

# McDonald, PA Carbon Dioxide Gas Investigation and Remediation

September 2021 – May 2022

*Omar Beckford, Ph.D., P.E.*

*Hydrologist*

*obeckford@osmre.gov*

*Paul Huemmrich, P.E.*

*Civil Engineer*

*phuemmrich@osmre.gov*



# Request for Assistance

- Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation (PA-BAMR) requested assistance to investigate **elevated carbon dioxide (CO<sub>2</sub>) with low oxygen (O<sub>2</sub>)** at a residence on September 7, 2021.
- **Issue was brought to PA-BAMR's attention due to a recent medical emergency.**
  - On September 1, 2021, the resident called for medical attention.
  - Medical attention found that the resident was suffering from **low oxygen**.
  - **The O<sub>2</sub> in the house was between 14-18%.**
  - **The CO<sub>2</sub> in the house was elevated.**
- **Successful remediation means (INDOOR) oxygen levels above 19.5% (MSHA) ~20%.**



# Atmospheric Air Percent by Volume

- Nitrogen - 78% by volume
- Oxygen - 20.9% by volume
- Argon - 0.93% by volume
- Carbon Dioxide – 0.03 - 0.04% by volume
  - CO<sub>2</sub> is often measured in parts per million (ppm). The equivalent is 300 - 400 ppm.
  - CO<sub>2</sub> is denser than O<sub>2</sub> and is usually found near the ground in unmixed environments.



# CO<sub>2</sub> in Abandoned Coal Mines

- Coal and other organics when in the presence of O<sub>2</sub> produce CO<sub>2</sub> 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.



# Effects of Low Oxygen

| Oxygen (%vol) | Effects & Symptoms  |
|---------------|---|
| 23.5          | Maximum "Safe Level" (23% is often the High level alarm of most O <sub>2</sub> detectors)   |
| 21            | Typical O <sub>2</sub> concentration in air   |
| 19.5          | Minimum "Safe Level" (19% is often the Low level alarm of most O <sub>2</sub> 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<br>8 minutes – 100% probability of death   |
| 4-6           | Coma in 40 seconds, convulsions, respiration ceases, death  |



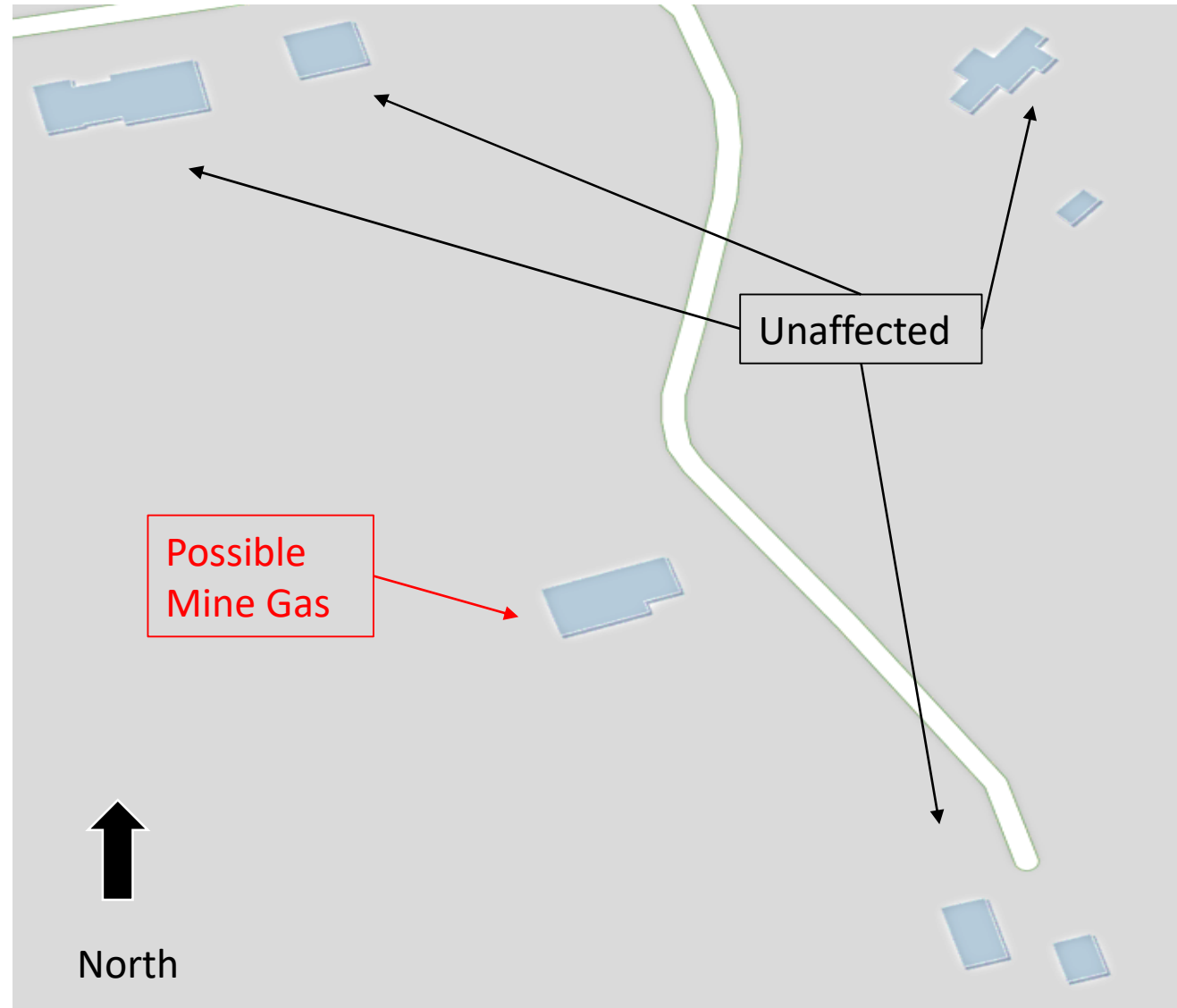
# Carbon Dioxide Exposures

| 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>               |





# McDonald, PA





# Coal Mine Map



- Pittsburgh coal seam.
- The last mining in 1937.
- Approximately 30 feet of cover.
- PHUMMIS
  - PA Historic Underground Mine Map Inventory System





