

St. Clairsville, OH Carbon Dioxide Gas Investigation and Remediation

February 2025 – May 2025

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Disclaimer

- This presentation describes a site-specific response to a unique **fugitive gas** incident and is provided solely for informational purposes.
- The approach outlined herein was developed based on the particular facts and conditions present at the time and **does not** represent an official policy, position, or recommendation of the Office of Surface Mining (OSM) or the U.S. Department of the Interior.



Disclaimer (cont'd)

- Nothing in this presentation should be construed as technical guidance, nor should any individual or entity attempt to replicate the measures described here without an appropriate professional evaluation.
- **OSM** expressly disclaims any implication that reversing, modifying, or otherwise altering radon ventilation systems is advisable in any other circumstance.



Request for Assistance

- Ohio Department of Natural Resources (ODNR) requested assistance to investigate **elevated carbon dioxide (CO₂) with low oxygen (O₂)** at a residence on February 18, 2025.
- ***Issue was brought to ODNR's attention due to a report a resident almost fainted due to low oxygen in their basement.***
 - The initial O₂ in the house was between 19.3-20.9%.
 - The CO₂ in the house was elevated.
- Successful remediation means (INDOOR) oxygen levels above 19.5% (MSHA) ~20%, for 4 weeks (~ 1 month).



Atmospheric Air Percent by Volume

- Nitrogen - 78% by volume
- Oxygen – 20.5 - 20.9% by volume
- Argon - 0.93% by volume
- Carbon Dioxide – 0.03 - 0.04% by volume
 - CO₂ is often measured in parts per million (ppm). The equivalent is 300 - 400 ppm.
 - CO₂ is denser than O₂ and is usually found near the ground in unmixed environments.



Effects of Low Oxygen

Oxygen (%vol)	Effects & Symptoms
23.5	Maximum "Safe Level" (23% is often the High level alarm of most O ₂ detectors)
21	Typical O ₂ concentration in air
19.5	Minimum "Safe Level" (19% is often the Low level alarm of most O ₂ detectors)
15-19	First sign of hypoxia. Decreased ability to work strenuously. May induce early symptoms in persons with coronary, pulmonary or circulatory problems
12-14	Respiration increases with exertion, pulse up, impaired muscular coordination, perception and judgment
10-12	Respiration further increases in rate and depth, poor judgment, lips blue
8-10	Mental failure, fainting, unconsciousness, ashen face, blueness of lips, nausea, vomiting, inability to move freely
6-8	6 minutes - 50% probability of death 8 minutes – 100% probability of death
4-6	Coma in 40 seconds, convulsions, respiration ceases, death



Carbon Dioxide Exposures

Concentration of Carbon Dioxide in Air (percent by Volume)	Maximum Exposure Limit (Minutes)
<i>0.5</i>	<i>indefinite</i>
<i>1.0</i>	<i>indefinite</i>
<i>1.5</i>	<i>480</i>
<i>2.0</i>	<i>60</i>
<i>3.0</i>	<i>20</i>
<i>4.0</i>	<i>10</i>
<i>5.0</i>	<i>7</i>
<i>6.0</i>	<i>5</i>
<i>7.0</i>	<i>Less than 3</i>



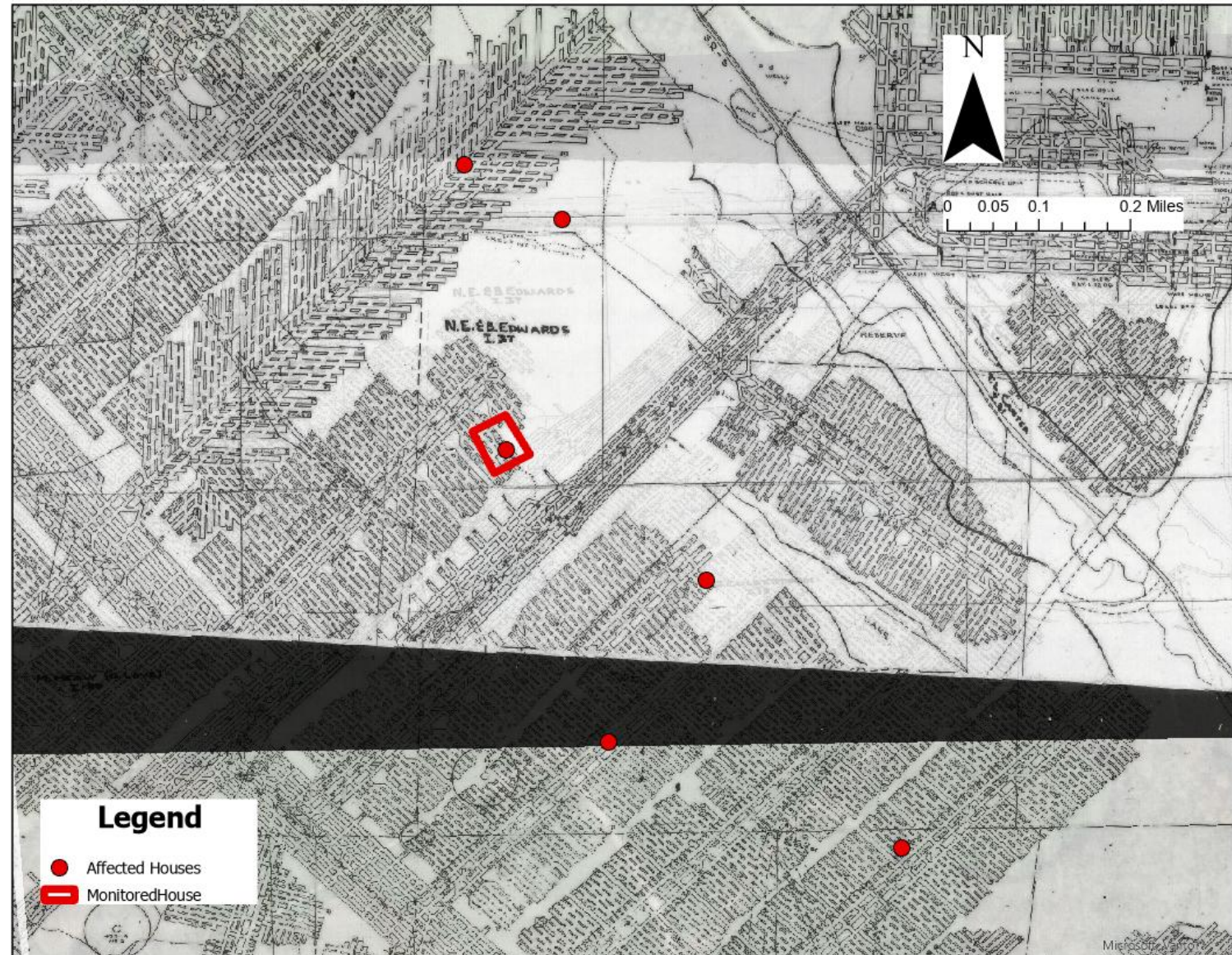
<https://www.epa.gov/sites/production/files/2015-06/documents/co2appendixb.pdf>.

