Plan
- 9.2 Fan Monitors
- 9.3 Electrical
- 9.4 Labeling

10.0 Non-ASD Methods

11.0 Post-Mitigation

12.0 Operations, Maintenance and Monitoring Plans

13.0 Health and Safety

Radon Entry

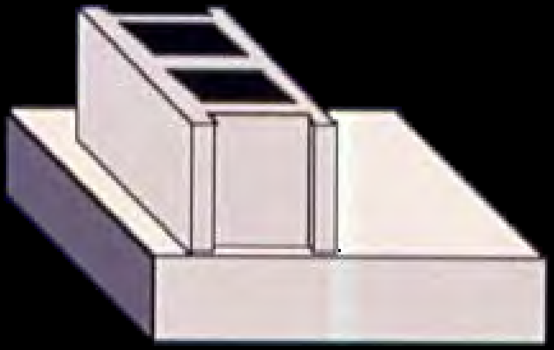
Radon Control in Schools

Three Factors Needed for an Indoor Air Quality Problem

1. **Sources of air contaminants**
   - Radioactive decay of Uranium in underlying rock and soil
2. **Building occupants (the affected persons)**
3. **Transport mechanisms that move the contaminant to and from the occupant**
   - Air pressure differences
   - Pathways

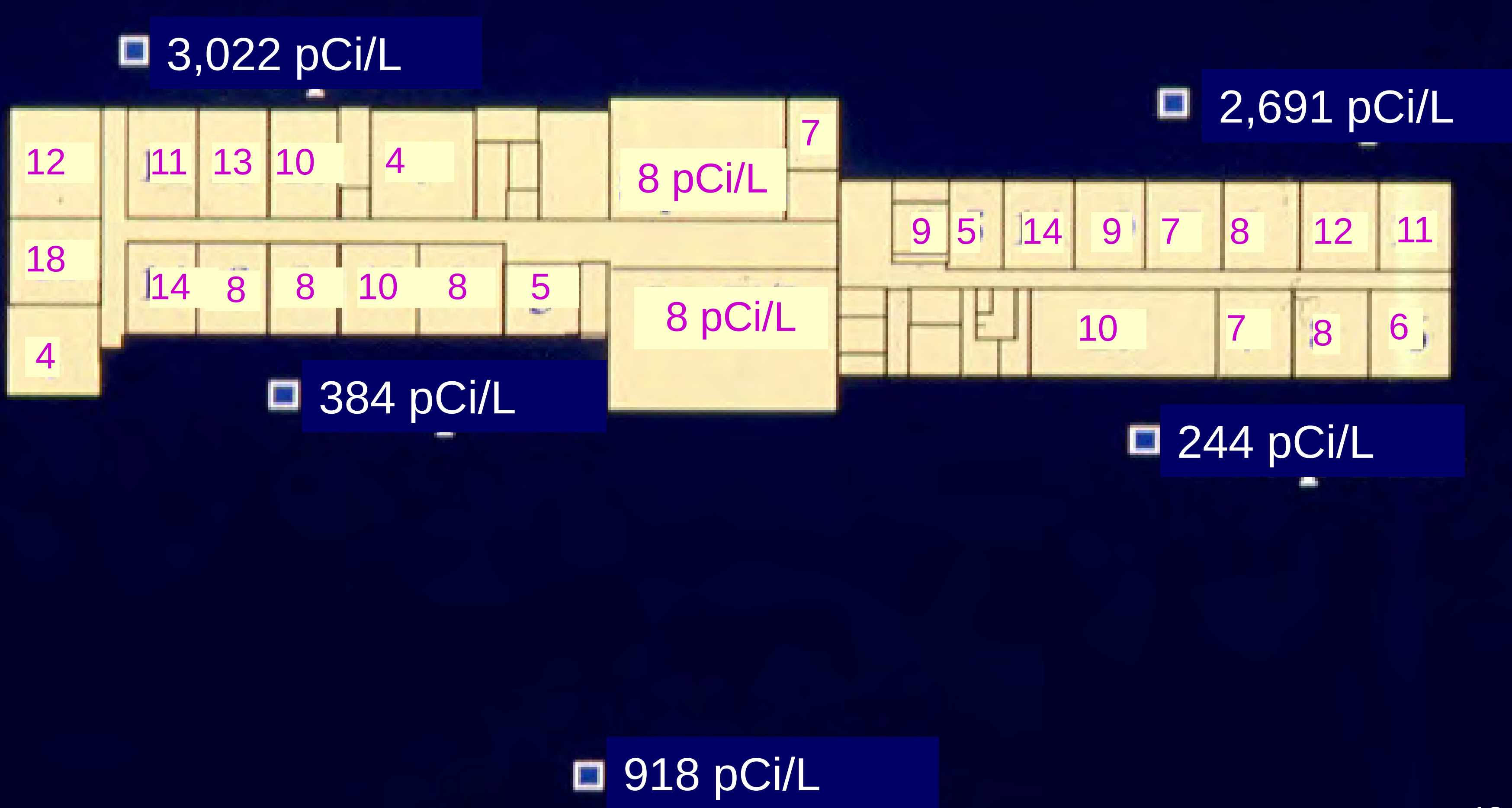
Radon Sources

- **Soil and geology**
  - **Most common source**
- Uncommon
  - Indoor building materials
    - Such as concrete and masonry
    - Rarely a major source
  - Well water used indoors
    - Released into air with aeration
    - Rarely a major source

