High-Resolution Diagnostic Mapping:

Leveraging Large-Scale CRM Deployment to Optimize School HVAC Operations and Radon Mitigation

Non-commercial research presentation highlighting diagnostic methodologies and HVAC operational findings across school building portfolios

By Dallas Jones, VP

ecosense
Build a radon-free lifestyle

Large-Scale CRM Deployment in Schools Enable Immediate HVAC Adjustments and Re-testing



- **Core Problem:** Integrated passive detectors provide single-point average concentrations, masking dynamic diurnal swings tied to building schedules.
- **Methodology Shift:** High-density continuous monitoring across every ground-contact room to map real-time structural and mechanical radon behavior.
- **Over 240 Schools:** Significant day-night fluctuations associated with occupied vs. unoccupied hours are common.
- **Key Findings:** While we found some instances of localized room depressurization, diagnostic identification of ventilation-driven cycles frequently led to zero-capital mitigation via HVAC optimization.



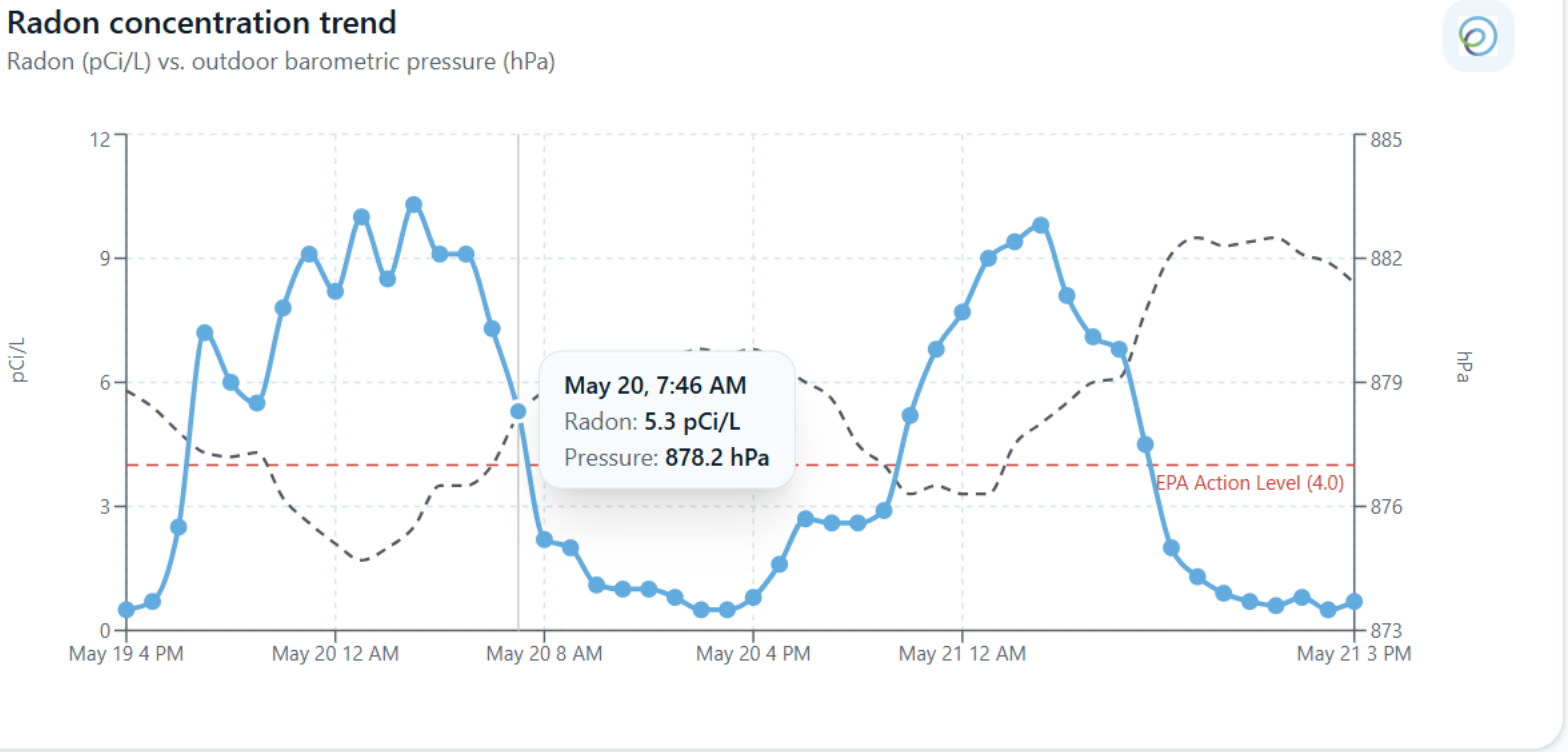
South Jr. High – Boise, ID 1 of 52 Schools Tested