# Pathway for Gas



# Methodology

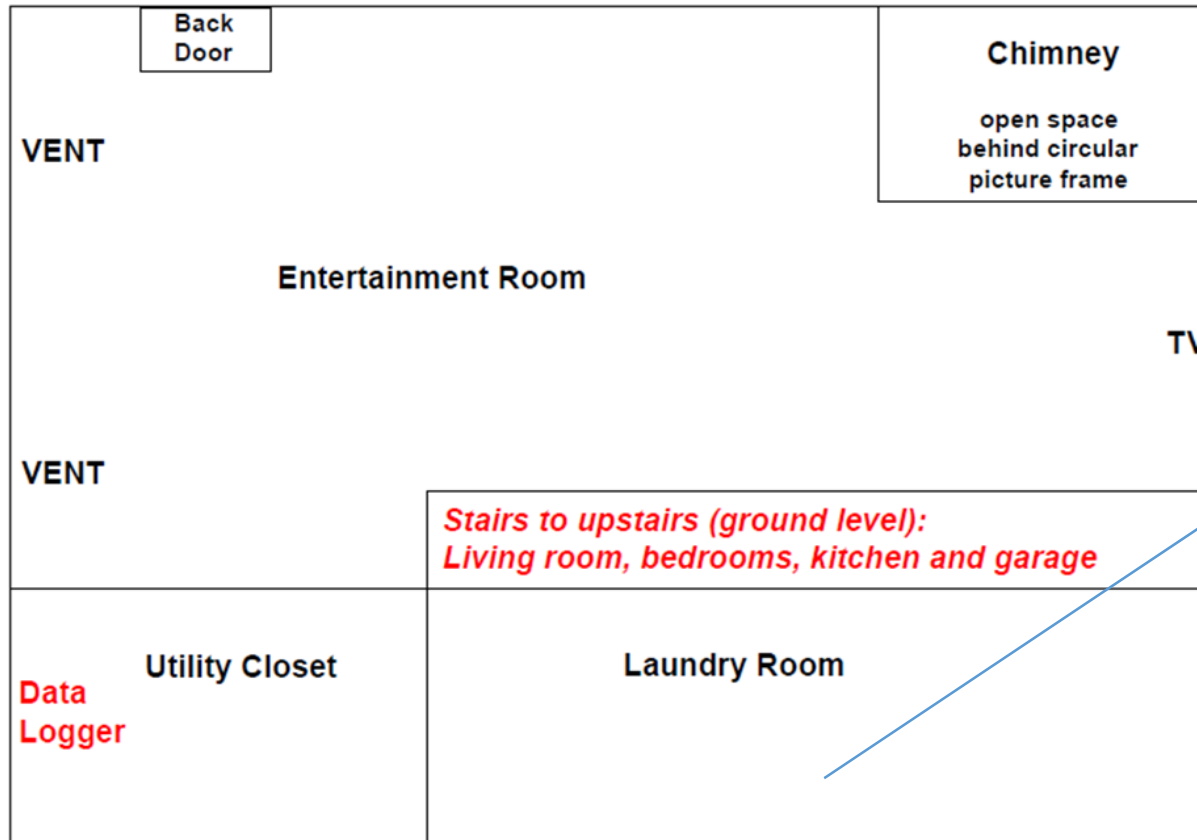
- A gas meter was placed inside the residence to record gas values every 10 minutes during the investigation. Since  $\text{CO}_2$  is heavier than  $\text{O}_2$ , the gas meter was placed in the **basement**. Barometric pressure was tracked during the investigation.
- Spot gas samples were taken around the property and in the residence.





# Indoor (Basement) Samples

| Date              | Time           | CO <sub>2</sub> | O <sub>2</sub> |
|-------------------|----------------|-----------------|----------------|
| 10/1/2021         | 11:05 AM       | 0.37            | 20.6           |
| 10/7/2021         | 9:44 AM        | 0.34            | 20.6           |
| 10/15/2021        | 10:03 AM       | 0.27            | 20.9           |
| 10/22/2021        | 9:29 AM        | 0.27            | 20.9           |
| <b>10/29/2021</b> | <b>9:06 AM</b> | <b>1.52</b>     | <b>19.6</b>    |