St. Clairsville, OH



Underground Mine Map

- Pittsburgh Coal Seam #8
- 1980



Surface Coal Mine Map



- Pittsburgh Coal Seam #8 and #9
- Surface Mine
 - Map of Surface Disturbance
- Permit from 1983



CO₂ in Abandoned Coal Mines

- Coal and other organics when in the presence of O₂ produce CO₂ as they oxidize.
- This happens at relatively *low temperatures*.
 - Below 100 degrees F.



Abandoned Coal Mine Ventilation

- Underground Void Space interacts with the environment.
- Barometric pressure changes affect air density.
 - When the barometric pressure decreases, the volume of gas in the void space expands while the volume of gas contracts when the barometric pressure increases
- The void space is breathing in and out.



CO₂ and Reclaimed Land

- The site had Underground and Surface Mining. The underground void was daylighted during surface mining.
- There is no underground void for CO₂. All accessible coal at the site has been removed.



Unintended Consequences

- A major concern with abandoned coal mines is the production of acid.
- To neutralize the production of acid;
 - Limestone is generally added to the fill.
 - $\text{CaCO}_3 + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2 + \text{CO}_2$
 - We have neutralized the acid but we inadvertently are producing CO_2 .
 - This is not a huge issue as long as the land remains undeveloped.
 - Issue when we develop the land.
 - This can be an issue for houses with basements on early era reclaimed mine land.



Can we tell the difference?

- Organic sources of CO₂
 - Coal + O₂ → CO₂ + heat
- Inorganic sources of CO₂
 - $\text{CaCO}_3 + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{CO}_2$



Isotopic Analysis

- CO₂ derived from organic substrates by microbial activity is enriched in ¹²C.
 - Oxidizing coal
- Whereas CO₂ derived from carbonate materials is enriched in ¹³C.
 - Limestone reaction

Table 1. Variations in $\delta^{13}\text{CO}_2$ from Different Sources*

Atmospheric CO ₂	– 8 ‰
Volcanic degassing	– 8 ‰
Thermal destruction of carbonates	+4 to – 5 ‰
Thermal degradation of organic matter	– 8 to – 12 ‰
Bacterial oxidation of methane	– 20 to – 59 ‰
CO ₂ in coal bed gases	+ 18.6 to – 26.6 ‰

*Data from Rice (1993), Hunt (1996), and Hoefs (1997).