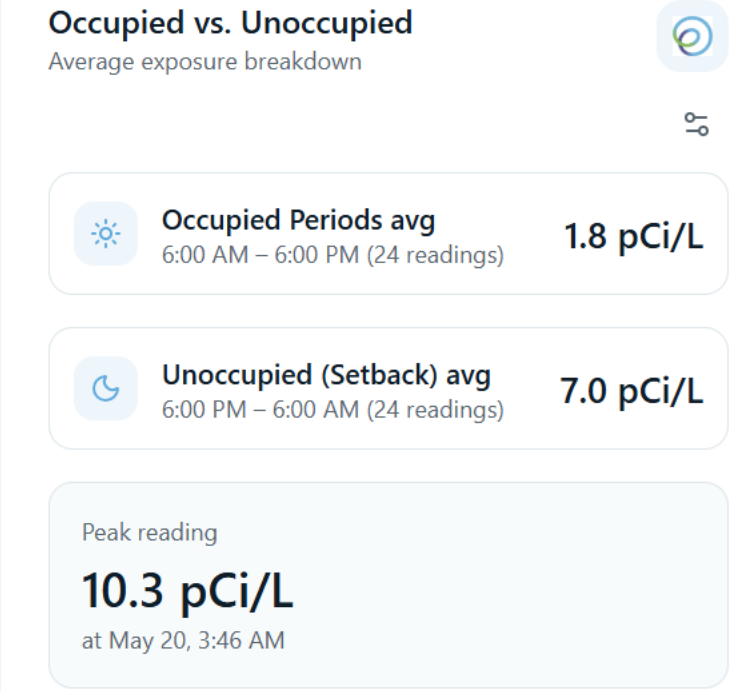


- During the 2005 facility reconstruction, the original library facade was preserved and converted into a community outdoor amphitheater
- Not tested previously
- A total of **40** NRPP certified EQ200B CRMs (BC-8465) were deployed during the testing period including 4 duplicates.
- **Results ranged from the lowest reading of 0.4 pCi/L, and the highest room reading of 5.5 pCi/L.**

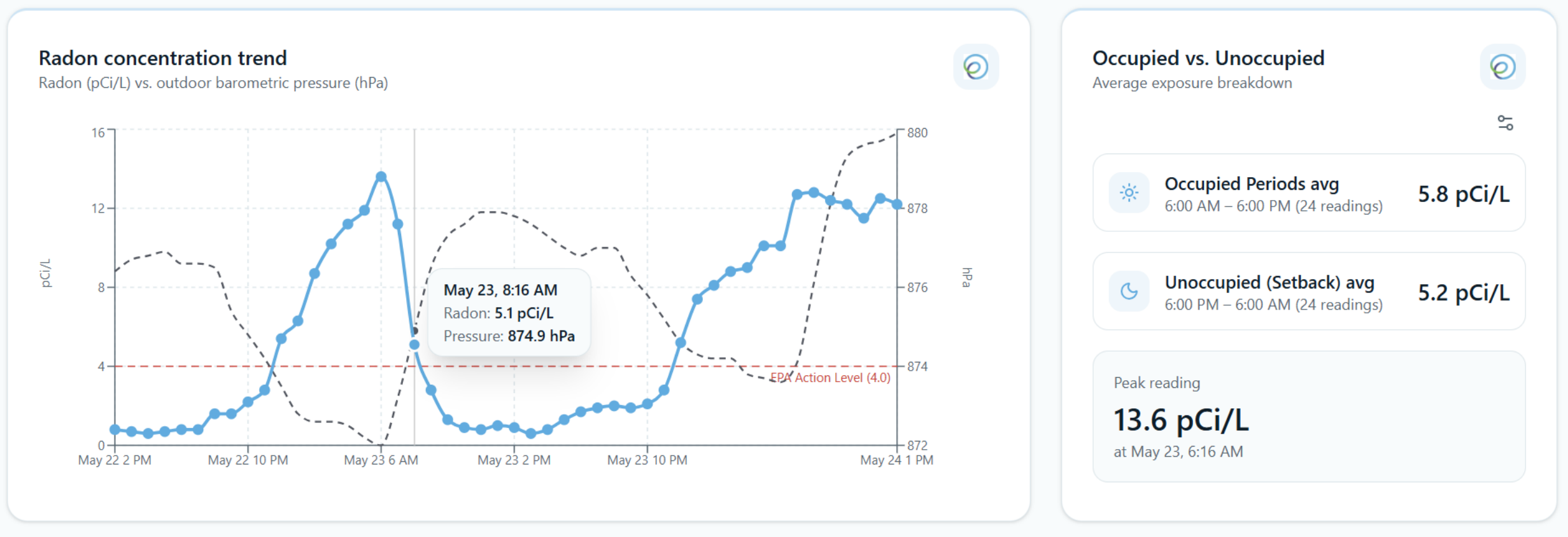
	0 - 1.9 pCi/L	2.0 - 3.9 pCi/L	> 4.0 pCi/L
Percentage of Total Samples Placed	82.5%	**10%**	**7.5%**

South Jr. High-Boise, ID Psych Office 28 4.4 pCi/L





South Jr. High-Boise, ID Psych Office 28 (Test 2) 5.5 pCi/L (overall avg.)



South Jr. High-Boise, ID Psych Office 28 (Test 2) 5.5 pCi/L (overall avg.)

Atmospheric & Structural Diagnostics

Open-Meteo historical weather · Boise, ID

Ventilation-driven diurnal cycle

Diagnostic Notice: Although a 4.6 hPa barometric drop coincided with the 13.6 pCi/L peak, radon levels show a pronounced day/night swing (78.1% variance) that repeats beyond the pressure event — concentrations climb during daytime hours and fall overnight — the inverse of the typical setback pattern, which commonly indicates the air handler is pulling in radon-laden sub-slab or crawlspace air while it runs (for example depressurizing the building through return leakage or an inadequate/closed fresh-air intake). This recurring pattern points to HVAC/ventilation scheduling as the dominant mechanism rather than a purely pressure-driven sub-slab migration. Because the buildup occurs while the system runs, extending HVAC run-time is unlikely to help; verify fresh-air intake position, return-air leakage, and building pressure before scheduling changes. The barometric pressure declined gradually across the entire deployment (with minor rises in between) rather than as a single rapid drop-and-recover, so the overall average is not biased by a one-off transient event. Peak outdoor winds over the deployment reached 13 mph sustained winds.