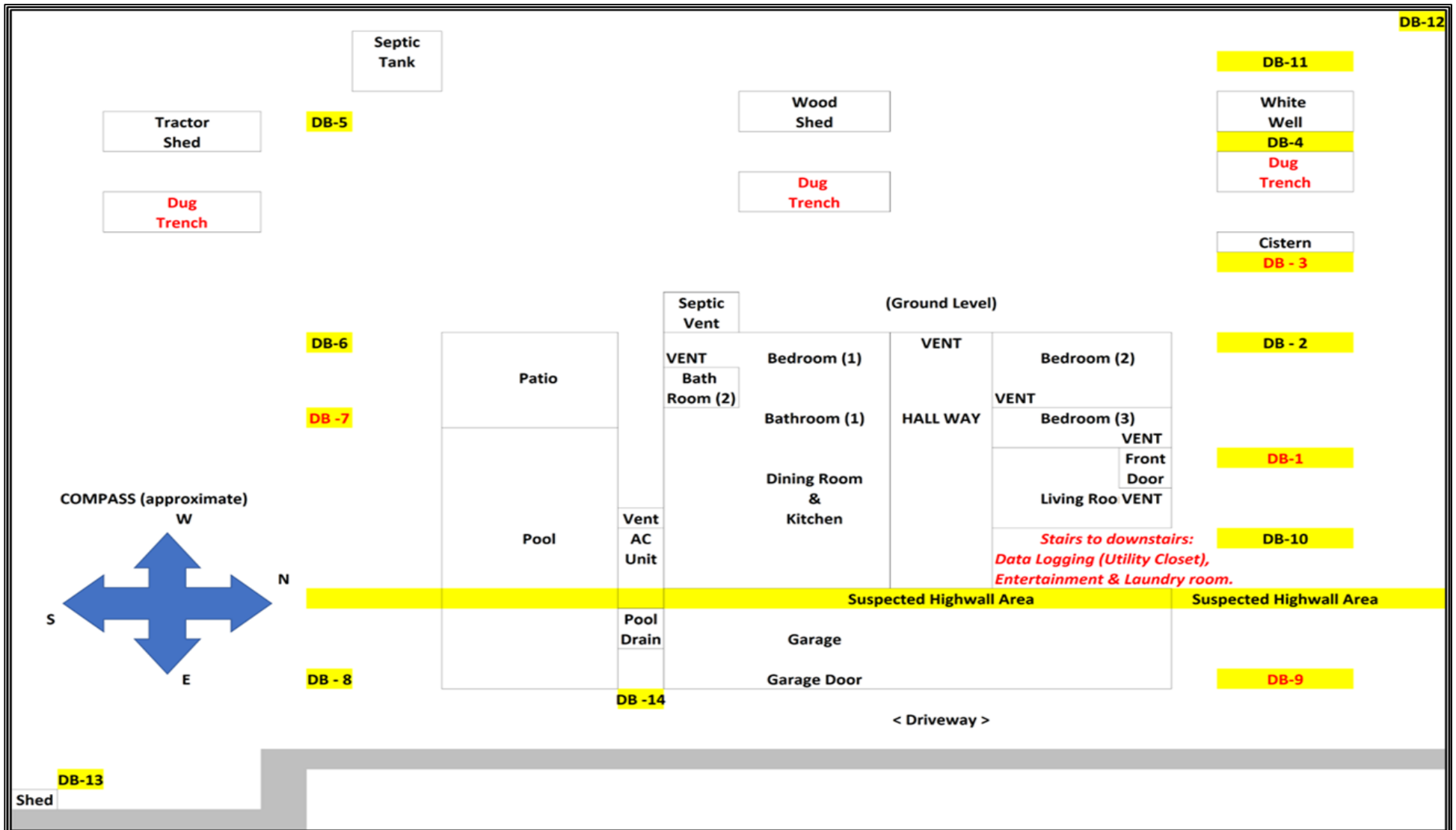




# Dug Trench Samples



# Site Layout – Dug Trench Samples



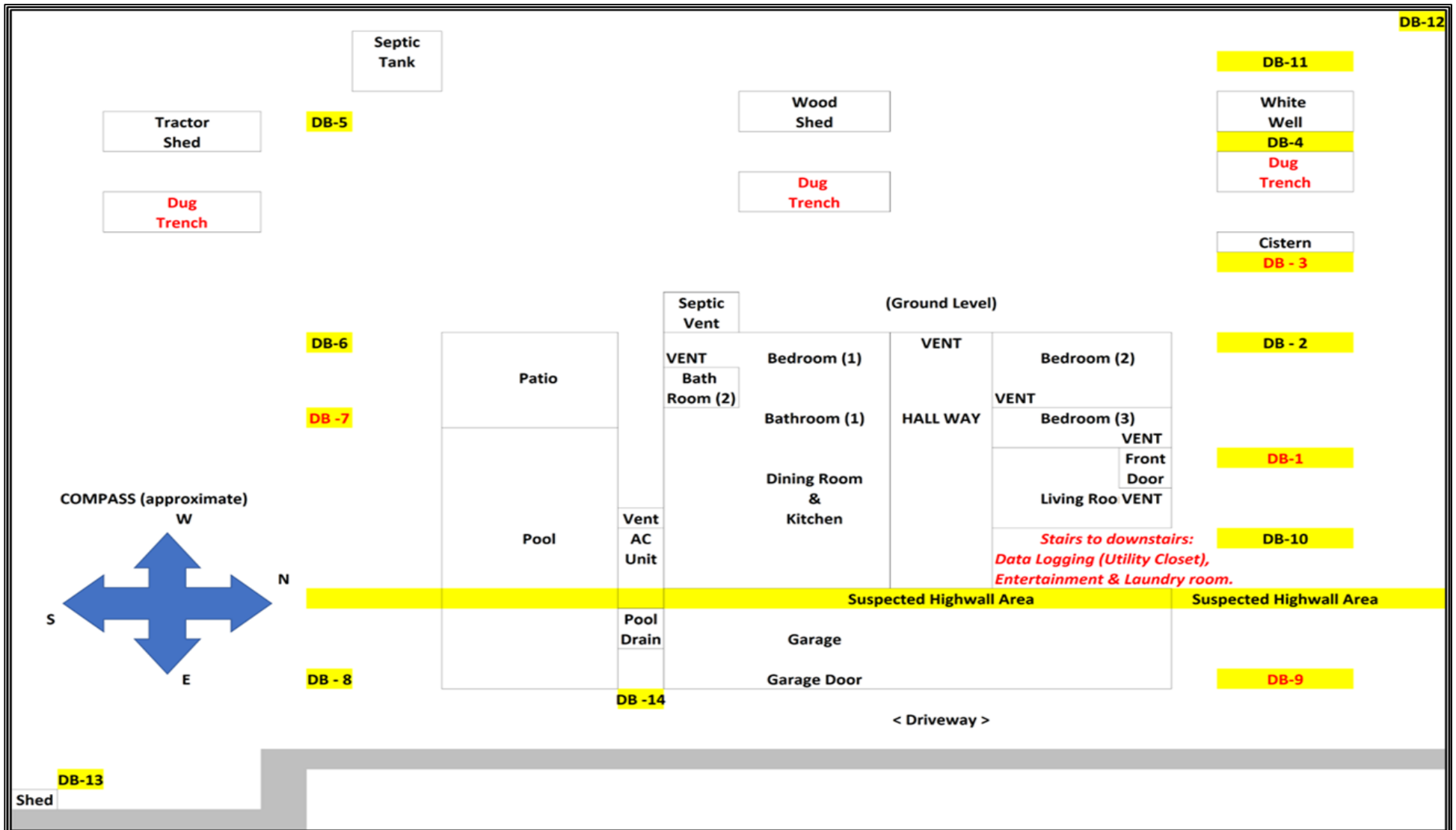


# Dug Trench Samples



| Site                        | Date       | Time     | CO2 % volume | O2 % volume |
|-----------------------------|------------|----------|--------------|-------------|
| Cistern                     | 10/1/2021  | 11:15 AM | 0.39         | 20.9        |
|                             | 10/7/2021  | 9:59 AM  | 0.25         | 20.9        |
|                             | 10/15/2021 | 10:23 AM | 0.35         | 20.9        |
| Dug Trench by White Well    | 10/1/2021  | 11:18 AM | 0.05         | 20.9        |
|                             | 10/7/2021  | 10:04 AM | 0.12         | 20.9        |
|                             | 10/15/2021 | 10:27 AM | 4.9          | 17.4        |
|                             | 10/22/2021 | 9:57 AM  | 0.03         | 20.9        |
|                             | 10/26/2021 | 9:50 AM  | 0.02         | 20.9        |
|                             | 10/28/2021 | 10:12 AM | 0.03         | 20.9        |
| White Well                  | 10/1/2021  | 11:21 AM | 0.04         | 20.9        |
|                             | 10/7/2021  | 10:07 AM | 0.04         | 20.9        |
|                             | 10/15/2021 | 10:35 AM | 0.03         | 20.9        |
| Septic Vent                 | 10/1/2021  | 11:23 AM | 0.04         | 20.9        |
|                             | 10/7/2021  | 10:11 AM | 0.05         | 20.9        |
|                             | 10/15/2021 | 10:41 AM | 0.05         | 20.9        |
| Dug Trench by Wood Shed     | 10/1/2021  | 11:24 AM | 0.04         | 20.9        |
|                             | 10/7/2021  | 10:09 AM | 0.04         | 20.9        |
|                             | 10/15/2021 | 10:39 AM | 1.34         | 19.5        |
|                             | 10/22/2021 | 10:01 AM | 0.03         | 20.9        |
|                             | 10/26/2021 | 9:52 AM  | 0.02         | 20.9        |
|                             | 10/28/2021 | 10:15 AM | 0.03         | 20.9        |
|                             | 10/29/2021 | 9:43 AM  | under water  |             |
| Dug Trench by Tractor Shed  | 10/1/2021  | 11:25 AM | 0.03         | 20.9        |
|                             | 10/7/2021  | 10:20 AM | 4.4          | 18          |
|                             | 10/15/2021 | 10:49 AM | 2.15         | 19.6        |
|                             | 10/22/2021 | 10:03 AM | 0.03         | 20.9        |
|                             | 10/26/2021 | 9:54 AM  | 0.02         | 20.9        |
|                             | 10/28/2021 | 10:18 AM | 0.03         | 20.9        |
|                             | 10/29/2021 | 9:44 AM  | under water  |             |
| Pool Drain by Garage        | 10/7/2021  | 10:33 AM | 0.05         | 20.9        |
|                             | 10/15/2021 | 10:56 AM | 0.03         | 20.9        |
|                             | 10/22/2021 | 10:18 AM | 0.03         | 20.9        |
|                             | 10/29/2021 | 9:37 AM  | 0.03         | 20.9        |
| Vent by AC outdoor by Pool* | 10/22/2021 | 10:22 AM | 0.11         | 20.9        |
|                             | 10/29/2021 | 9:38 AM  | 0.03         | 20.9        |
|                             | 10/15/2021 | 10:58 AM | 0.03         | 20.9        |
|                             | 10/29/2021 | 9:38 AM  | 0.03         | 20.9        |
|                             | 10/7/2021  | 10:36 AM | 0.05         | 20.9        |