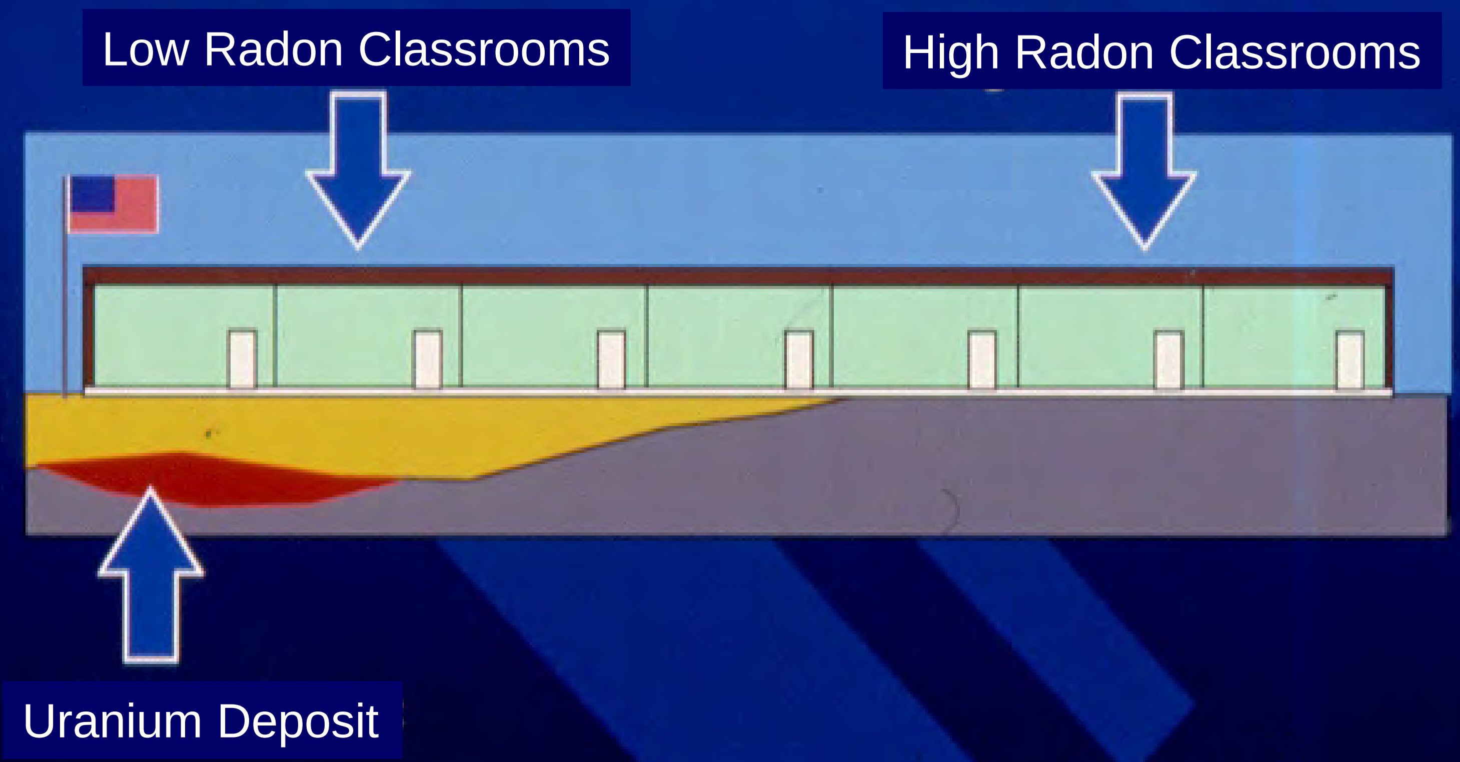


Radon Entry

Radon Concentrations: Classrooms and Soil (4 feet)

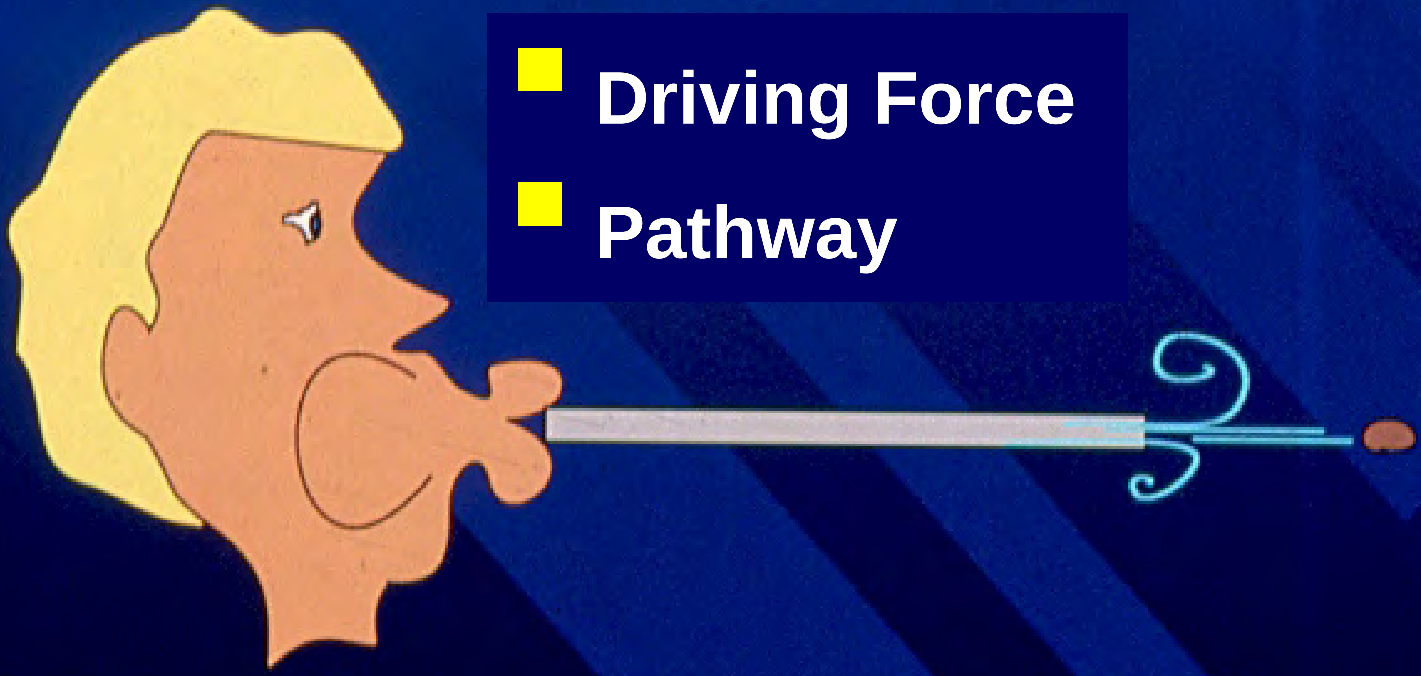


Radon Source and Other Factors



What could account for
this pattern of indoor radon?