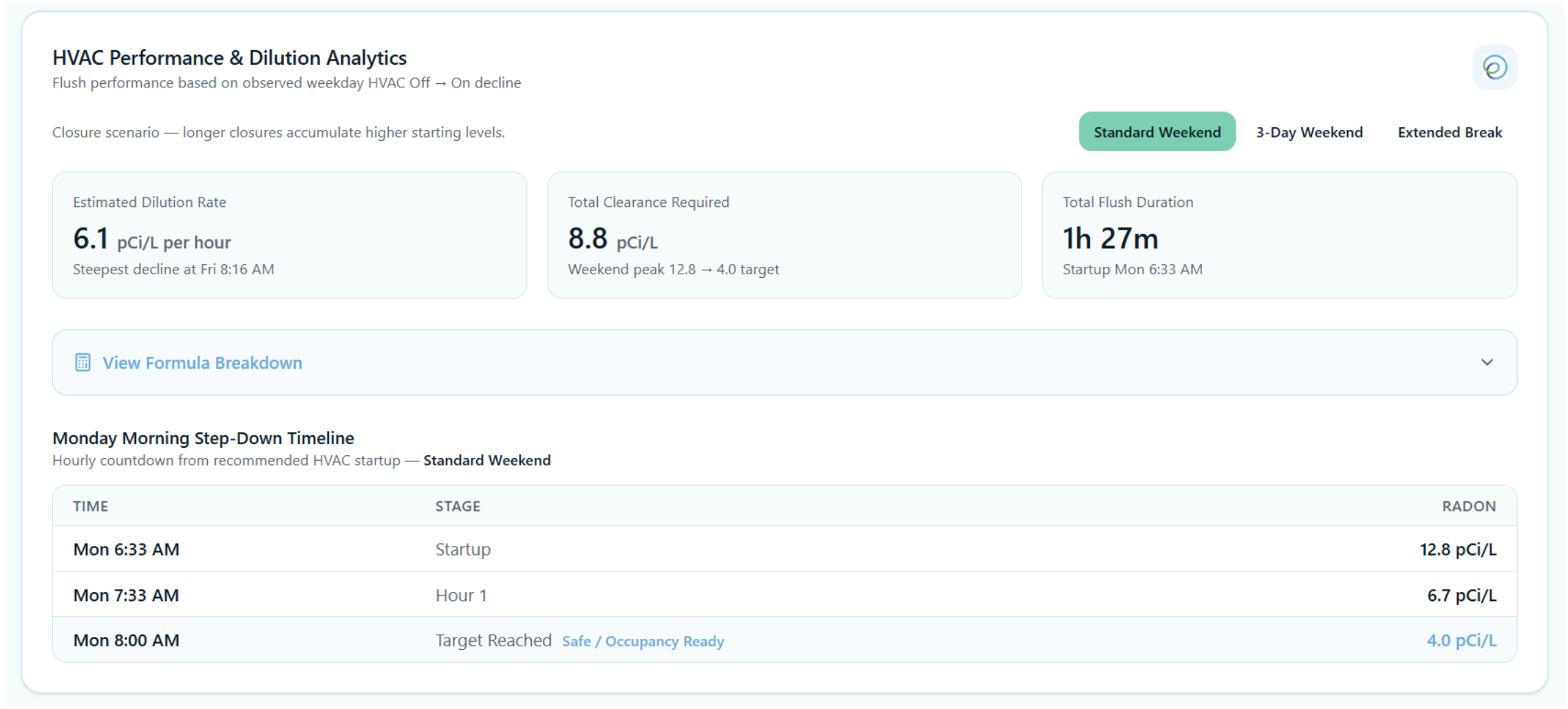
Pre-spike pressure change	Peak wind (sustained / gust)	Precipitation (12h window)	Test duration
4.6 hPa	13 mph / 30 mph	0.0 mm	2 days

Exhibit 8.3.2: Comparison of Building Operating Conditions

AARST §B-3.2 climate baseline · Boise, ID

Average Annual Outdoor Temperature (Decadal Baseline) 10-year reanalysis average	49.1 °F
Average Outdoor Temperature During Test	55.5 °F
Prevailing Operating Condition (Heating / Cooling / Mixed)	Mixed
Water table elevation (general status) – per USGS WaterWatch baseline	Low **Average** High

South Jr. High-Boise, ID Psych Office 28 (Test 2) 5.5 pCi/L (overall avg.)



HVAC Performance & Dilution Analytics

Flush performance based on observed weekday HVAC Off → On decline

Closure scenario — longer closures accumulate higher starting levels.

Standard Weekend | 3-Day Weekend | Extended Break

Estimated Dilution Rate	Total Clearance Required	Total Flush Duration
6.1 pCi/L per hour	**8.8** pCi/L	**1h 27m**
Steepest decline at Fri 8:16 AM	Weekend peak 12.8 → 4.0 target	Startup Mon 6:33 AM

View Formula Breakdown

Monday Morning Step-Down Timeline

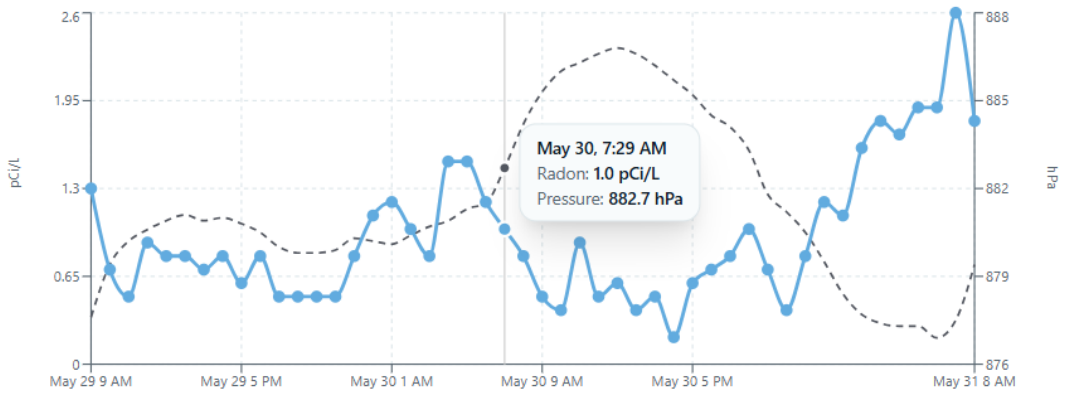
Hourly countdown from recommended HVAC startup — **Standard Weekend**