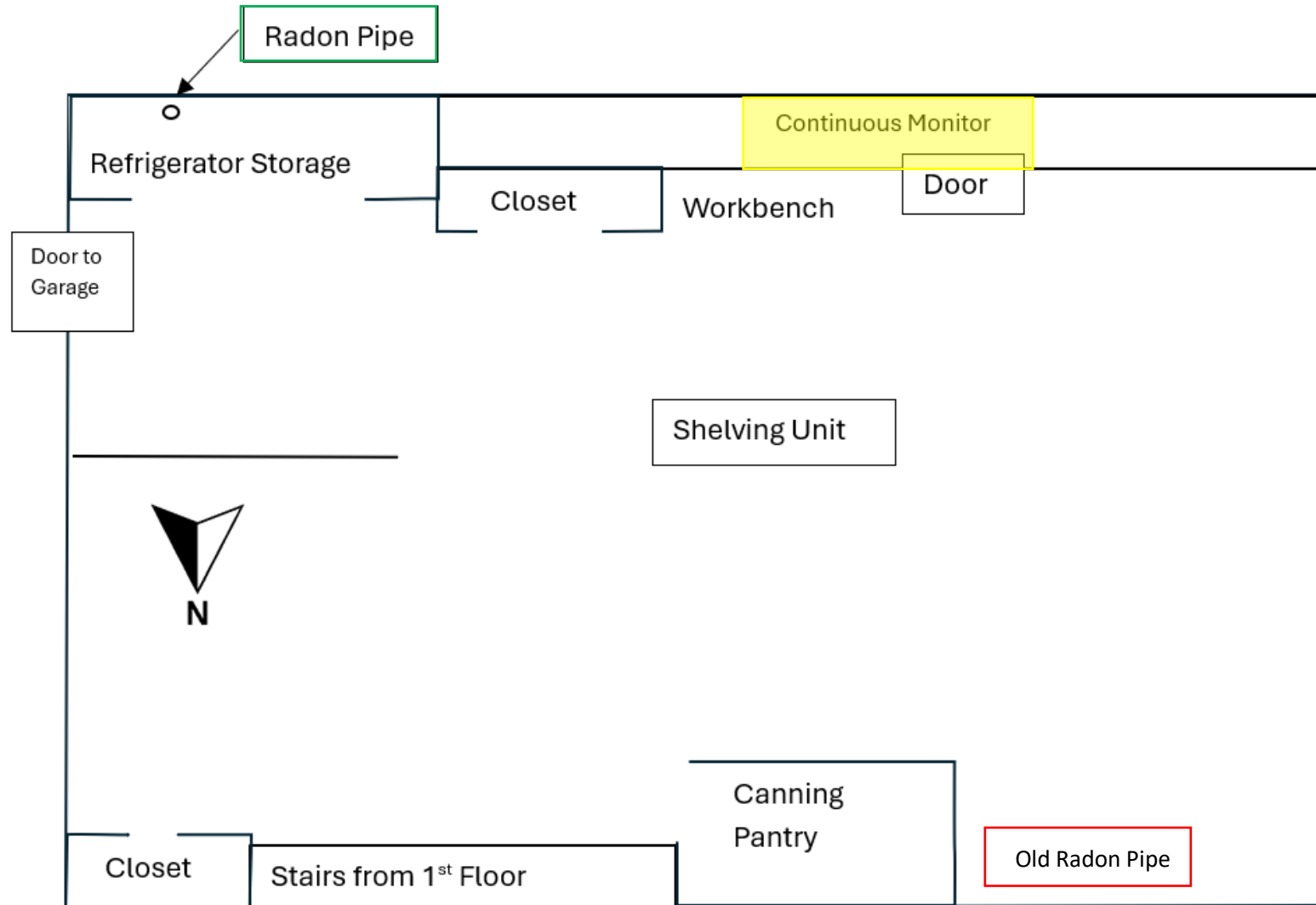


Methodology

- A gas meter was placed inside the residence to record gas values every 10 minutes during the investigation. Since CO₂ is heavier than O₂, the gas meter was placed in the **basement**. Barometric pressure was tracked during the investigation.
- Spot gas samples were taken around the property and in the residence.



Basement Layout

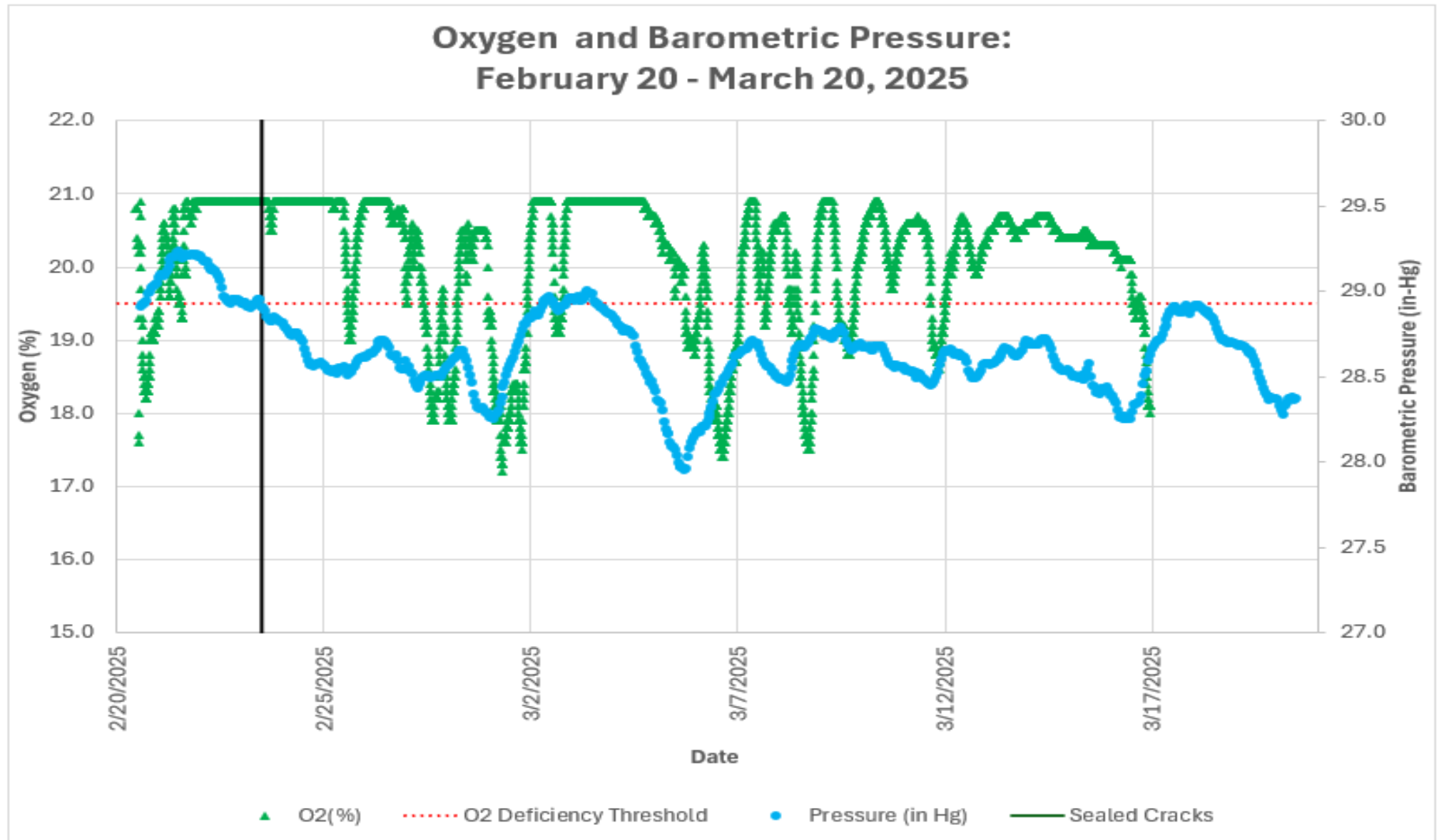


Indoor (Basement) Samples from 2/20/25

Date	Time	Location	O ₂ (% volume)	CO ₂ (% volume)
2/20/2025	11:00 AM	Steps	20.9	0.22
2/20/2025	11:01 AM	Closet	20.5	0.36
2/20/2025	11:02 AM	Canning Pantry	20.9	0.16
2/20/2025	11:04 AM	Radon Pipe	16.5	3.21
2/20/2025	11:06 AM	Refrigerator Storage	20.6	0.16
2/20/2025	11:11 AM	Cracks in South Wall by Continuous Monitor	19.3	1.48
2/20/2025	11:19 AM	East Wall	20.2	0.22
2/20/2025	11:22 AM	North Wall (old radon pipe)	19.6	0.84
2/20/2025	11:25 AM	Plugged Pipe in Refrigerator Storage	20.2	0.22
2/20/2025	11:27 AM	Steps to Garage	20.9	0.00