Review: Transport Mechanisms

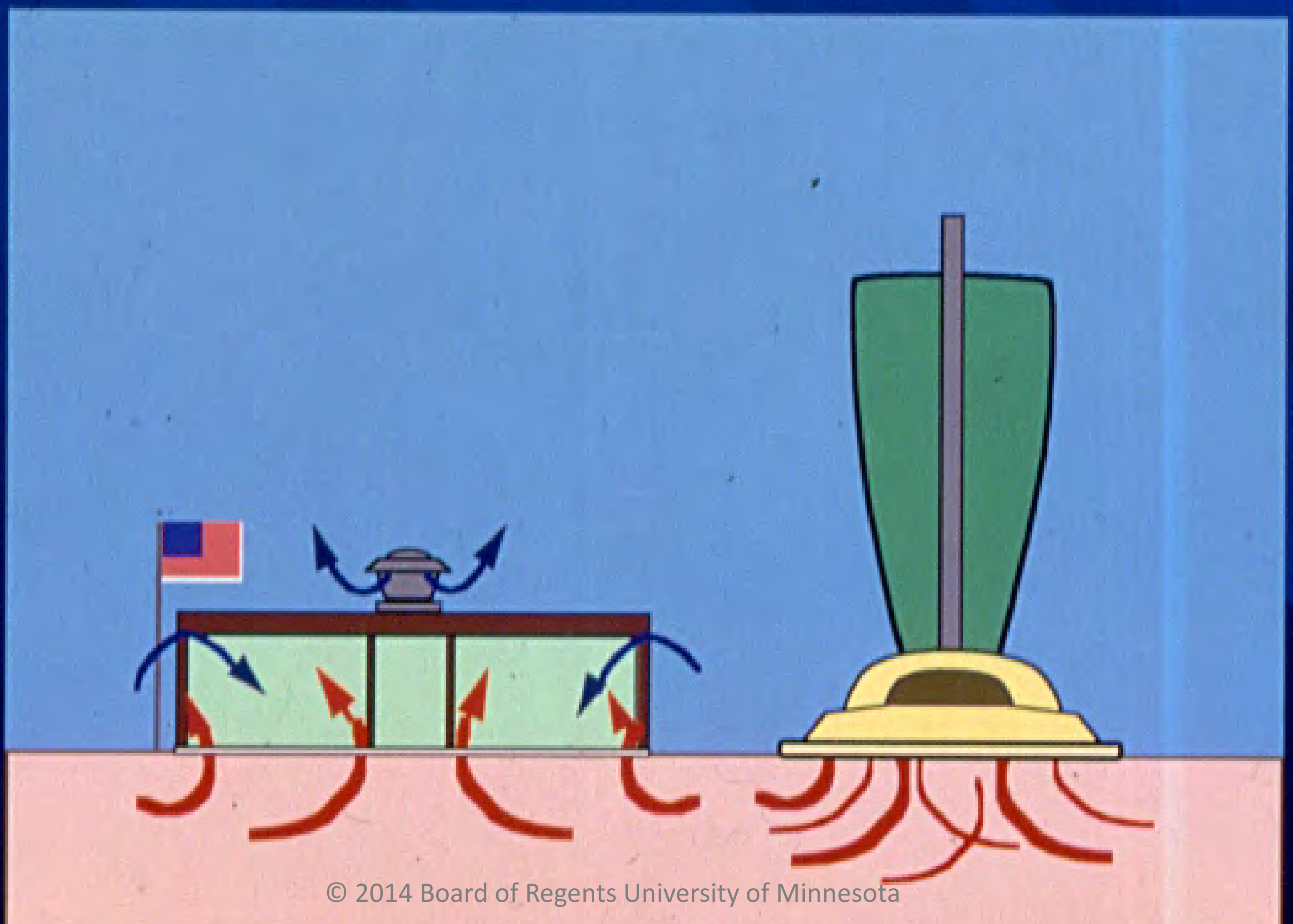


- Driving Force
- Pathway

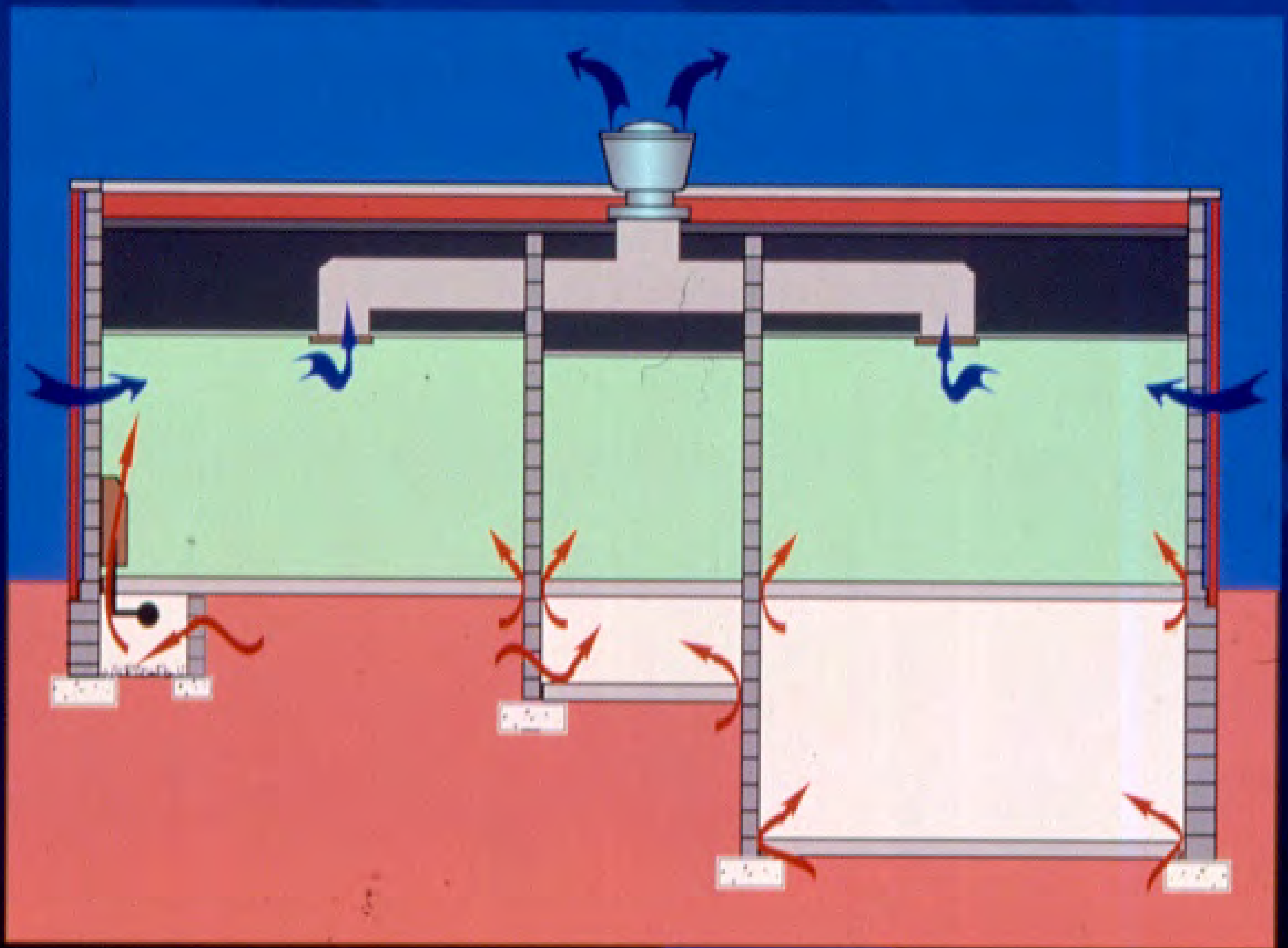
Pressure Driven Airflow

- Air enters building through both
  - Above grade air leaks
    - Dilutes indoor radon concentrations
  - Below grade air leaks
    - Delivers radon from the soil to the indoors
- Air pressure differences are the dominant driving force for radon entry in schools
  - Air always moves from high to low pressure