TIME	STAGE	RADON
Mon 6:33 AM	Startup	**12.8 pCi/L**
Mon 7:33 AM	Hour 1	**6.7 pCi/L**
Mon 8:00 AM	Target Reached Safe / Occupancy Ready	4.0 pCi/L

South Jr. High-Boise, ID Psych Office 28 0.9 pCi/L

Radon concentration trend

Radon (pCi/L) vs. outdoor barometric pressure (hPa)



Occupied vs. Unoccupied

Average exposure breakdown

Occupied Periods avg	7:00 AM – 4:00 PM (18 readings)	0.9 pCi/L
Unoccupied (Setback) avg	4:00 PM – 7:00 AM (30 readings)	1.0 pCi/L

Peak reading

2.6 pCi/L

at May 31, 7:29 AM

Atmospheric & Structural Diagnostics

Open-Meteo historical weather · Boise, ID

Ventilation-driven diurnal cycle

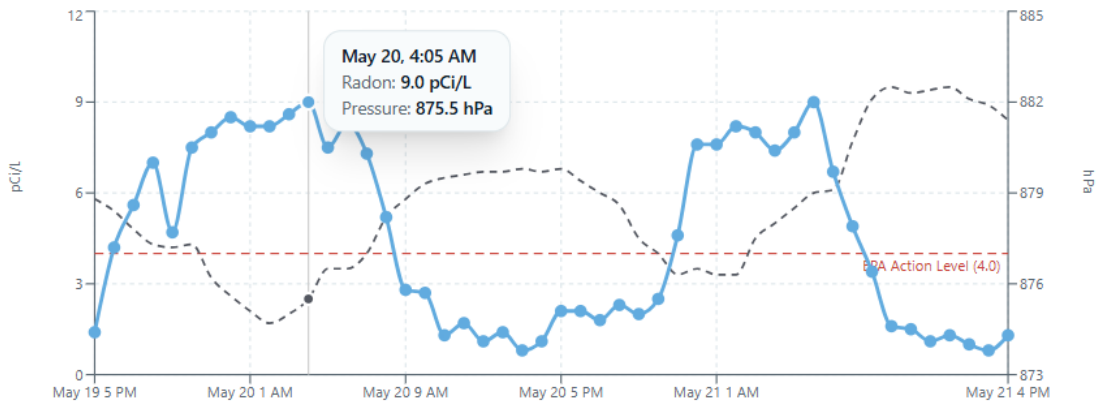
Diagnostic Notice: Although a 5.8 hPa barometric drop coincided with the 2.6 pCi/L peak, radon levels show a pronounced day/night swing (66.7% variance) that repeats beyond the pressure event — concentrations climb overnight when the air handler is off and fall during occupied daytime hours. This recurring pattern points to HVAC/ventilation scheduling as the dominant mechanism rather than a purely pressure-driven sub-slab migration. The barometric pressure declined gradually across the entire deployment (with minor rises in between) rather than as a single rapid drop-and-recover, so the overall average is not biased by a one-off transient event. Peak outdoor winds over the deployment reached 12 mph sustained winds.

Pre-spike pressure change	Peak wind (sustained / gust)	Precipitation (12h window)	Test duration
5.8 hPa	12 mph / 27 mph	0.0 mm	2 days

South Jr. High-Boise, ID Room 118-93 OD 4.6 pCi/L

Radon concentration trend

Radon (pCi/L) vs. outdoor barometric pressure (hPa)



Occupied vs. Unoccupied

Average exposure breakdown

Occupied Periods avg 7:00 AM – 4:00 PM (18 readings)	2.6 pCi/L
Unoccupied (Setback) avg 4:00 PM – 7:00 AM (30 readings)	5.7 pCi/L

Peak reading

9.0 pCi/L

at May 20, 4:05 AM

Atmospheric & Structural Diagnostics

Open-Meteo historical weather · Boise, ID

Ventilation-driven diurnal cycle

Diagnostic Notice: Although a 3.3 hPa barometric drop coincided with the 9.0 pCi/L peak, radon levels show a pronounced day/night swing (88.5% variance) that repeats beyond the pressure event — concentrations climb overnight when the air handler is off and fall during occupied daytime hours. This recurring pattern points to HVAC/ventilation scheduling as the dominant mechanism rather than a purely pressure-driven sub-slab migration. The barometric pressure declined gradually across the entire deployment (with minor rises in between) rather than as a single rapid drop-and-recover, so the overall average is not biased by a one-off transient event. Peak outdoor winds over the deployment reached 14 mph sustained winds.

Pre-spike pressure change	Peak wind (sustained / gust)	Precipitation (12h window)	Test duration
3.3 hPa	**14 mph** / 29 mph	**1.4 mm**	**2 days**

South Jr. High-Boise, ID Room 118-93 OD 4.6 pCi/L

Overall Average

4.6 pCi/L

Exceeds EPA action level

Occupied Periods

7:00 AM – 4:00 PM

2.6 pCi/L

Below EPA action level

Unoccupied (Setback) Periods

4:00 PM – 7:00 AM

5.7 pCi/L

Exceeds EPA action level

EPA 4.0 Crossings

Evening rise above 4.0

May 19, 6:05 PM

Morning drop below 4.0

May 20, 9:05 AM

HVAC Performance & Dilution Analytics

Flush performance based on observed weekday HVAC Off → On decline

Closure scenario — longer closures accumulate higher starting levels.