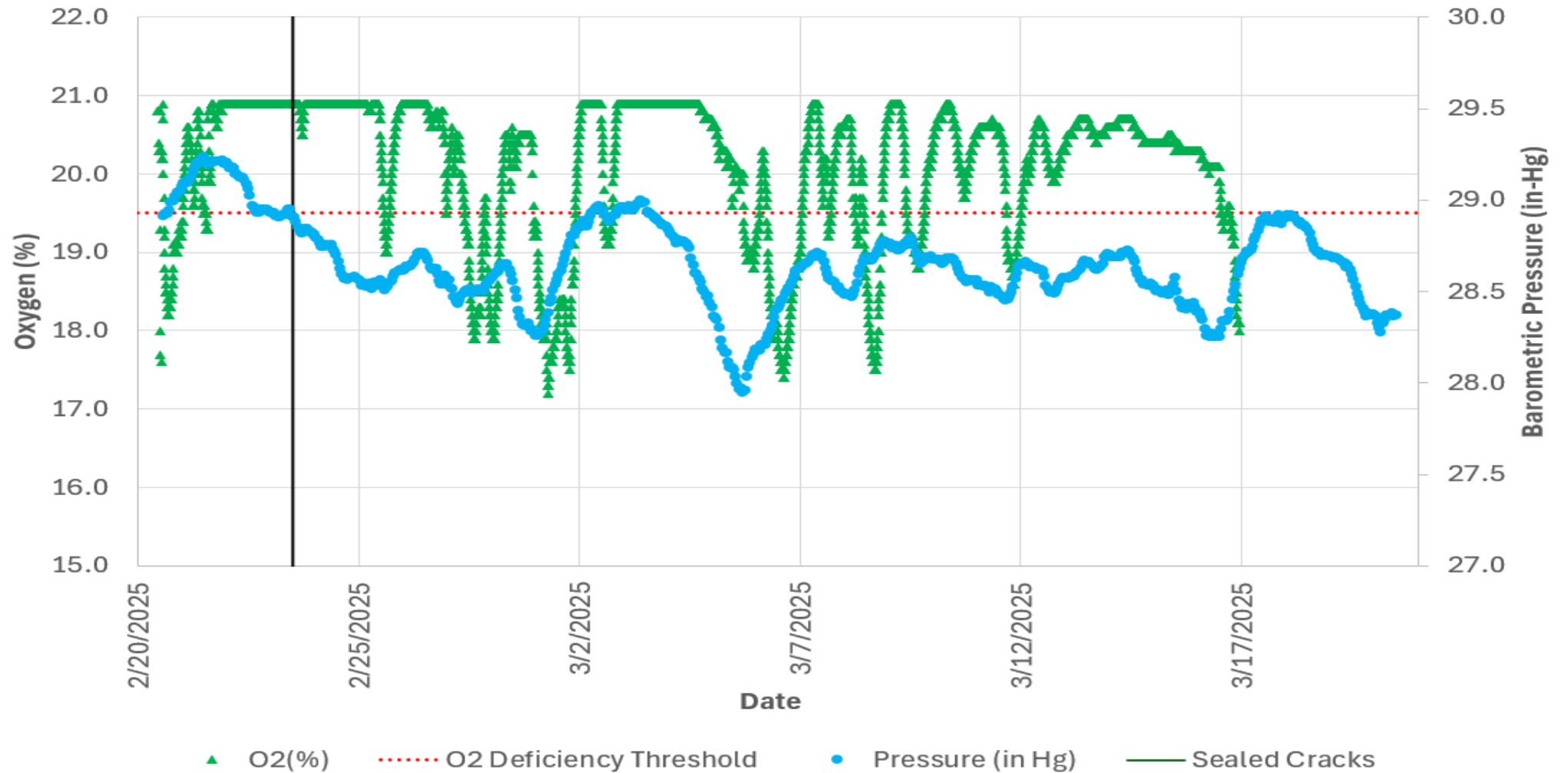


Indoor Long-term Monitoring



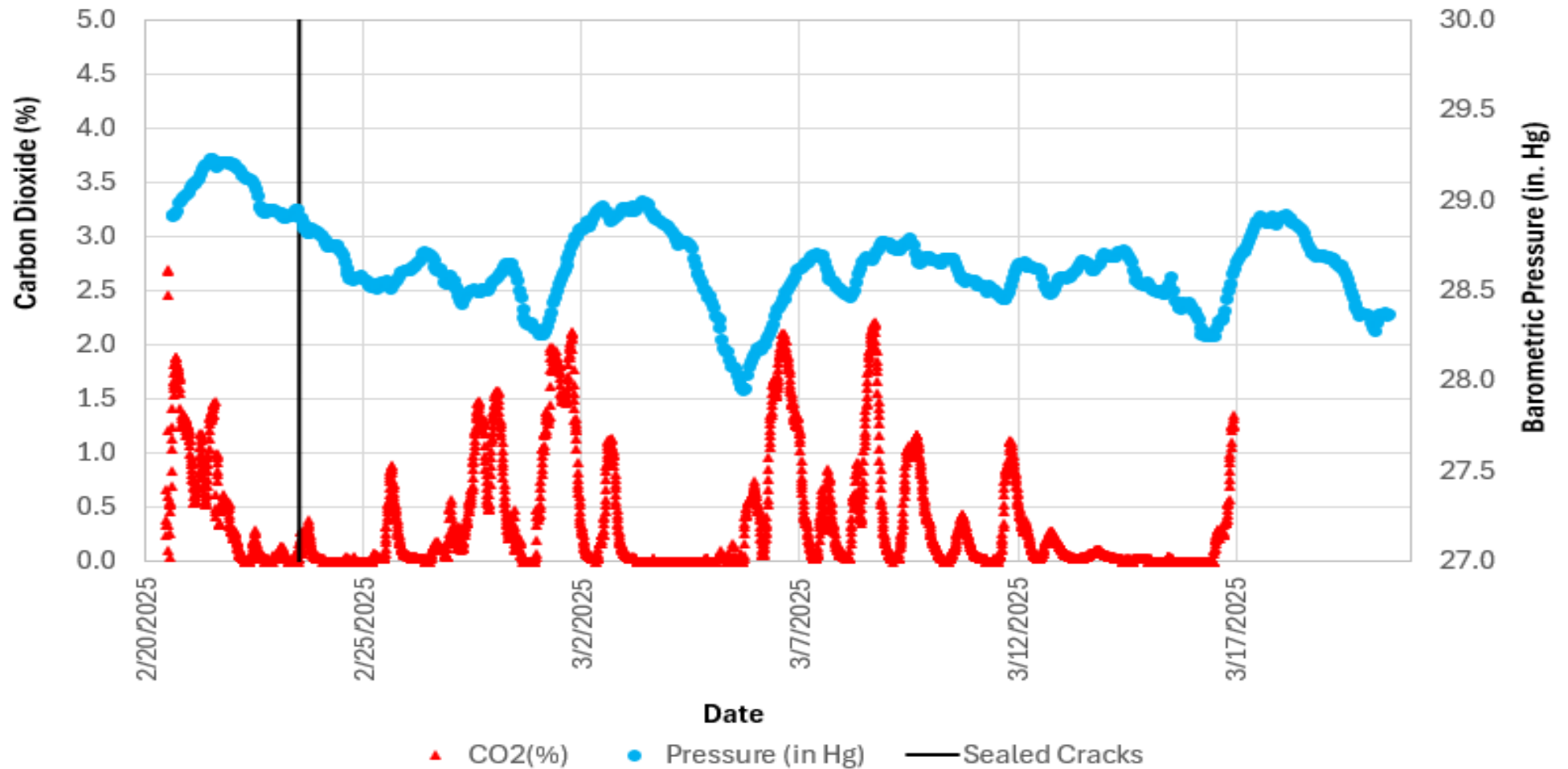
Indoor Long-term Monitoring

Oxygen and Barometric Pressure:
February 20 - March 20, 2025