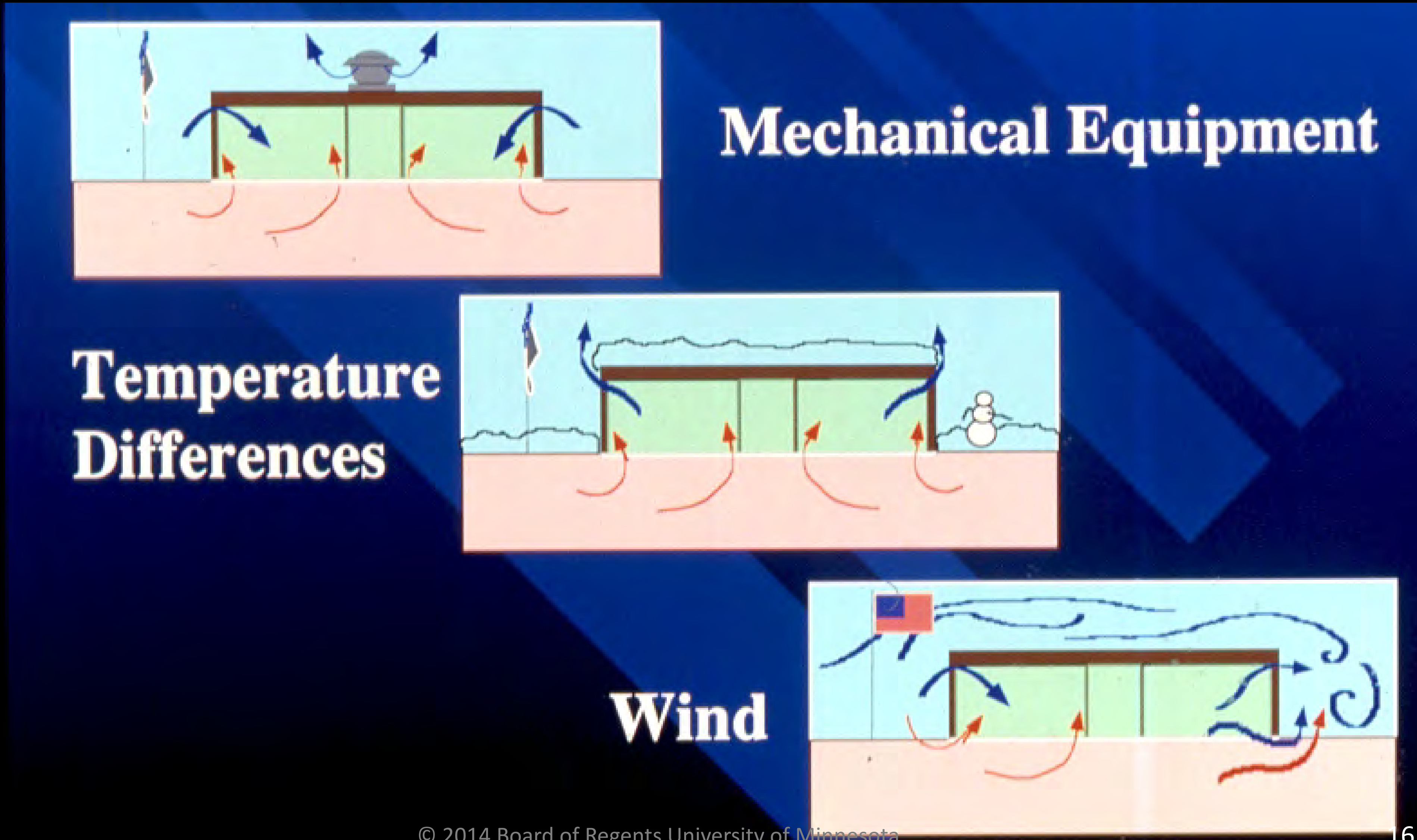
Lower Indoor Air Pressure Draws Soil Gas Indoors



Soil Gas Entry – Unplanned Airflow



What Powers Air Pressure Differences?