Standard Weekend | 3-Day Weekend | Extended Break

Estimated Dilution Rate

2.4 pCi/L per hour

Steepest decline at Tue 9:05 AM

Total Clearance Required

5.0 pCi/L

Weekend peak 9.0 → 4.0 target

Total Flush Duration

2h 5m

Startup Mon 5:55 AM

View Formula Breakdown

Monday Morning Step-Down Timeline

Hourly countdown from recommended HVAC startup — **Standard Weekend**

TIME	STAGE	RADON
Mon 5:55 AM	Startup	**9.0 pCi/L**
Mon 6:55 AM	Hour 1	**6.6 pCi/L**
Mon 7:55 AM	Hour 2	**4.2 pCi/L**
Mon 8:00 AM	Target Reached Safe / Occupancy Ready	4.0 pCi/L

South Jr. High-Boise, ID Room 118-93 OD 4.6 pCi/L

HVAC Performance & Dilution Analytics

Flush performance based on observed weekday HVAC Off → On decline

Closure scenario — longer closures accumulate higher starting levels.

Standard Weekend | 3-Day Weekend | Extended Break

Estimated Dilution Rate	Total Clearance Required	Total Flush Duration
2.4 pCi/L per hour	**12.3** pCi/L	**5h 7m**
Steepest decline at Tue 9:05 AM	Projected peak 16.3 → 4.0 target	Startup Tue 2:53 AM

Projected 3-day weekend peak: 16.3 pCi/L — observed weekend peak 9.0 pCi/L plus the measured overnight buildup rate (0.62 pCi/L per closed hour) extrapolated over the extra closed days, capped at a saturation plateau.

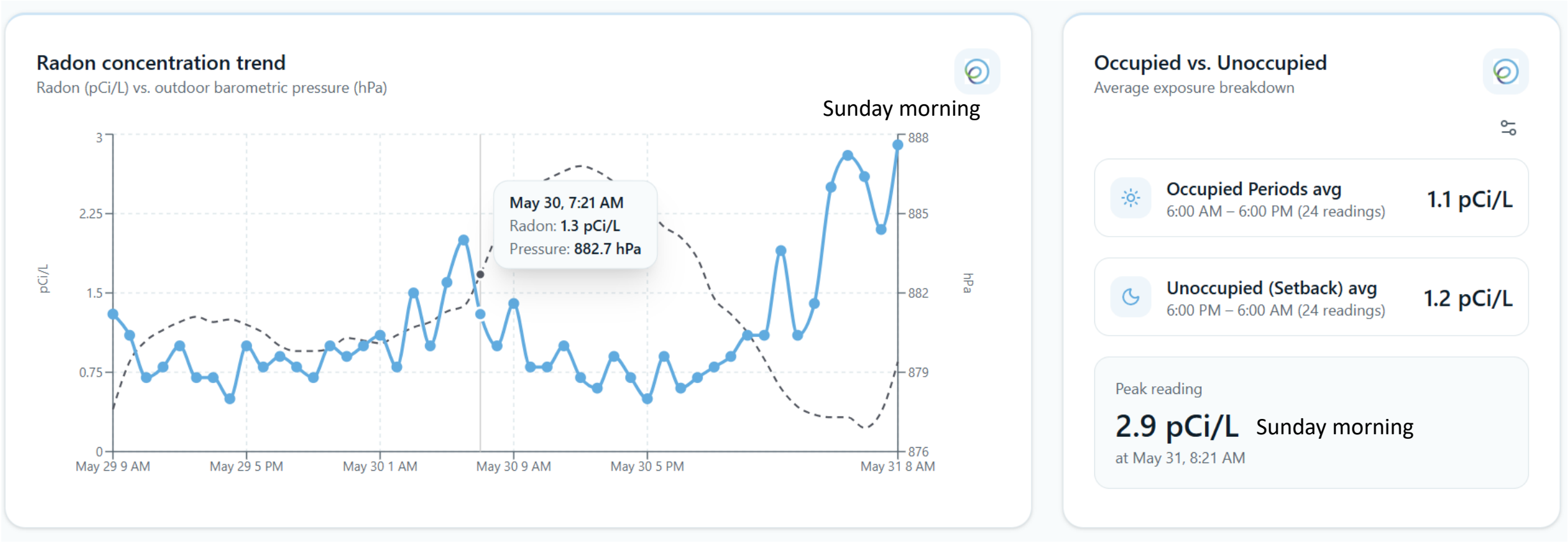
View Formula Breakdown

Tuesday Morning Step-Down Timeline

Hourly countdown from recommended HVAC startup — **3-Day Weekend**

TIME	STAGE	RADON
Tue 2:53 AM	Startup	**16.3 pCi/L**
Tue 3:53 AM	Hour 1	**13.9 pCi/L**
Tue 4:53 AM	Hour 2	**11.5 pCi/L**
Tue 5:53 AM	Hour 3	**9.1 pCi/L**
Tue 6:53 AM	Hour 4	**6.7 pCi/L**
Tue 7:53 AM	Hour 5	**4.3 pCi/L**
Tue 8:00 AM	Target Reached Safe / Occupancy Ready	4.0 pCi/L