Indoor Long-term Monitoring

**Carbon Dioxide and Barometric Pressure:
February 20 - March 20, 2025**



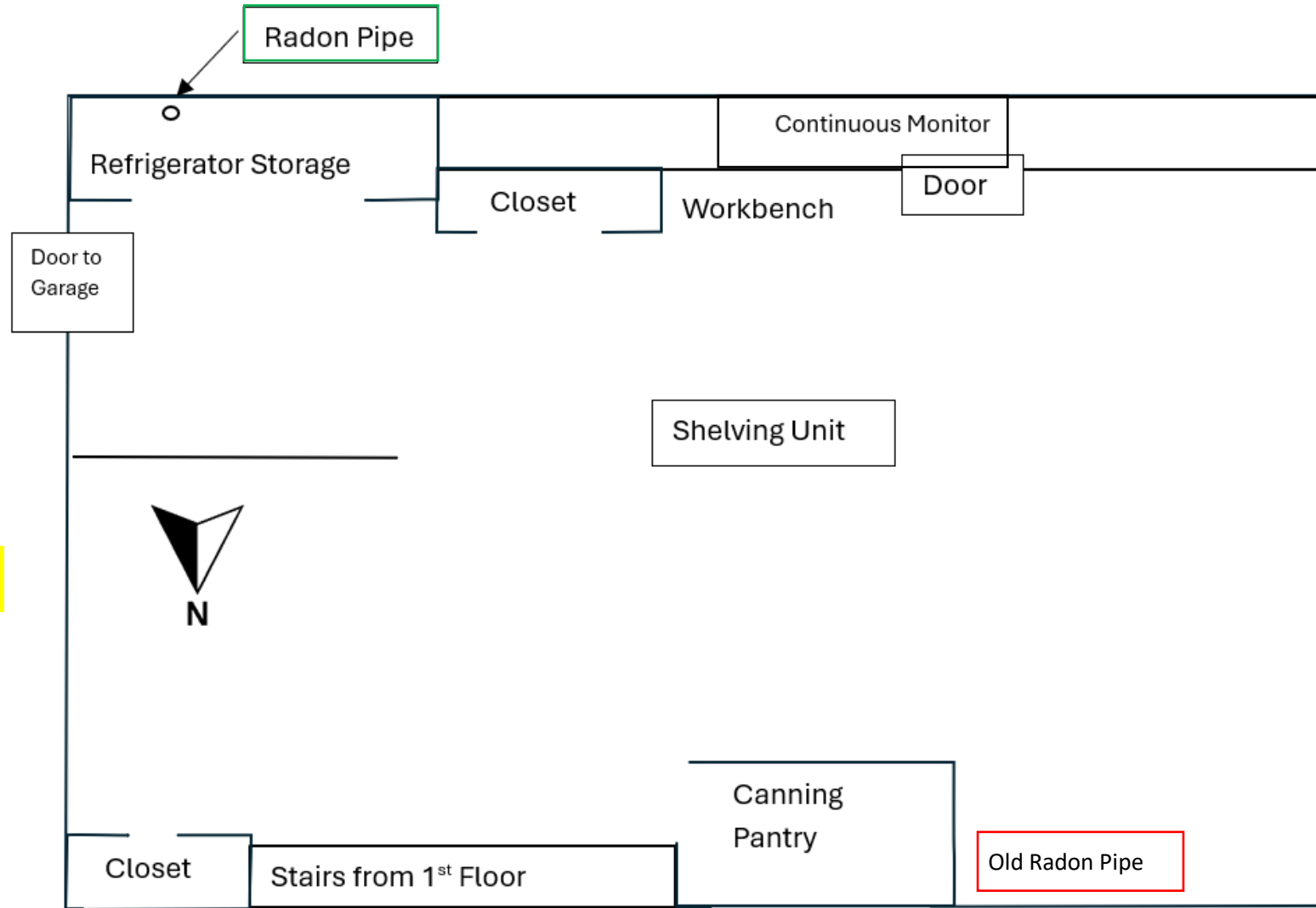
Spot Gas Readings: Inside Basement and Outside 4/3/2025