# Site Layout – Dug Trench Samples

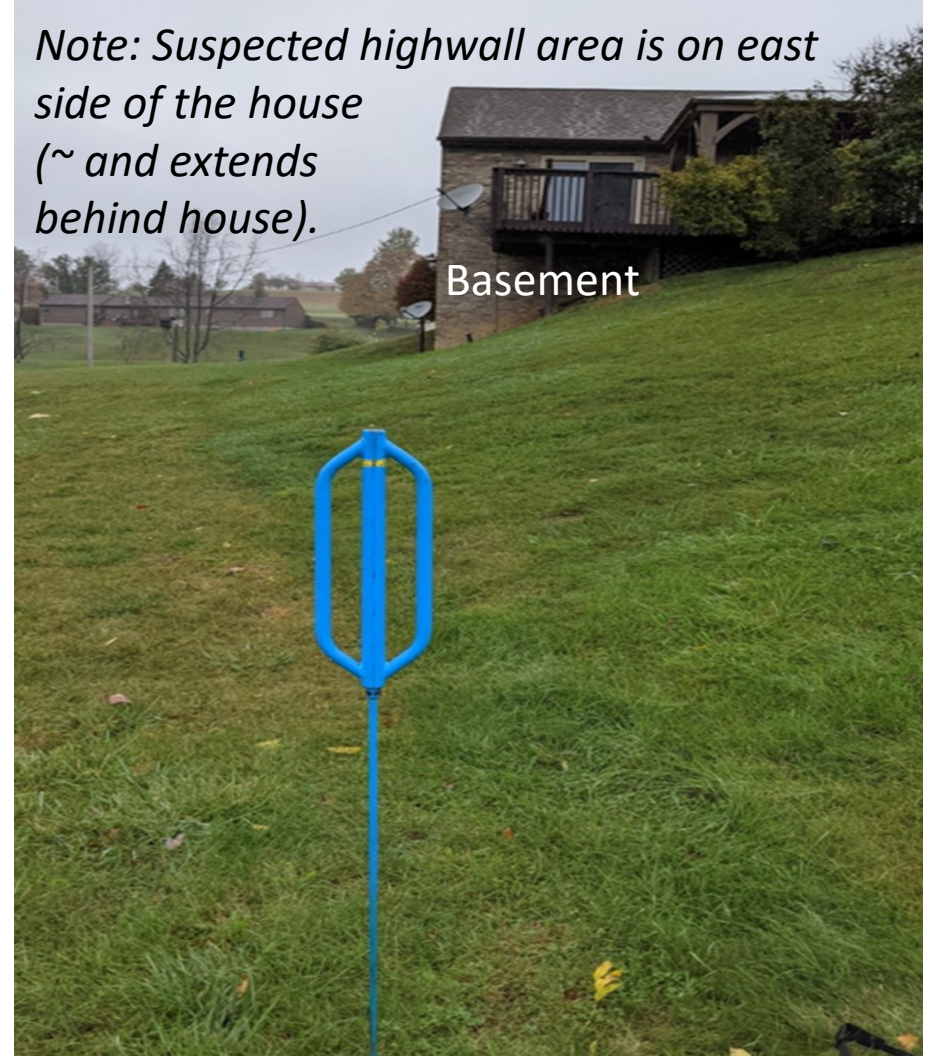




# Drive Bar Gas Samples



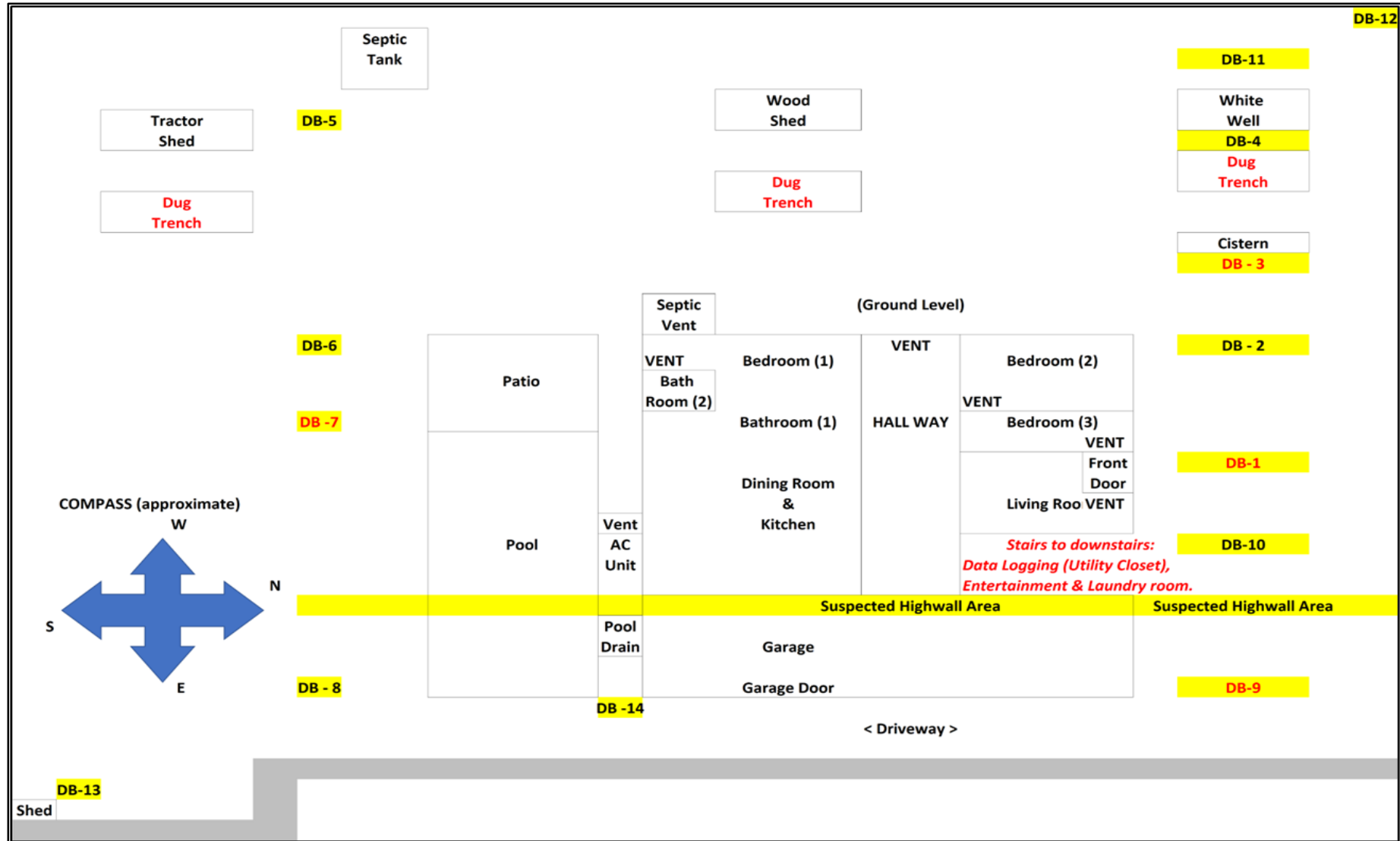
*Note: Suspected highwall area is on east side of the house (~ and extends behind house).*