South Jr. High-Boise, ID Room 118-93 OD 1.1 pCi/L



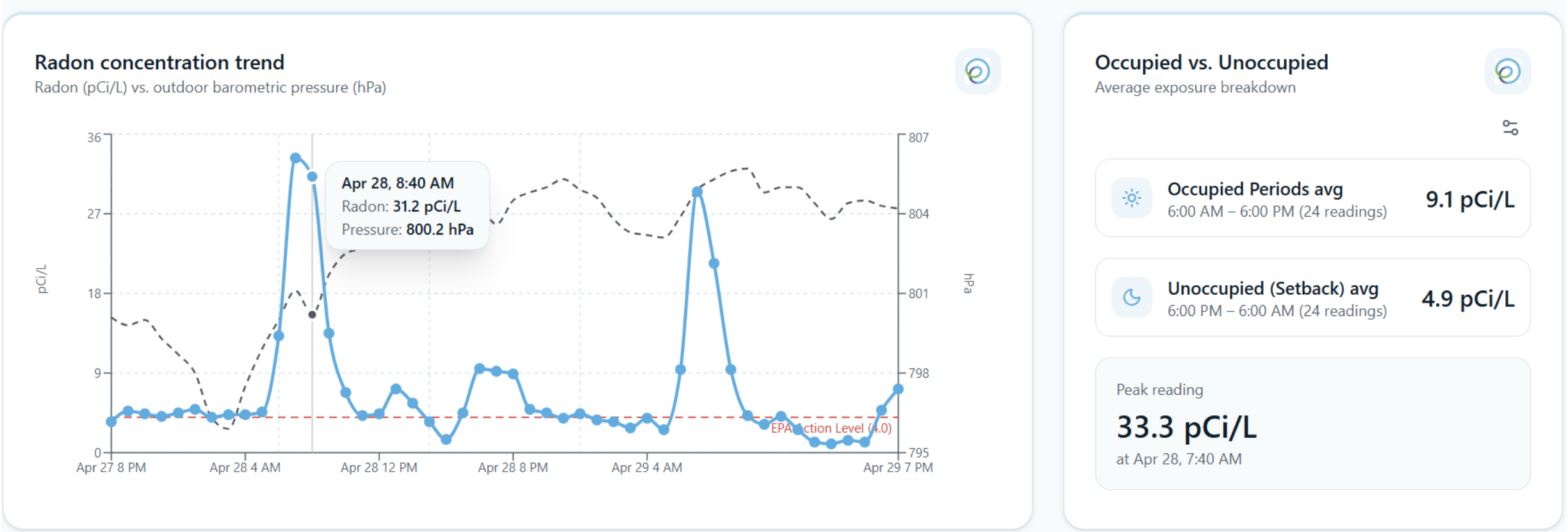
North High School - Denver 1 of 80 Schools Tested



- 1911 building underwent a major historical renovation in 2010-2011
- Previously tested in 2021 with charcoal kits
- A total of **138** NRPP certified EQ200B CRMs (BC-8465) were deployed. The total number of tests include 12 duplicate placements.
- **Results ranged from the lowest reading of 0.3 pCi/L, and the highest reading of 7.0 pCi/L.**

	0 - 1.9 pCi/L	2.0 - 3.9 pCi/L	> 4.0 pCi/L
Percentage of Total Samples Placed	94.9%	**2.9%**	**2.2%**

North High-Denver Room 182L 7.0 pCi/L



North High-Denver Room 182L 7.0 pCi/L

Atmospheric & Structural Diagnostics

Open-Meteo historical weather · Castle Rock, CO

Ventilation-driven diurnal cycle

Diagnostic Notice: radon levels show a pronounced day/night swing (91.1% variance) that repeats beyond the pressure event — concentrations climb during daytime hours and fall overnight — the inverse of the typical setback pattern, which commonly indicates the air handler is pulling in radon-laden sub-slab or crawlspace air while it runs (for example depressurizing the building through return leakage or an inadequate/closed fresh-air intake). This recurring pattern points to HVAC/ventilation scheduling as the dominant mechanism rather than a purely pressure-driven sub-slab migration. Because the buildup occurs while the system runs, extending HVAC run-time is unlikely to help; verify fresh-air intake position, return-air leakage, and building pressure before scheduling changes. The barometric pressure declined gradually across the entire deployment (with minor rises in between) rather than as a single rapid drop-and-recover, so the overall average is not biased by a one-off transient event. Peak outdoor winds over the deployment reached 14 mph sustained winds.

Pre-spike pressure change	Peak wind (sustained / gust)	Precipitation (12h window)	Test duration
0.1 hPa	14 mph / 25 mph	16.6 mm	2 days

Exhibit 8.3.2: Comparison of Building Operating Conditions

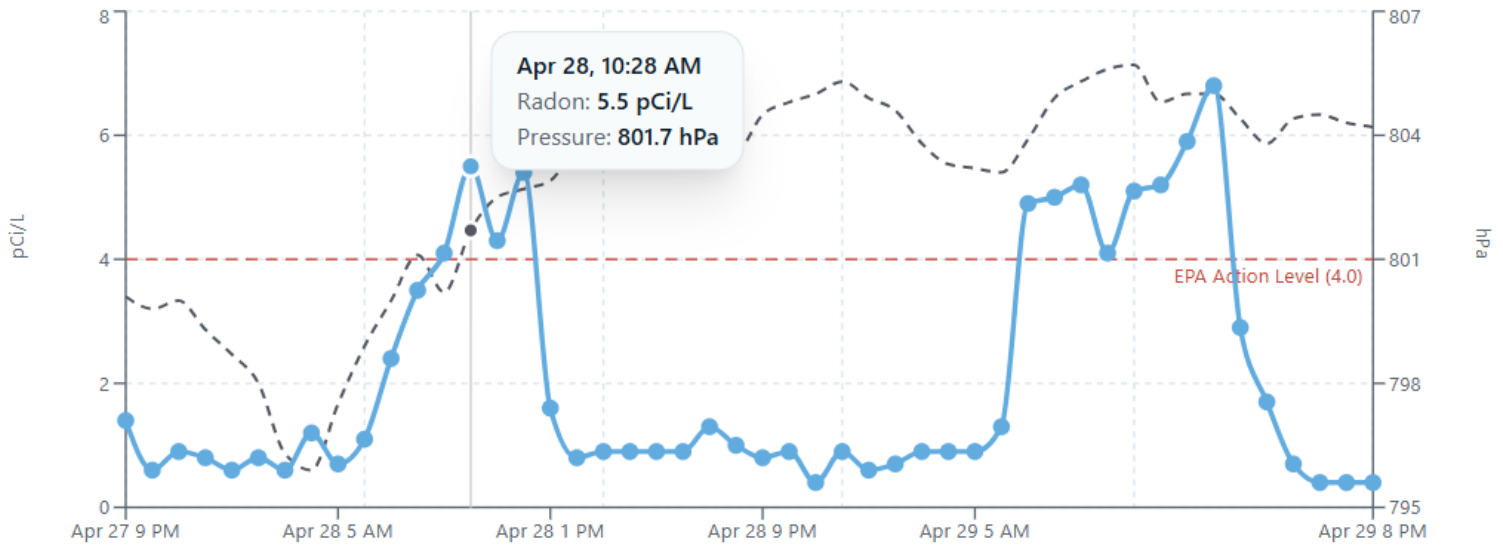
AARST §B-3.2 climate baseline · Castle Rock, CO