Date	Time	Location	O ₂ (% volume)	CO ₂ (% volume)
4/3/2025	10:45 AM	Radon Pipe	15.7	4.00
4/3/2025	11:12 AM	Radon Pipe (East Side of House)	20.1	0.60
4/3/2025	11:21 AM	Radon Pipe (Near Basement Stairs)	20.4	0.40
4/3/2025	11:35 AM	Drive Bar Sample (North Side of House)	20.9	0.28
4/3/2025	11:41 AM	Drive Bar Sample (West Side of House)	20.9	0.02
4/3/2025	11:45 AM	Drive Bar Sample (South Side of House by Back Stairs)	20.9	0.02
4/3/2025	11:51 AM	Drive Bar Sample (South Side of House by Radon Fan)	20.6	0.00
4/3/2025	11:56 AM	Drive Bar Sample (East Side of House by Trampoline)	15.2	2.90
4/3/2025	11:59 AM	Drive Bar Sample (East Side of House by Road to Greenhouse)	20.5	0.00
4/3/2025	12:10 PM	Drive Bar Sample (Northeast Side of House)	19.5	0.00
4/3/2025	12:15 PM	Drive Bar Sample (Southeast Side of House)	20.9	0.00



Basement Layout



Trampoline



Remediation

- Sealing the cracks in the basement was ineffective.
- O₂ concentration still regularly fell below 19.5%.
- After consultation with PA-BAMR, they suggested reversing the radon fan.
- The basement is a low pressure zone attracting the low O₂/high CO₂.
- Reversing the radon fan creates a high pressure zone around the foundation of the house which should prevent the low O₂/high CO₂ from entering the basement.



When to reverse the radon fan?

- This is more effective in newer constructed houses built on gravel foundations.
- Gravel foundations have more void space so the high-pressure bubble can impact a larger area.
- For older homes on dirt foundations, the practice would be less effective.
- Usually, an exhausting radon fan would be most effective.
- Dirt foundations have less void space, so radon fans have smaller impact area.