Basement



# Site Layout – Drive Bar (DB) Gas Samples



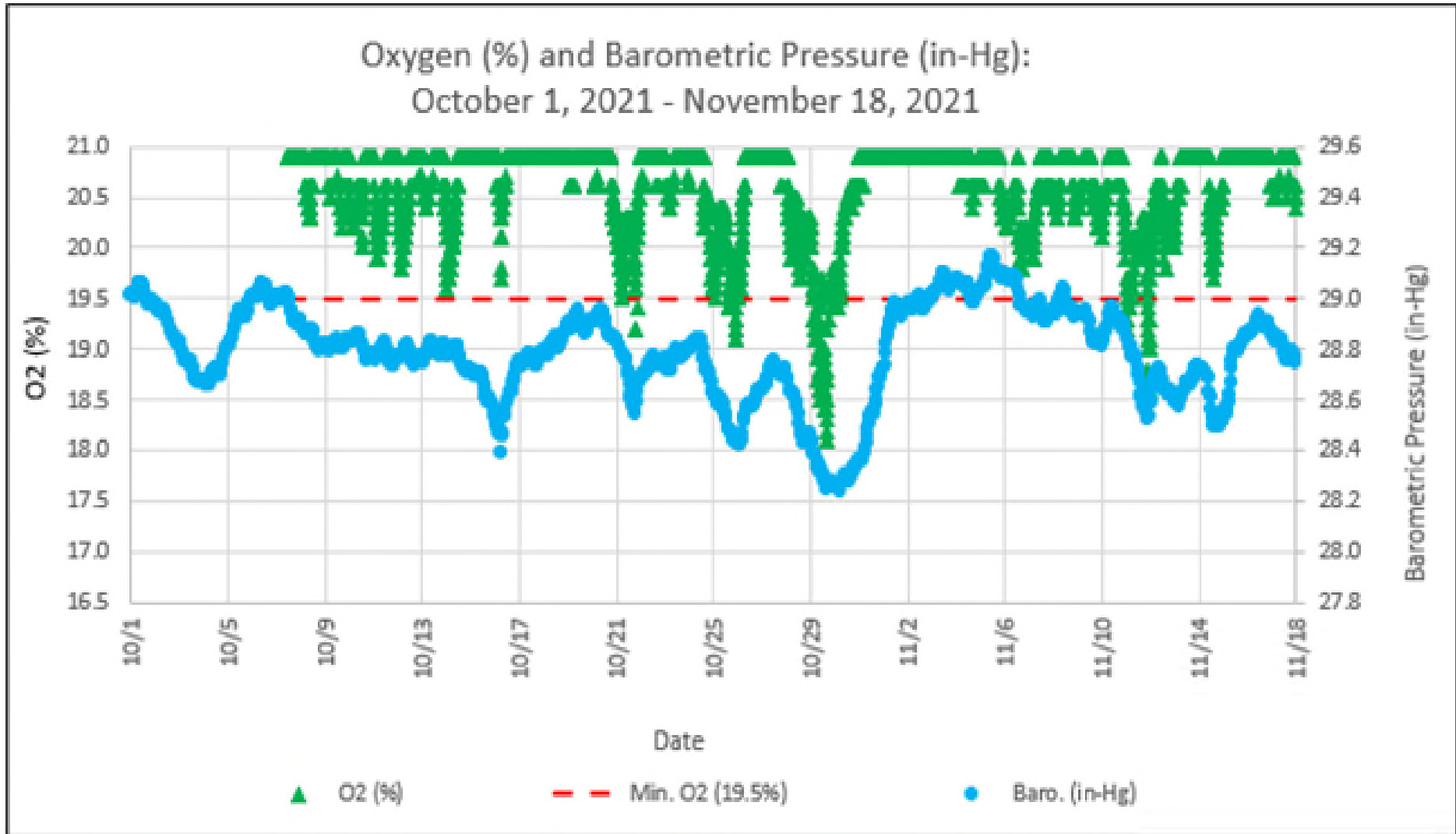


# Drive Bar (DB) Samples



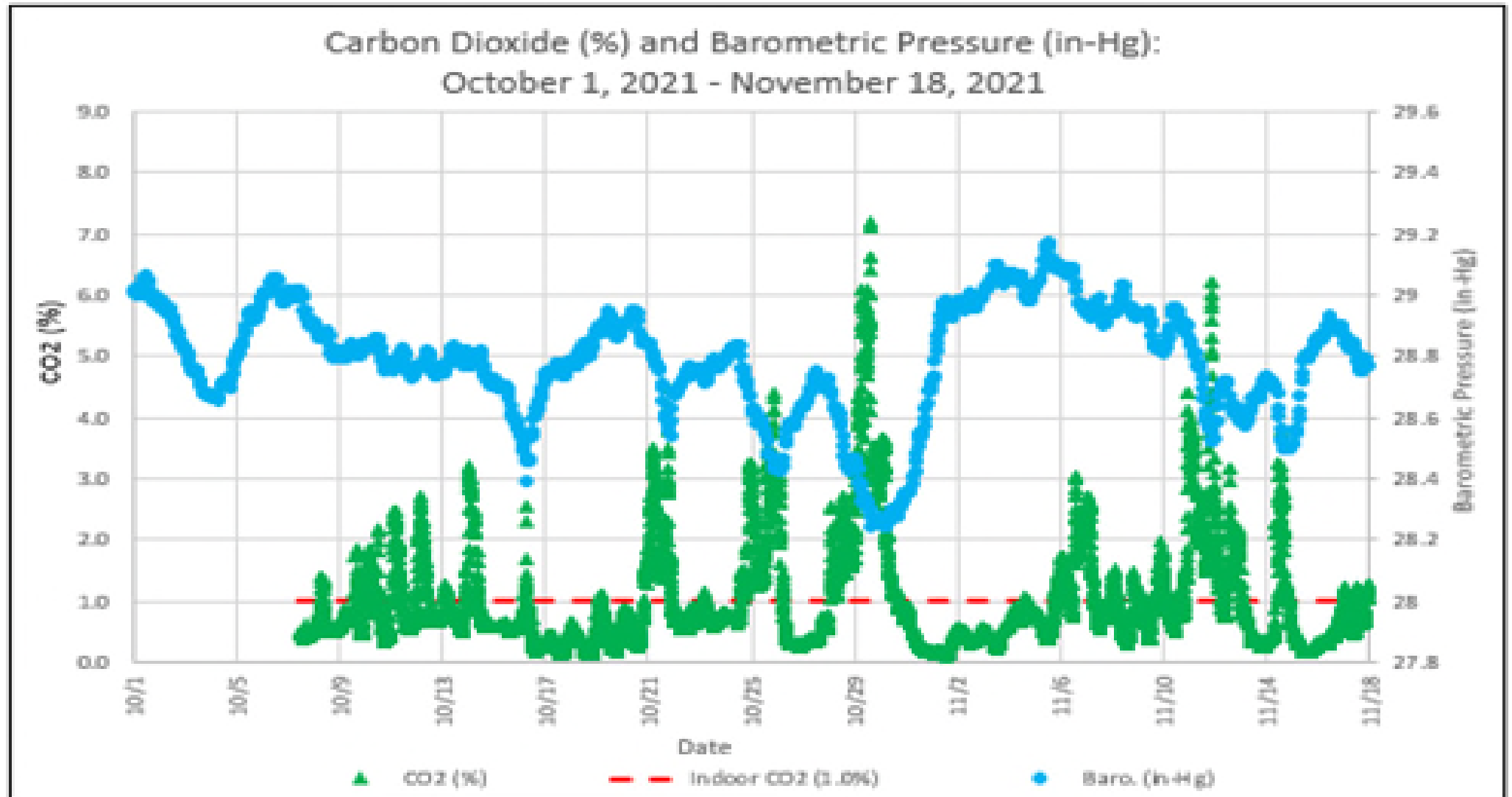
| Site                                     | Date       | Time     | CO <sub>2</sub> % volume | O <sub>2</sub> % volume |
|--|------------|----------|--------------------------|-------------------------|
| DB-1: Front of House (Front Door)        | 10/22/2021 | 10:37 AM | 0.16                     | 20.9                    |
|  | 10/26/2021 | 10:01 AM | 0.12                     | 20.9                    |
|  | 10/28/2021 | 10:34 AM | 1.74                     | 19.4                    |
|  | 10/29/2021 | 9:58 AM  | 5.0++                    | 14.2                    |
| DB-2: Front Corner of House (NW Corner)  | 10/22/2021 | 10:50 AM | 0.18                     | 20.9                    |
|  | 10/26/2021 | 10:05 AM | 0.13                     | 20.9                    |
|  | 10/28/2021 | 10:37 AM | 0.96                     | 20.1                    |
| DB-3: Near Cistern                       | 10/22/2021 | 10:59 AM | 0.96                     | 20.4                    |
|  | 10/26/2021 | 10:08 AM | 0.45                     | 20.4                    |
|  | 10/28/2021 | 10:43 AM | 4.10                     | 17.6                    |
| DB-4: Uphill of White Well               | 10/29/2021 | 10:00 AM | 5.0++                    | 14.6                    |
|  | 10/22/2021 | 11:03 AM | 0.12                     | 20.9                    |
|  | 10/26/2021 | 10:12 AM | 0.16                     | 20.9                    |
| DB-5: Back of House by Tractor           | 10/28/2021 | 10:49 AM | 0.53                     | 20.2                    |
|  | 10/22/2021 | 11:20 AM | 0.13                     | 20.9                    |
|  | 10/26/2021 | 10:17 AM | 0.04                     | 20.9                    |
| DB-6: Back Corner of House (SW Corner)   | 10/28/2021 | 11:02 AM | 0.15                     | 20.6                    |
|  | 10/22/2021 | 11:25 AM | 0.14                     | 20.9                    |
|  | 10/26/2021 | 11:14 AM | 0.06                     | 20.9                    |
| DB-7: Behind Pool**                      | 10/28/2021 | 11:09 AM | 0.37                     | 20.4                    |
|  | 10/22/2021 | 11:30 AM | 0.08                     | 20.9                    |
|  | 10/26/2021 | 11:17 AM | 0.15                     | 20.9                    |
| DB-8: Back Corner of House (SE Corner)   | 10/28/2021 | 11:12 AM | 5.0++                    | 17.5                    |
|  | 10/29/2021 | 10:04 AM | 5.0++                    | 15.3                    |
|  | 10/22/2021 | 11:36 AM | 0.08                     | 20.9                    |
| DB-9: Front Corner of House (NE Corner)  | 10/26/2021 | 11:24 AM | 0.08                     | 20.9                    |
|  | 10/28/2021 | 11:15 AM | 0.16                     | 20.6                    |
|  | 10/26/2021 | 11:27 AM | 0.12                     | 20.9                    |
| DB-10: Downspout                         | 10/28/2021 | 11:27 AM | 1.06                     | 19.4                    |
|  | 10/29/2021 | 9:50 AM  | 3.30                     | 15.2                    |
|  | 10/26/2021 | 11:29 AM | 0.08                     | 20.9                    |
| DB-11: Downhill of White Well            | 10/28/2021 | 11:29 AM | 0.39                     | 20.3                    |
| DB-12: Bottom of Slope                   | 10/28/2021 | 10:54 AM | 0.64                     | 20.2                    |
| DB-13: Front of Shed (Door)              | 10/28/2021 | 10:57 AM | 0.32                     | 20.5                    |
| DB-14: Back Corner of Garage (SE Corner) | 10/28/2021 | 11:18 AM | 0.57                     | 20.2                    |
|  | 10/28/2021 | 11:33 AM | 1.22                     | 19.5                    |
|  | 10/29/2021 | 10:09 AM | 0.15                     | 20.4                    |