Average Annual Outdoor Temperature (Decadal Baseline) 10-year reanalysis average	47.6 °F
Average Outdoor Temperature During Test	41.7 °F
Prevailing Operating Condition (Heating / Cooling / Mixed)	Heating
Water table elevation (general status) – per USGS WaterWatch baseline	Low **Average** High

North High-Denver Room C130

Radon concentration trend

Radon (pCi/L) vs. outdoor barometric pressure (hPa)



Occupied vs. Unoccupied

Average exposure breakdown

Occupied Periods avg
7:00 AM – 4:00 PM (18 readings)
4.1 pCi/L

Unoccupied (Setback) avg
4:00 PM – 7:00 AM (30 readings)
0.9 pCi/L

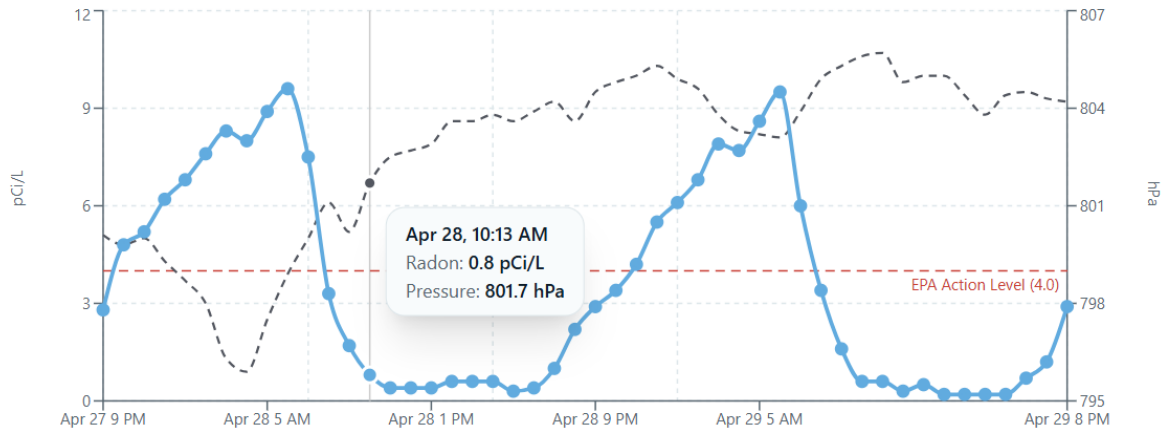
Peak reading

6.8 pCi/L

at Apr 29, 2:28 PM

Radon concentration trend

Radon (pCi/L) vs. outdoor barometric pressure (hPa)



Occupied vs. Unoccupied

Average exposure breakdown

pCi/L

Occupied Periods avg
7:00 AM – 4:00 PM (18 readings) — **1.6 pCi/L**

Unoccupied (Setback) avg
4:00 PM – 7:00 AM (30 readings) — **4.7 pCi/L**

Peak reading

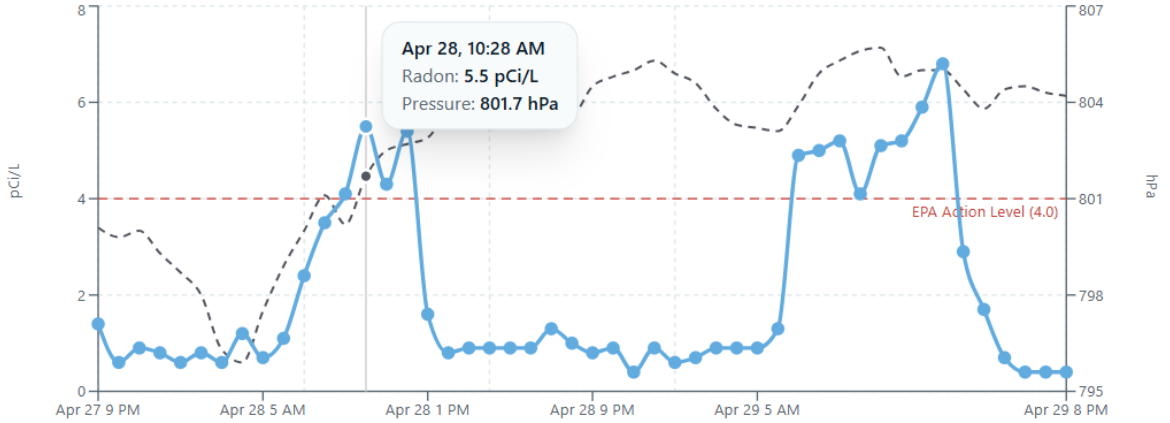
9.6 pCi/L

at Apr 28, 6:13 AM

North High-Denver
Room C163C

Radon concentration trend

Radon (pCi/L) vs. outdoor barometric pressure (hPa)