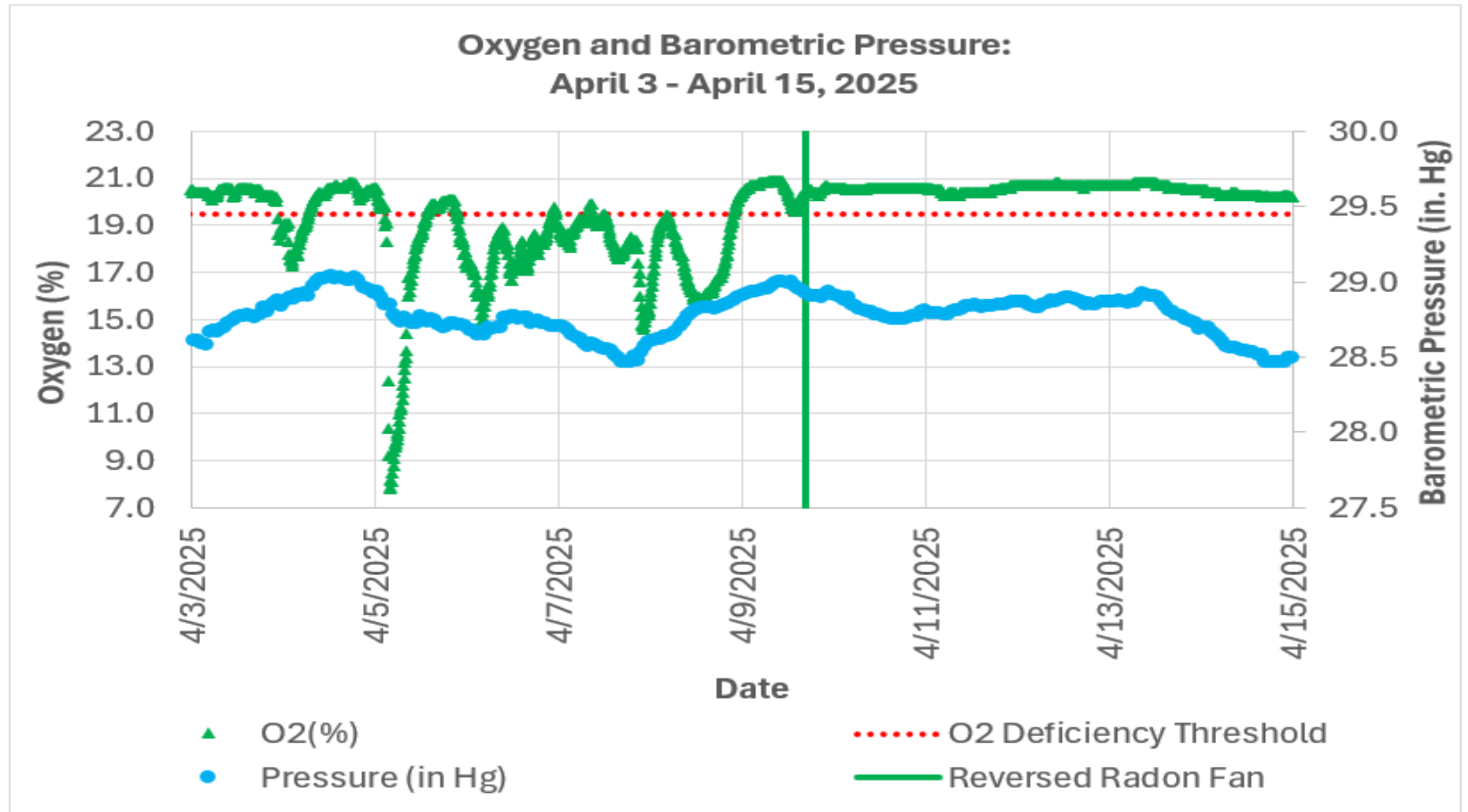


Reversing the Radon Fan

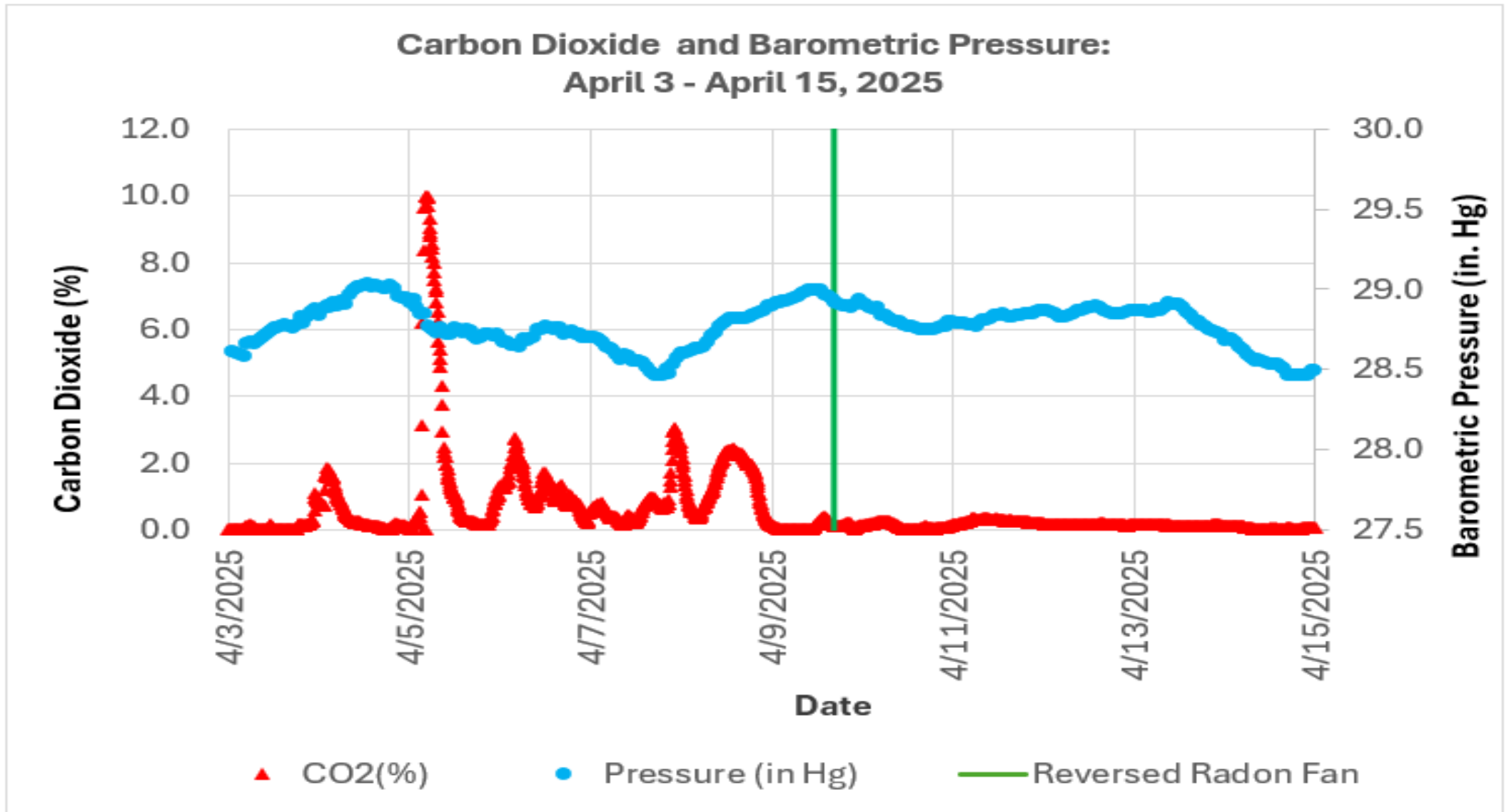
- ODNR passed the recommendation to the homeowner.
- Radon fan usually installed with rubber couplings.
 - Usually, a simple job.
- On April 9, 2025, the homeowner reversed the radon fan.
- Gas Monitoring continued to determine effectiveness.