Investigation and Diagnostics

Radon Control in Schools

PA Middle School

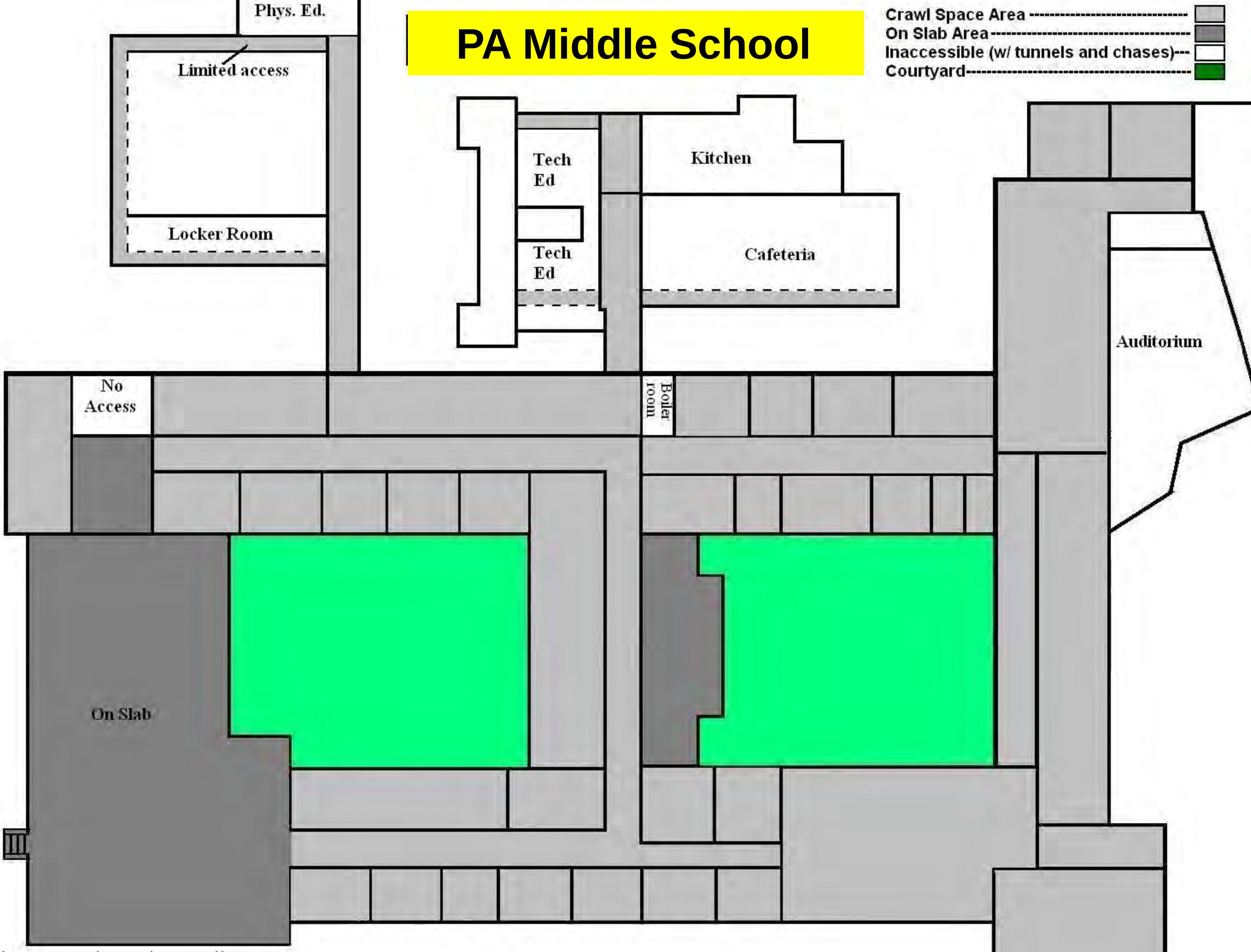


Photo Credit: John Mallon

PA Middle School

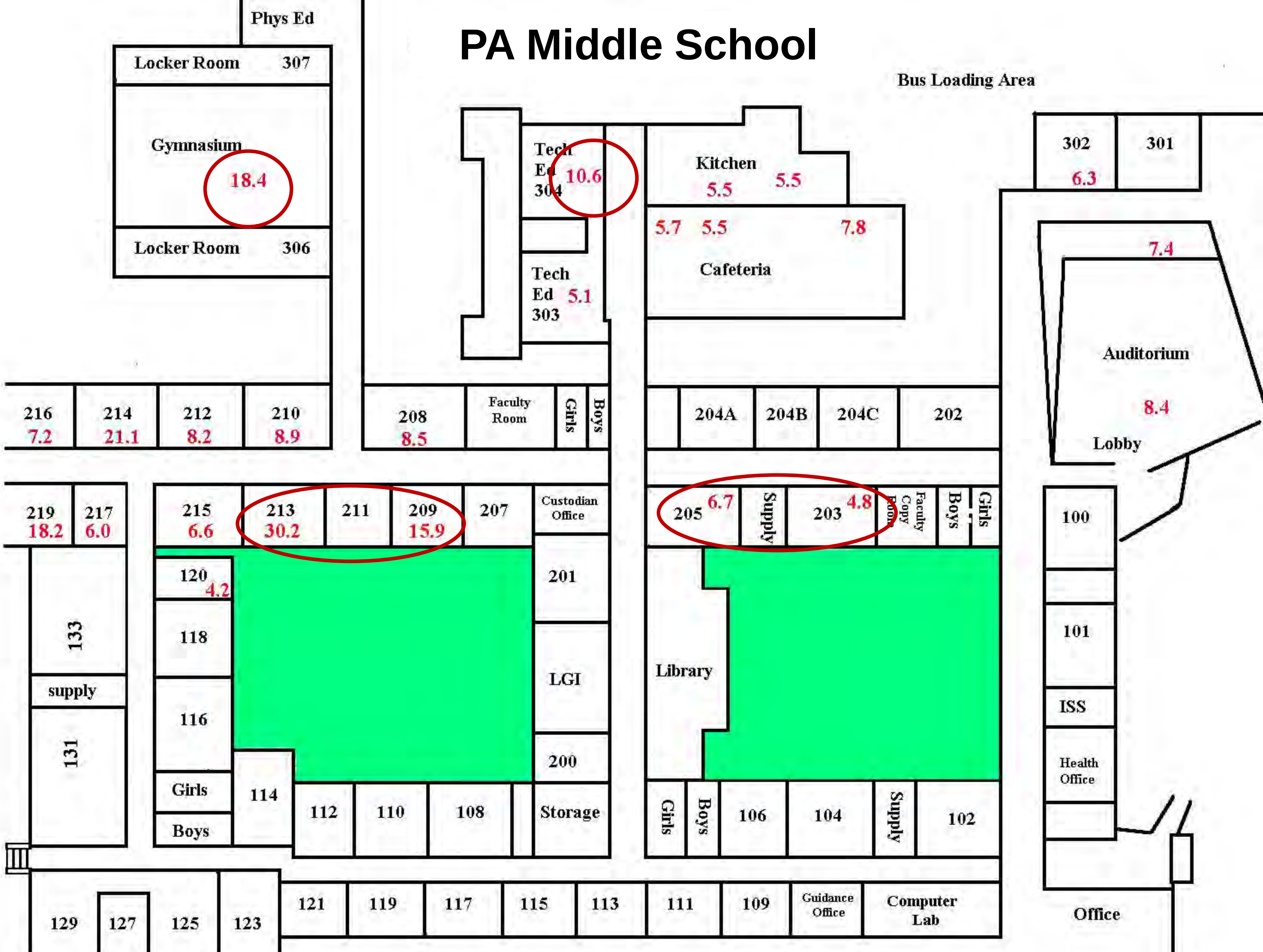


Photo Credit: John Mallon

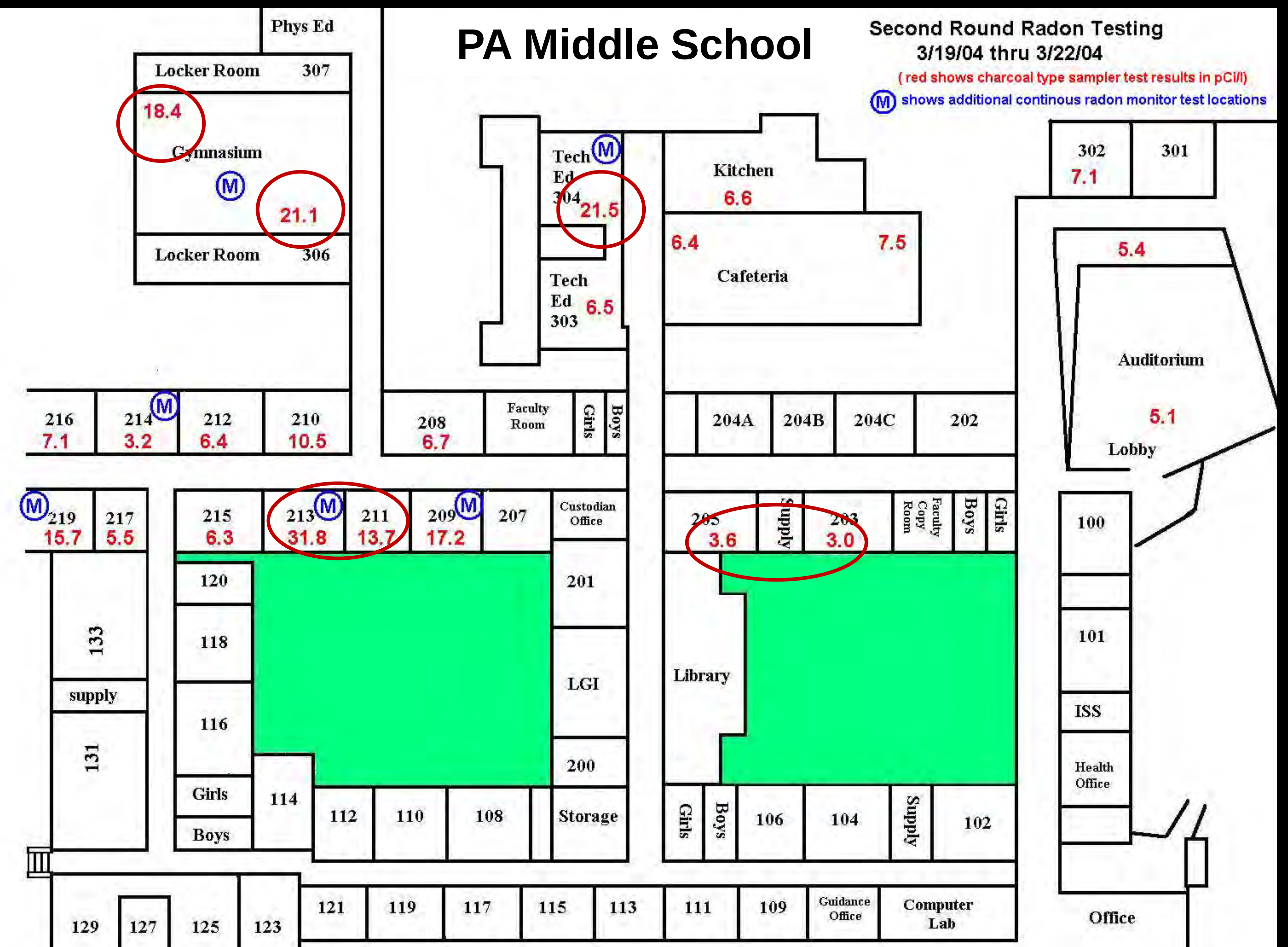
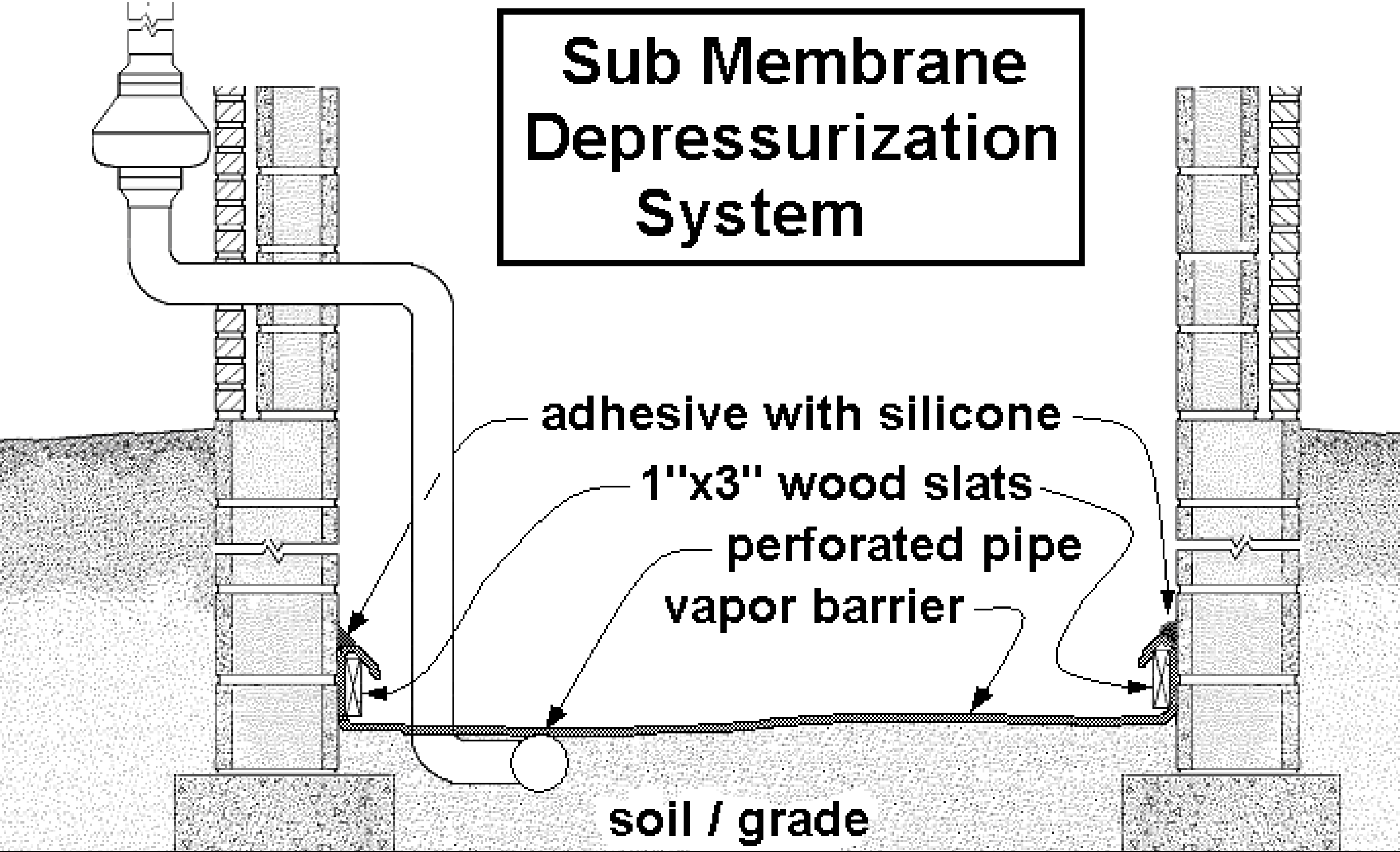