# Indoor Long-term Monitoring

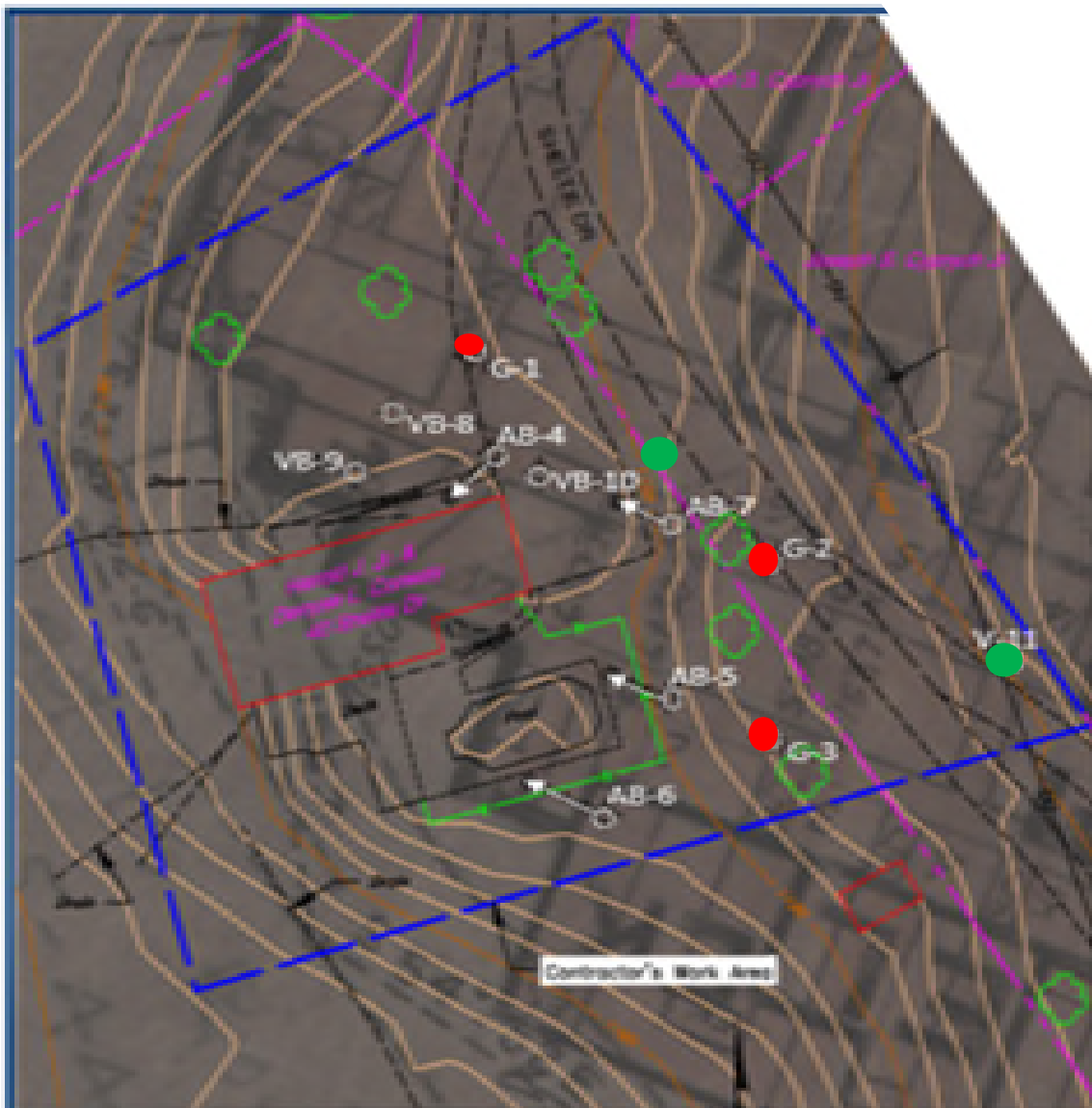




# Indoor Long-term Monitoring



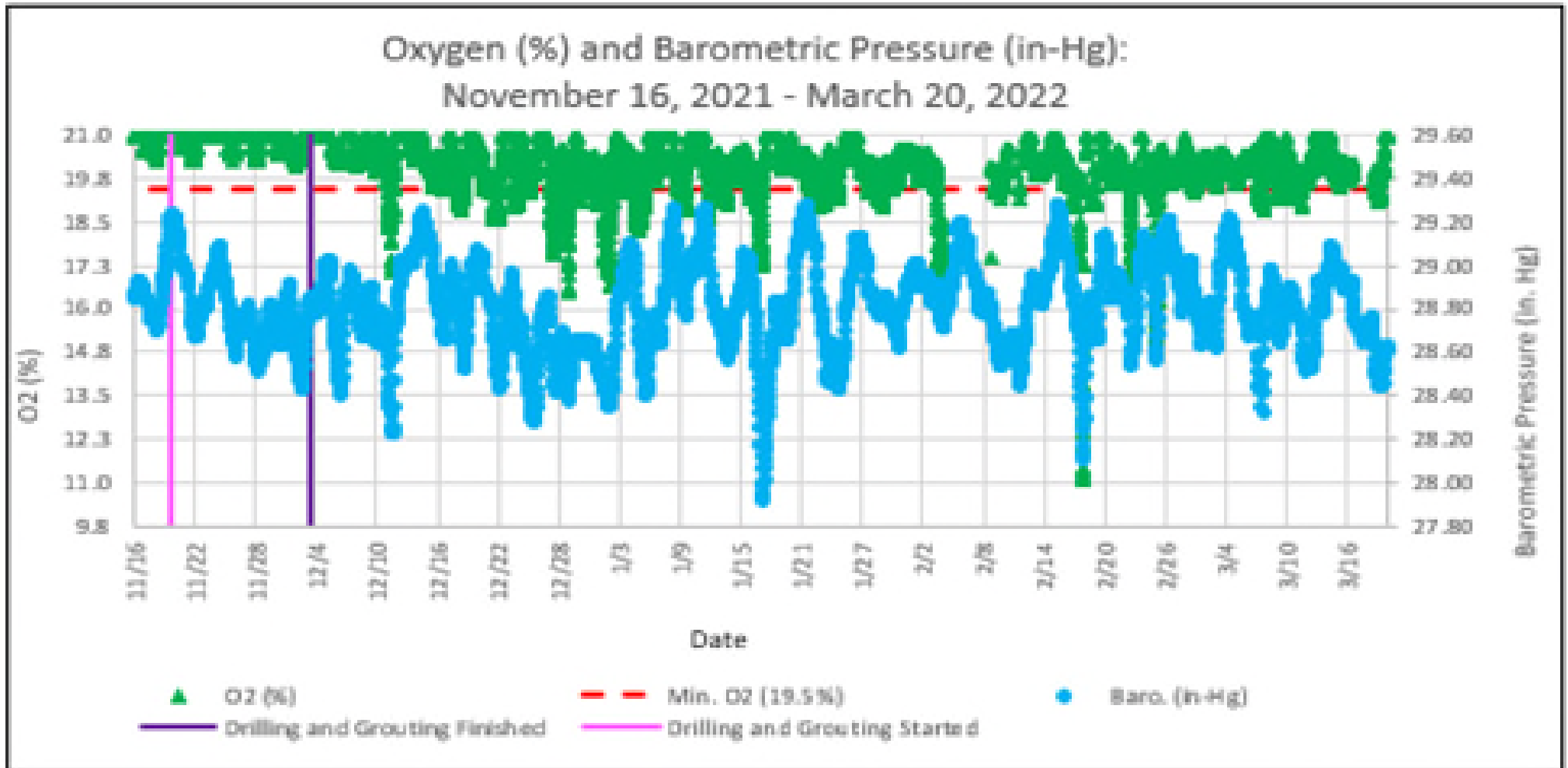
# PADEP-BAMR Remediation Plan



- 12 holes in total
- 3 locations will be bulk heads (G1-G3)
- “The plan is to build three bulkheads to reduce run away grout and allowing for the increased flowability of a fly ash grout to make sure to saturate the mine and roof fracturing.”
- 8 angle and vertical drill holes
- 2 degasification holes
- 1 degasification by driveway (unlabeled) [green filled circles]
- Used historical mine map for the location of void spaces.

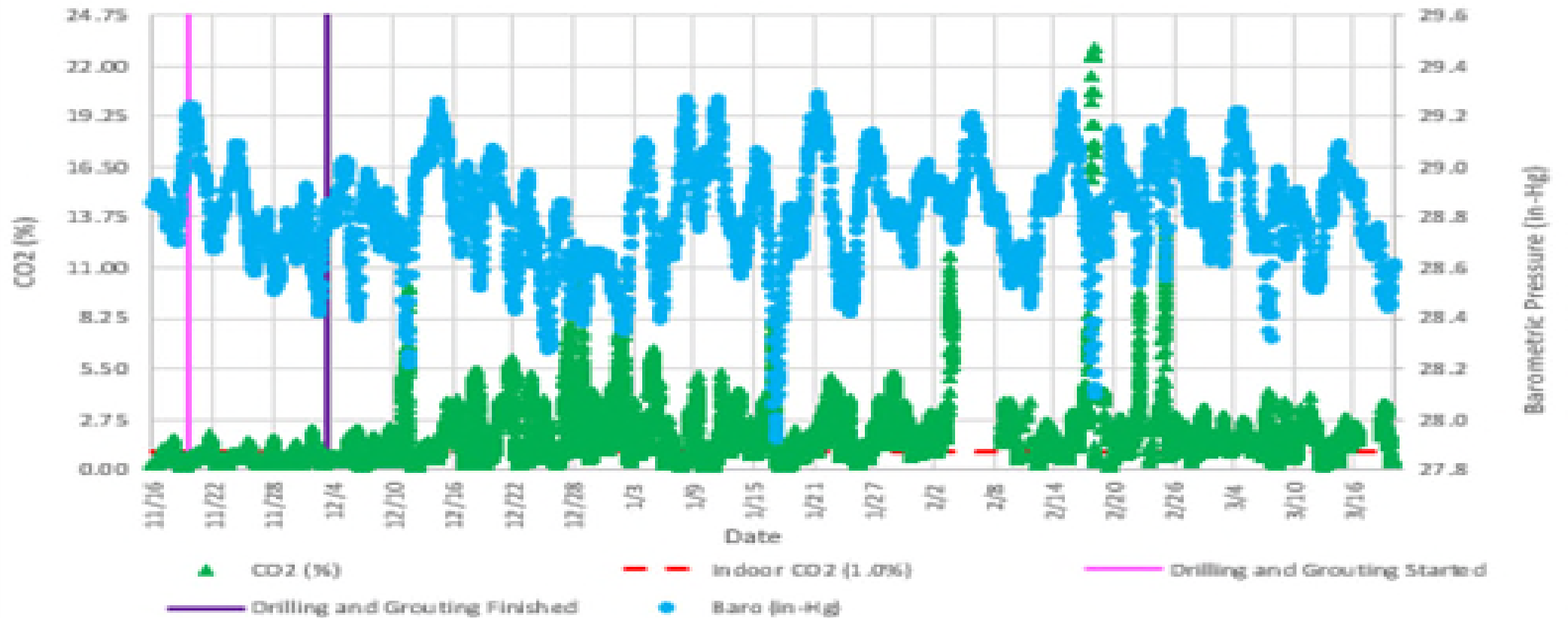


# Remediation Plan Effectiveness



# Remediation Plan Effectiveness

Carbon Dioxide (%) and Barometric Pressure (in-Hg):  
November 16, 2021 - March 20, 2022



# Borehole Air Quality – Before Ventilation Fans

Driveway Borehole

| Date       | Time    | CO <sub>2</sub> % | O <sub>2</sub> % |
|------------|---------|-------------------|------------------|
| 12/10/2021 | 3:23 PM | 5+                | 13.2             |
| 12/17/2021 | 1:44 PM | 6.6               | 13.6             |
| 1/7/2022   | 3:35 PM | 0.00              | 20.9             |
| 1/21/2022  | 2:25 PM | 5+                | 10.8             |
| 2/4/2022   | 2:26 PM | 5+                | 9.9              |
| 2/8/2022   | 2:37 PM | 5+                | 8.9              |
| 2/25/2022  | 1:58 PM | 10.6              | 9.4              |