Occupied vs. Unoccupied

Average exposure breakdown

pCi/L

Occupied Periods avg
7:00 AM – 4:00 PM (18 readings) — **4.1 pCi/L**

Unoccupied (Setback) avg
4:00 PM – 7:00 AM (30 readings) — **0.9 pCi/L**

Peak reading

6.8 pCi/L

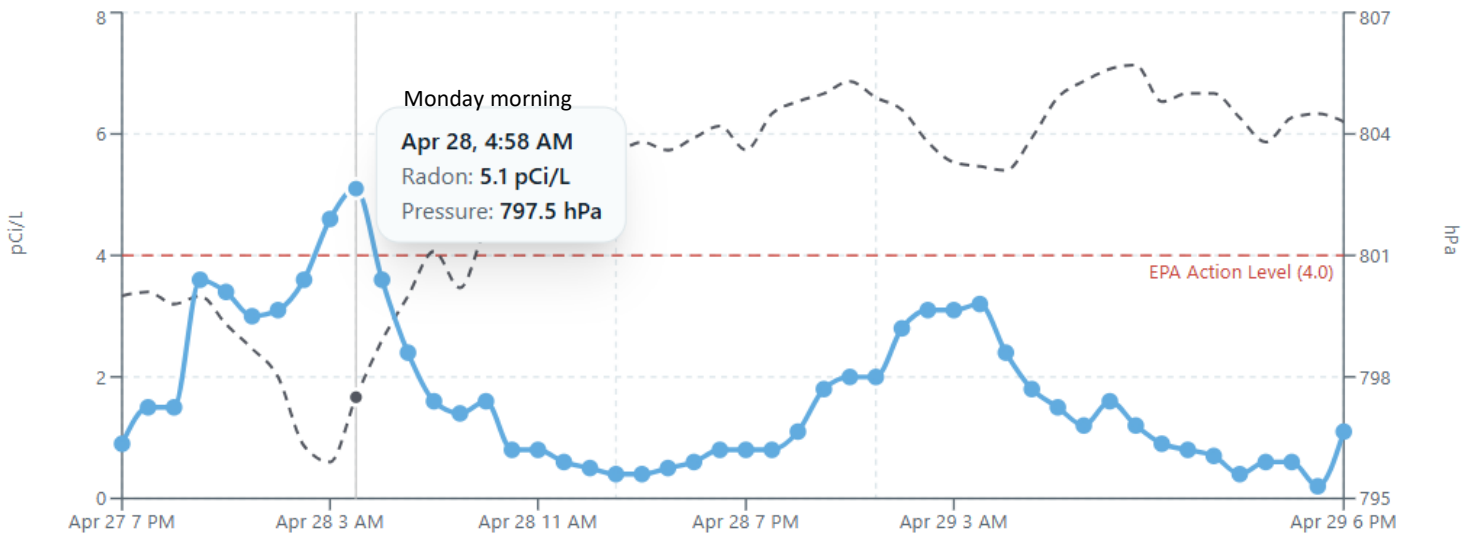
at Apr 29, 2:28 PM

North High-Denver
Room C130

North High-Denver Room A103D 1.7 pCi/L

Radon concentration trend

Radon (pCi/L) vs. outdoor barometric pressure (hPa)



Occupied vs. Unoccupied

Average exposure breakdown

Occupied Periods avg
7:00 AM – 4:00 PM (18 readings)
0.9 pCi/L

Unoccupied (Setback) avg
4:00 PM – 7:00 AM (30 readings)
2.2 pCi/L

Peak reading
5.1 pCi/L
at Apr 28, 4:58 AM

Atmospheric & Structural Diagnostics

Open-Meteo historical weather · Castle Rock, CO

Ventilation-driven diurnal cycle

Diagnostic Notice: Although a 4.2 hPa barometric drop coincided with the 5.1 pCi/L peak, radon levels show a pronounced day/night swing (87.4% variance) that repeats beyond the pressure event — concentrations climb overnight when the air handler is off and fall during occupied daytime hours. This recurring pattern points to HVAC/ventilation scheduling as the dominant mechanism rather than a purely pressure-driven sub-slab migration. The barometric pressure declined gradually across the entire deployment (with minor rises in between) rather than as a single rapid drop-and-recover, so the overall average is not biased by a one-off transient event. Peak outdoor winds over the deployment reached 14 mph sustained winds.

Pre-spike pressure change	Peak wind (sustained / gust)	Precipitation (12h window)	Test duration
4.2 hPa	14 mph / 25 mph	17.1 mm	2 days

North High-Denver Room A103D 1.7 pCi/L

HVAC Performance & Dilution Analytics

Flush performance based on observed weekday HVAC Off → On decline

Closure scenario — longer closures accumulate higher starting levels.

Standard Weekend | 3-Day Weekend | Extended Break

Estimated Dilution Rate
1.5 pCi/L per hour
Steepest decline at Tue 5:58 AM

Total Clearance Required
4.2 pCi/L
Projected peak 8.2 → 4.0 target

Total Flush Duration
2h 48m
Startup Tue 5:11 AM

Projected 3-day weekend peak: 8.2 pCi/L — observed weekend peak 5.1 pCi/L plus the measured overnight buildup rate (0.20 pCi/L per closed hour) extrapolated over the extra closed days, capped at a saturation plateau.

View Formula Breakdown

Tuesday Morning Step-Down Timeline

Hourly countdown from recommended HVAC startup — **3-Day Weekend**

TIME	STAGE	RADON
Tue 5:11 AM	Startup	**8.2 pCi/L**
Tue 6:11 AM	Hour 1	**6.7 pCi/L**
Tue 7:11 AM	Hour 2	**5.2 pCi/L**
Tue 7:59 AM	Target Reached Safe / Occupancy Ready	**4.0 pCi/L**

Conclusions

- **High-Resolution Visibility Matters:**
  - Continuous hourly data & software analysis reveal true occupant exposure, separating daytime occupied levels from overnight setback buildup.
- **HVAC Systems as Primary Mitigation Tools:**
  - Simple adjustments to air handler run times, fresh-air dampers, and flush schedules can eliminate elevated levels without costly sub-slab depressurization.
- **Operational & Compliance Efficiency:**
  - Rapid, single-deployment testing compliant with ANSI/AARST standards eliminates secondary confirmatory test delays and laboratory turnaround bottlenecks.
- **Immediate On-Site Verification:**
  - On-site data retrieval enables immediate re-testing or schedule adjustments while testing teams are still on facility grounds

80 schools tested w/CRMs

52 schools tested w/CRMs

62 schools tested w/CRMs

10 schools tested w/CRMs

QUESTIONS?

2 schools tested w/CRMs

20 schools tested w/CRMs

14 schools tested w/CRMs

1 school tested w/CRMs