Photo Credit: John Mallon



Investigation and Diagnostics

Case Study of Crawlspace School

Photo Credit: John Mallon

"Extreme" Case Study: Difficult to Mitigation School

- Subslab utility tunnels that served as the outside air and return air mixing chamber
  - The HVAC system depressurized the utility tunnels and mined radon from the soil
- Radon concentrations up to 80 pCi/L

Initial Diagnostics

- Diagnostic radon concentrations
  - Utility tunnel block walls = 303 pCi/L
  - Utility tunnel subslab = 70 pCi/L in very tight soil
- Based upon PFE testing, we estimated that with very thorough sealing,
  - A tunnel subslab suction point required every 20 feet
  - If block wall depressurization (BWD) was the choice, we estimated
    - A wall suction point at least every 40 feet
    - A subslab depressurization (SSD) suction point in each classroom

Phase I Mitigation

- Based upon initial diagnostics and an extremely limited budget, a certified mitigator
  - Sealed openings between tunnel and soil as thoroughly as possible
  - Installed BWD
    - Found PFE lost after 3 to 6 feet from suction points
    - ***Then we found that utility tunnels were 6X more negative than found during diagnostics (80 Pa)***
      - ***Why?***
        - ***An energy management firm had replaced defective HVAC controls***

. . . Back to the drawing board . . .

RFP for Phase II Mitigation

RFP scope of work

1. Hard ducting the return/outdoor air to the low pressure side of the utility tunnel fan coils (isolate from source)
2. Reduce tunnel depressurization by
   A. Adding return/OA grills to the tunnel/mixed air plenum
   B. Add return/OA grills to the tunnel/mixed air plenum +
   C. Increase BWD suction points +
   D. Add sealing (BW coating) +
   E. Add further BWD fan capacity

Based upon our engineer's estimates, we expected:

1. Bids in the $40,000 to $50,000 range and
2. Additional annual costs of about $3,000

Response to RFP

- But the one mitigation bid we received was
  - $750,000
    - No guarantee ~ radon reduction and
  - $60,000/year increase energy use
- Therefore, we decided to recommend not accepting the proposal and
  - To invest in further diagnostics using HVAC flip – flop experiments

Baseline Experimental Condition

- CRM measurements in tunnel and classrooms
  - Daily cycle
    - FCU started at 0700 and shutdown at 1600
      - Radon at start-up = 3.3 pCi/L
      - Radon two hours after start-up to shutdown = 27 pCi/L
    - Radon from shutdown to 6 hours later dropped 27 to 3.2 pCi/L
- With zero OA with the FC on, the ΔP to the outdoors was
  - - 120 Pa in the tunnel
  - - 100 Pa in the block walls

Average Rn Concentration During Last 22 Hours of 24 Hour Trials and Percent Rn Compared to Previous Base Conditions

	Variables						Average Radon Concentration in pCi/L						Radon Reduction	
Experiment	BWD Fans	MA Fans	SSD Fans	MA Source	Fan Coils	East BWD	Tunnel	Room #1	Room #2	Room #7	Princ. Office	Music Room	Tunnel	Upstairs
00. Base Condition Average	off	off	off	tunnel	on	off	30.3	10.7	6.8	11.4	9.3	0.3		
01. Orginal Operation with BWD	ON	off	off	tunnel	on	off	30.0	8.3	6.8	10.2	6.9	0.3	7%	19%
02. Blockwall Pressurization (BWP)	REV	off	off	tunnel	on	off	7.6	6.0	3.3	5.0	4.3	0.2	75%	52%
03. Tunnel Pressurization	off	ON	off	tunnel	on	off	8.7	3.0	2.3	4.4	2.9	0.2	61%	62%
04. Subslab Depressurization	off	off	ON	tunnel	on	off	28.2	9.9	5.4	9.8	8.0	0.5	-9%	9%
05. Hard Duct Mixed Air (MA)	off	off	off	DUCT	on	off	28.5	9.3	5.3	10.1	7.7	0.3	6%	12%
06. BWD + MA Fans	ON	ON	off	tunnel	on	off	7.4	2.1	1.4	3.2	2.0	0.2	76%	73%
07. BWD + SSD Fans	ON	off	ON	tunnel	on	off	23.6	5.8	3.2	7.3	4.3	1.3	5%	41%
08. BWD + MA Duct	ON	off	off	DUCT	on	off	29.9	8.3	5.4	10.6	7.3	0.4	11%	12%
09. MA Fans + SSD Fans	off	ON	ON	tunnel	on	off	8.1	2.4	1.8	4.1	2.6	0.2	63%	65%
10. MA Fans + MA Duct	off	ON	off	DUCT	on	off	14.3	6.1	4.7	7.6	5.5	0.6	63%	38%
11. BWD + MA + SSD Fans	ON	ON	ON	tunnel	on	off	10.2	3.8	3.8	6.6	3.6	0.6	74%	67%
12. BWD + SSD Fans + Duct	ON	off	ON	DUCT	on	off	28.6	3.4	1.1	6.9	2.1	0.3	27%	67%
13. BWD + MA Fans on, FCUs off	ON	ON	off	tunnel	OFF	off	3.4	1.2	0.8	3.4	1.1	1.3	89%	80%
14. BWD + FCUs on Setback	ON	off	off	tunnel	SET	off	24.6	9.6	5.3	9.0	6.4	1.3		
15. BWD + Duct + FCU Setback	ON	off	off	DUCT	SET	off	33.0	6.5	3.7	8.4	4.7	0.6		
16. BWD + MA Fans + FCU Setback	ON	ON	off	tunnel	SET	off	16.6	6.9	5.0	7.9	6.1	1.8		
17. BWD on + FCUs off	ON	off	off	tunnel	OFF	off	1.1	0.8	0.7	0.6	0.8	1.0	96%	90%
18. BWD + Outside Air @ 20%	ON	off	off	tunnel	on	off	28.2	11.8	6.1	11.9	7.3	0.2		
19. BWP + FCU Setback	REV	off	off	tunnel	SET	off	20.8	7.4	3.8	8.6	4.9	1.0	31%	33%
20. BWP + MA Fans + 6 of 12 FCUs	REV	ON	off	tunnel	6 on	off	5.4	5.3	5.6	5.9	5.2	6.6	82%	25%
21. BWP + MA Fans + FCU Setback	REV	ON	off	tunnel	SET	ON	2.0	1.8	1.8	1.8	1.7	6.7	94%	64%
22. BWP + FCU Setback	REV	off	off	tunnel	SET	off	13.5	9.2	6.0	8.4	6.7	2.4		