| 3/18/2022  | 1:52 PM | 12.2              | 7.7              |

V-11 Borehole

| Date       | Time    | CO <sub>2</sub> % | O <sub>2</sub> % |
|------------|---------|-------------------|------------------|
| 12/10/2021 | 3:16 PM | 5+                | 10.0             |
| 12/17/2021 | 1:54 PM | 12.4              | 9.9              |
| 1/7/2022   | 3:40 PM | 0.00              | 20.9             |
| 1/21/2022  | 2:27 PM | 5+                | 9.2              |
| 2/4/2022   | 2:36 PM | 0.03              | 20.9             |
| 2/8/2022   | 2:51 PM | 5+                | 8.2              |
| 2/25/2022  | 2:03 PM | 10.4              | 7.3              |
| 3/18/2022  | 1:58 PM | 9.40              | 7.5              |

- “DECENT” airflow from the degasification holes.
- Items in red show only fresh air exhausting from the fans





# Remediation Plan Upgrade

- Ventilation Fans (shown with white PVC)



- Create a pressure gradient to increase the airflow through the degasification boreholes (shown in black below ventilation fans)



# Borehole Air Quality – After Ventilation Fans

Driveway Borehole

| Date      | Time    | CO <sub>2</sub> % | O <sub>2</sub> % |
|-----------|---------|-------------------|------------------|
| 4/1/2022  | 2:05 PM | 8.4               | 14.4             |
| 4/22/2022 | 1:56 PM | 8.2               | 16.5             |
| 5/13/2022 | 2:00 PM | 9.2               | 14.3             |
| 5/20/2022 | 1:45 PM | 8.4               | 14.9             |