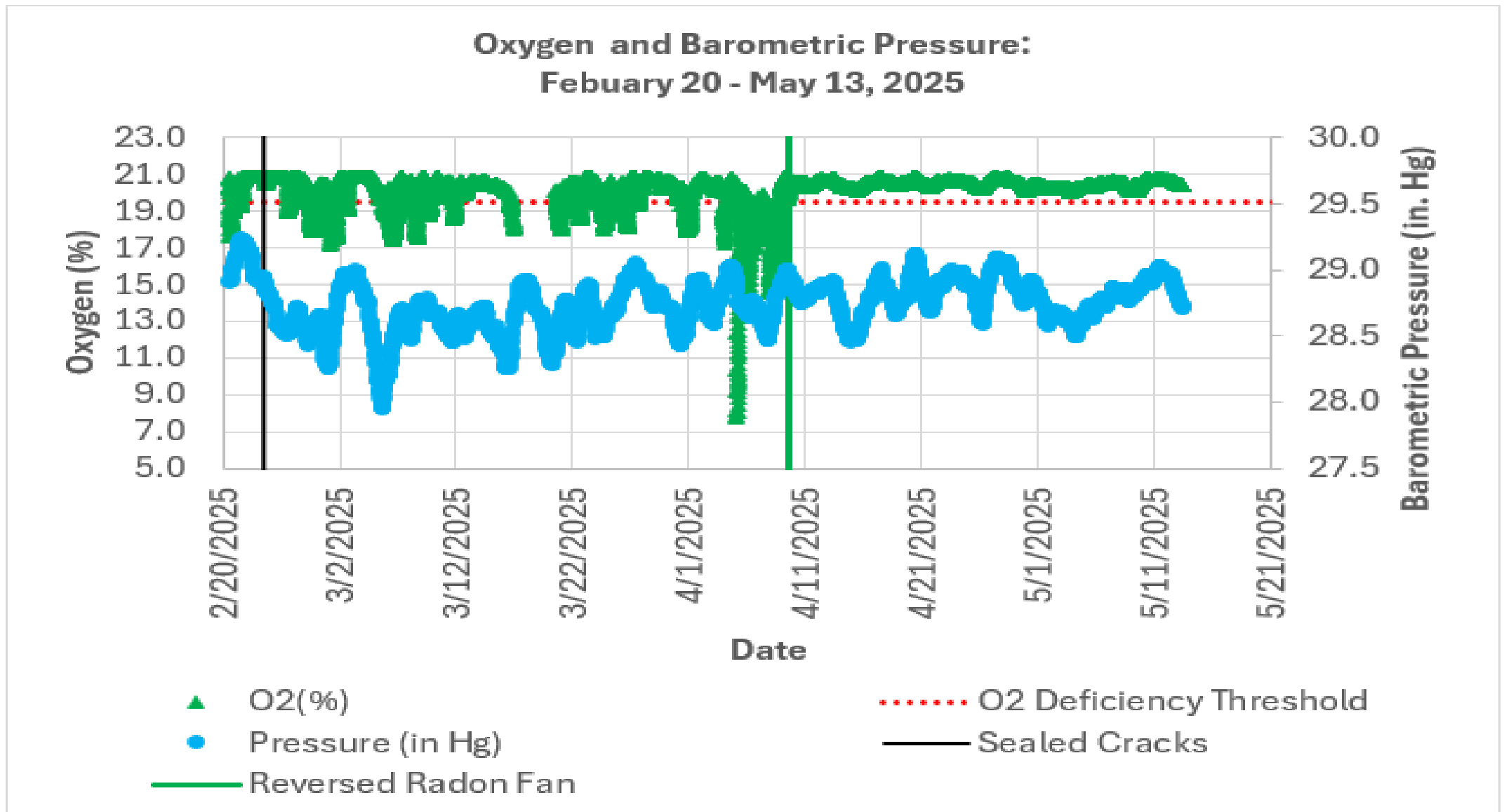
Remediation Plan Effectiveness



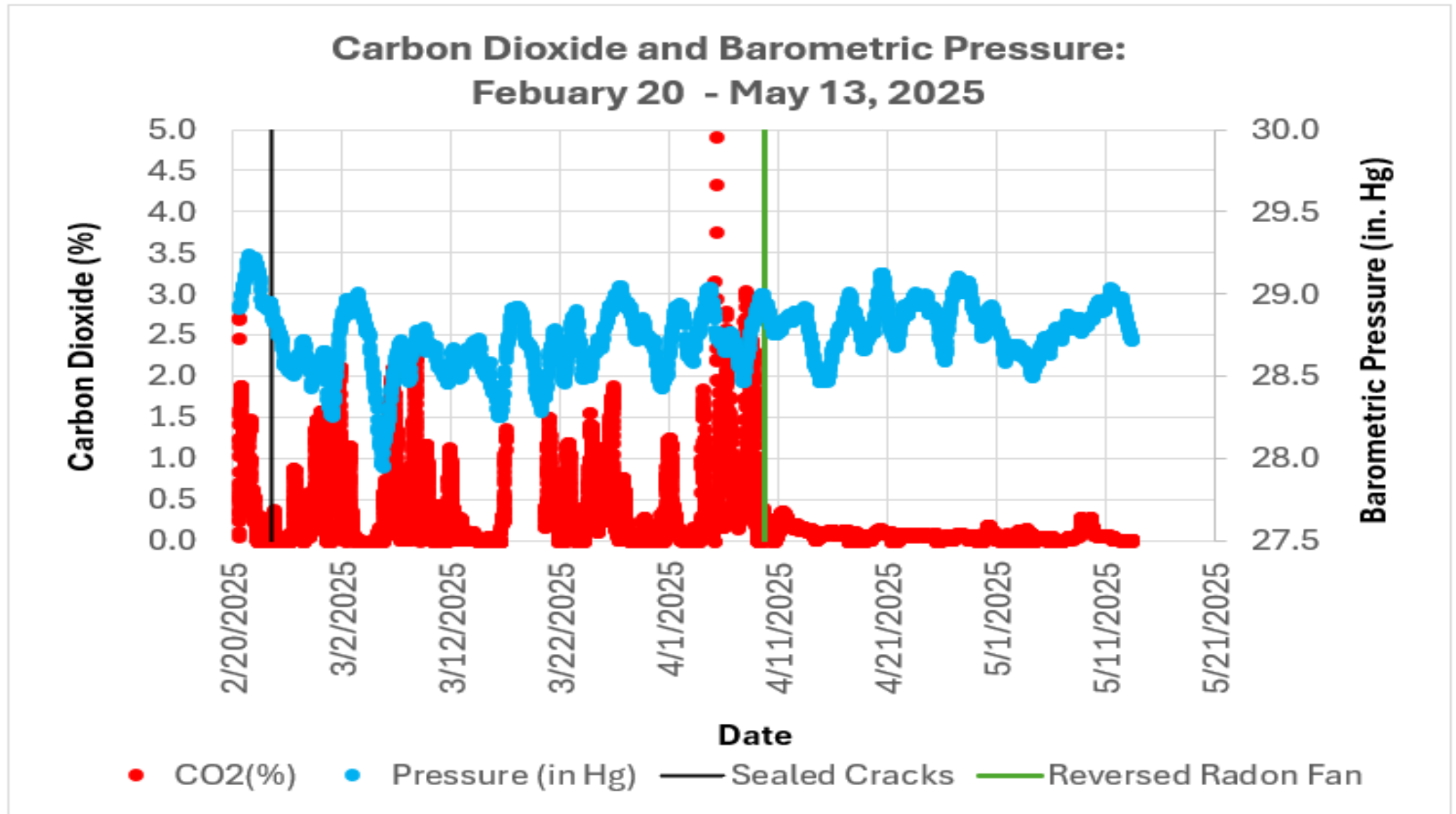
Remediation Plan Effectiveness



Complete Long-Term Data



Complete Long-Term Data



Conclusions

- Long-term gas monitoring was discontinued on May 13, 2025.
- **The O₂ levels remained above 19.5% (20%) for approximately 30 days (April 9 – May 13, 2025).**
- The CO₂ levels were below the EPA's recommended level of 1.0% for approx. 30 days.
- **Special thanks are extended to ODNR for allowing OSM to share their mine gas remediation project with the reclamation community.**
- **Special thanks are also extended to PADEP-BAMR (Art Crossman) for suggesting the reversal of the radon fan.**
- Reversing the radon fan created a high-pressure zone around the foundation of the house. This high-pressure zone prevented the low O₂/high CO₂ from entering the basement.
- **A lot of cooperation between, State & Federal partners!**



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THANK YOU!

QUESTIONS?

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