BWD = block wall depressurization
BWP = block wall pressurization
FCU = fan coil units
MA = mixed air
PRINC = principal's
REV = reversed
SET = setback at night and week-ends
SSD = subslab depressurization

Case Study: Findings

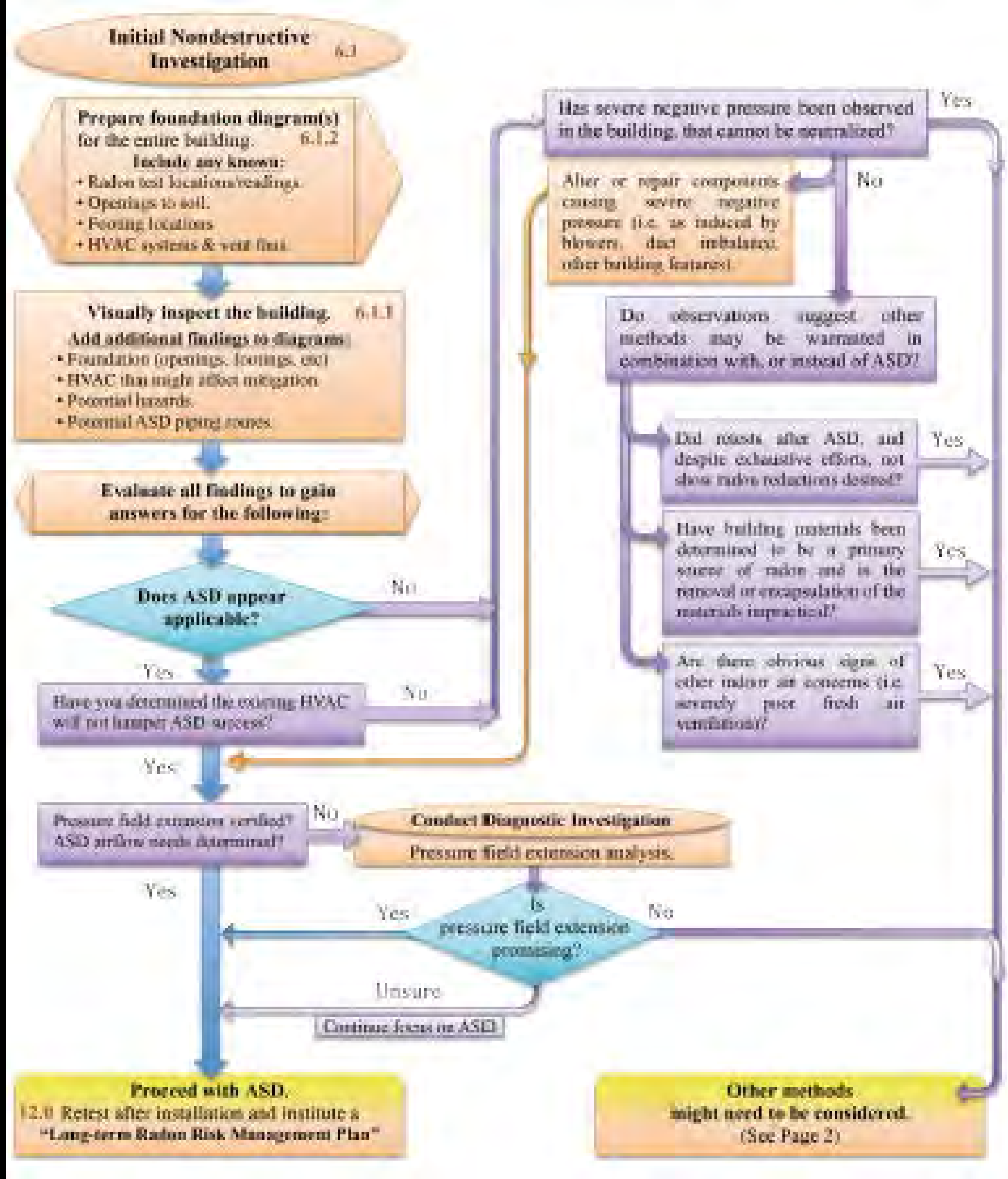
Thorough diagnostics of HVAC system and PFE:

1. Cost an additional $20,000 (1996 USD)
2. Reduced average indoor radon concentrations by 79%
   – From an average of 7.7 pCi/L to 1.6 pCi/L
3. Reduced installation costs by 96% to $30,000
4. Had no impact on energy costs
5. Improved overall classroom indoor air quality

Investigation and Diagnostics

Mitigation Design Decisions Flow Chart

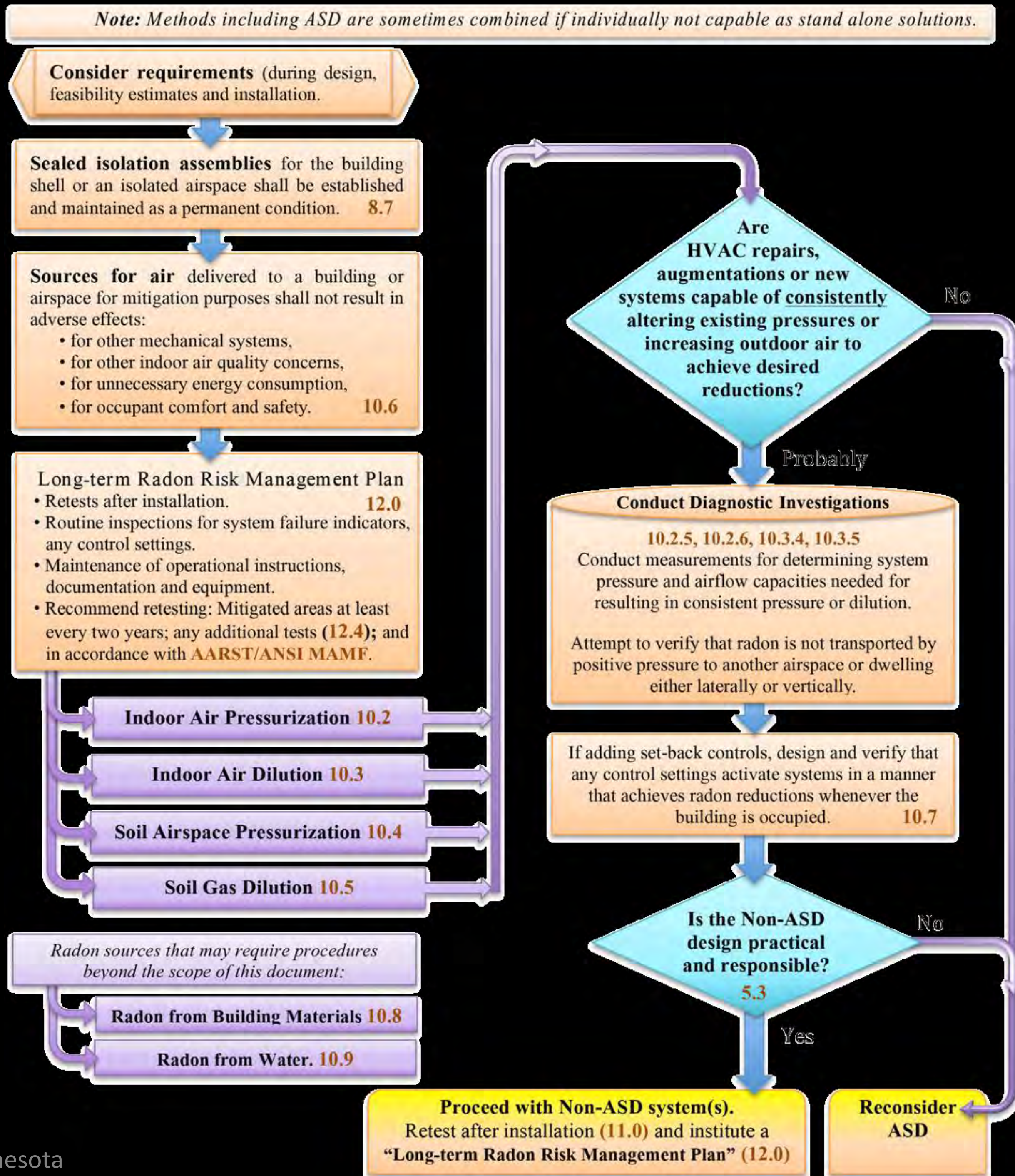
(1:2)



Investigation and Diagnostics

Mitigation Design Decisions Flow Chart

(2:2)



Mitigation Installation

Radon Control in Schools

Hiring Potential Professionals

- **NRPP radon contractor proficiency program**
  - Understands the control of soil air entry
- Mechanical engineer
  - Designs air handling systems and writes bid documents
- Mechanical contractor
  - Modifies and installs air handling and conditioning equipment
- Controls contractor
  - Adjusts, modifies and installs HVAC control systems
- Test, adjust and balance (TAB) contractor
  - Measures airflows

Radon Mitigation

Membrane in Place

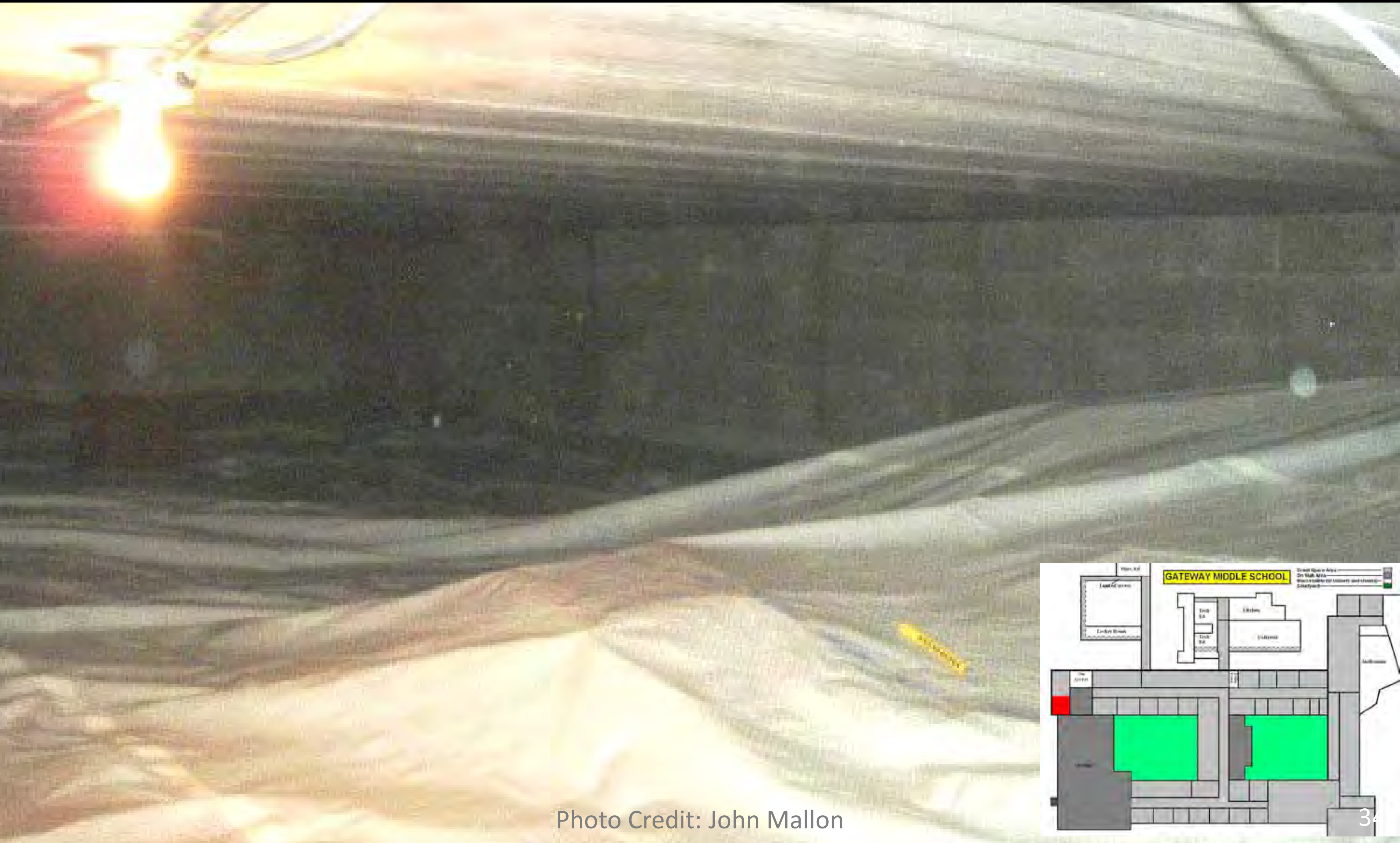


Photo Credit: John Mallon

Radon Mitigation

Installing a Suction Point

Photo Credit: John Mallon

Installing Vent Ducts (steel pipe in this case)

Photo Credit: John Mallon

Down-Blast Exhaust Fan

Theatrical Fog Showing Flow Pattern of Down-Blast Exhaust