V-11 Borehole

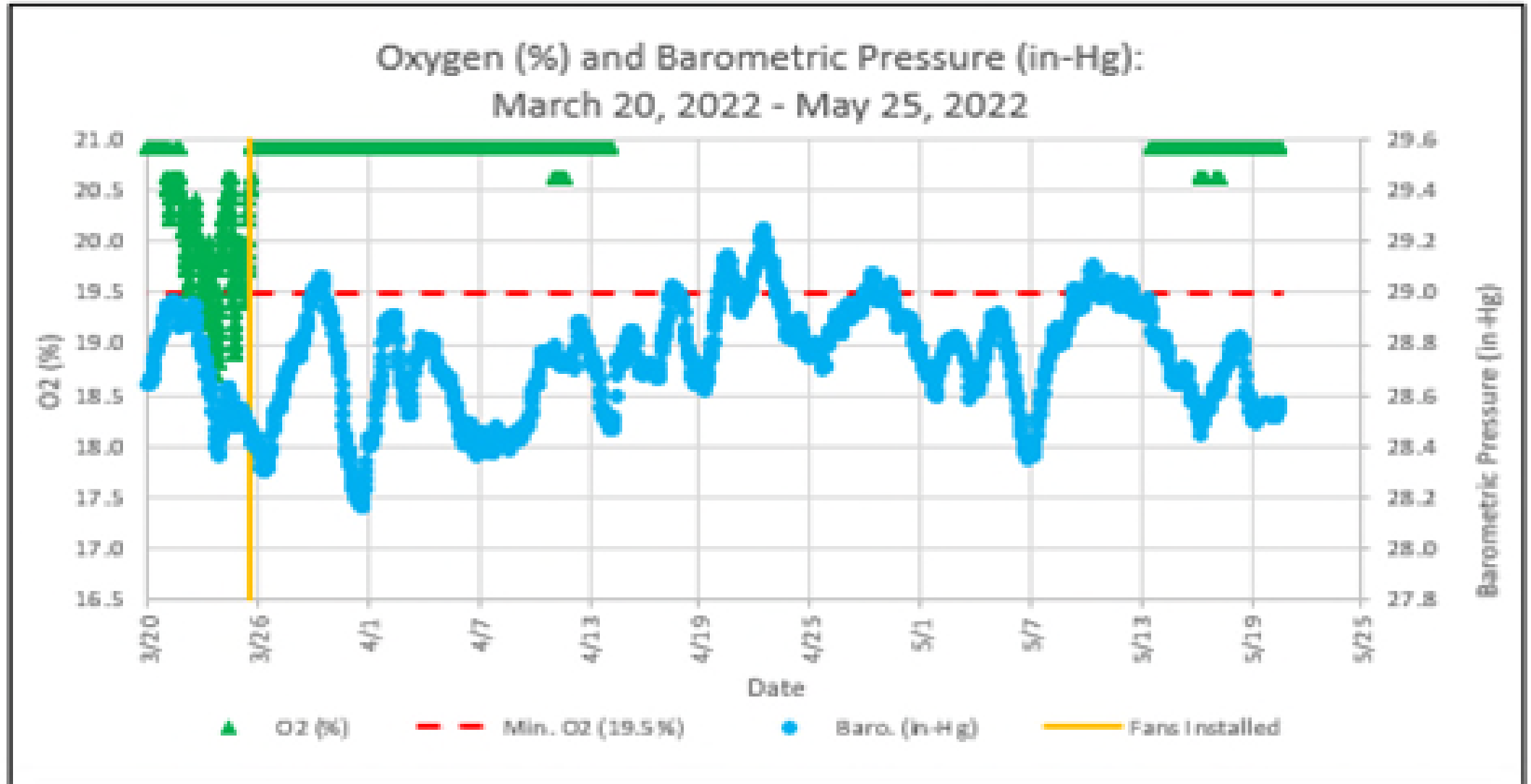
| Date      | Time    | CO <sub>2</sub> % | O <sub>2</sub> % |
|-----------|---------|-------------------|------------------|
| 4/1/2022  | 2:10 PM | 7.0               | 16               |
| 4/22/2022 | 2:00 PM | 8.4               | 16.2             |
| 5/13/2022 | 2:07 PM | 8.6               | 15.5             |
| 5/20/2022 | 1:50 PM | 8.2               | 15.9             |

- Ventilation fans installed on March 25, 2022
- Now more consistent ventilation
- Increased airflow



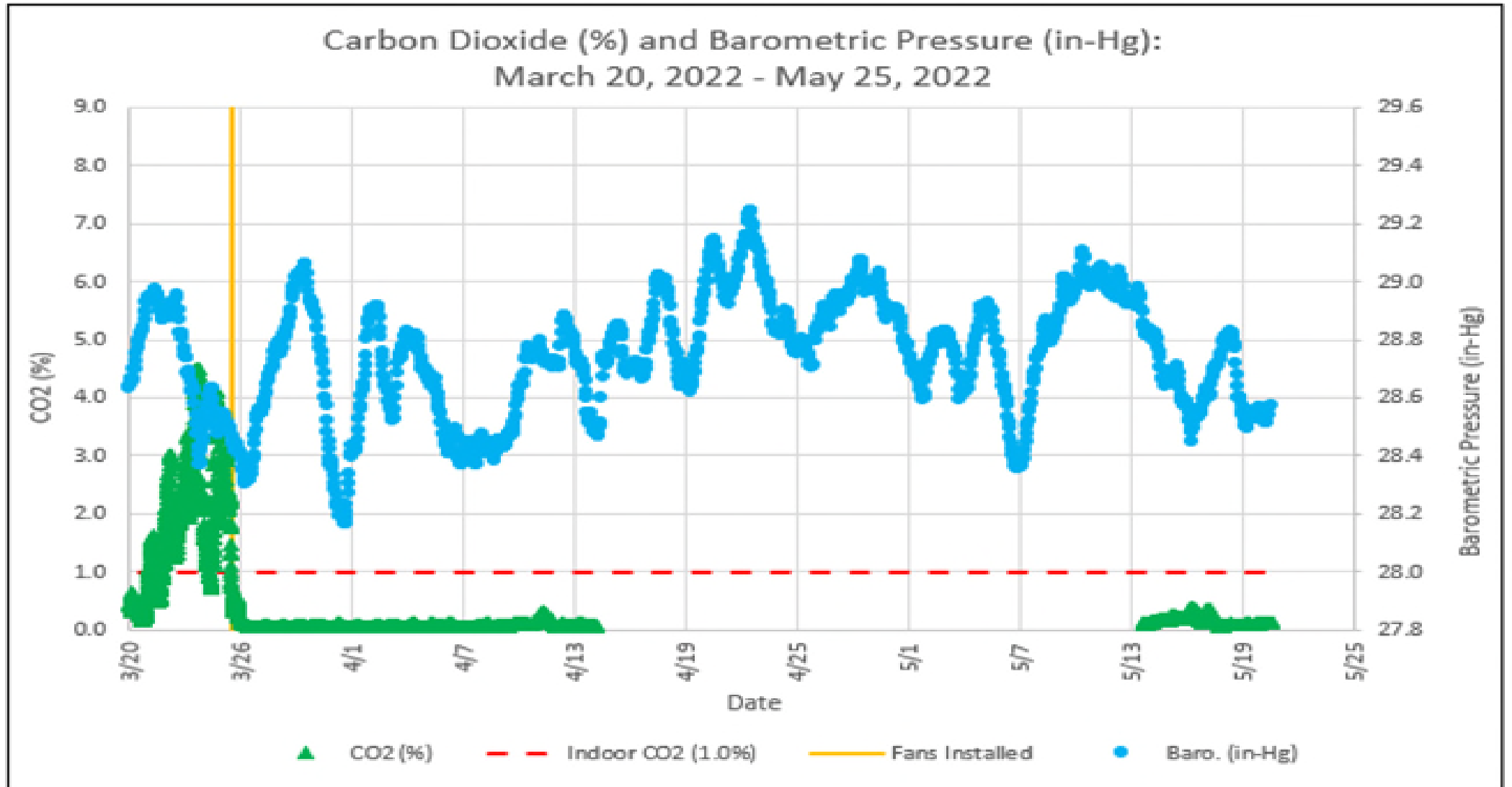


# Upgrade Plan Effectiveness





# Upgrade Plan Effectiveness



# Conclusions

- Long-term gas monitoring was discontinued on May 20, 2022.
- **The O<sub>2</sub> levels remained above 19.5% (20%) for approximately 30 days. (March 25 – April 14 and May 13 – 20, 2022).**
- The CO<sub>2</sub> levels were below the EPA's recommended level of 1.0% for approx. 30 days.
- **Special thanks are extended to PADEP-BAMR for allowing OSMRE to share their mine gas remediation project with the reclamation community and Ken Eltschlager (OSMRE-Mining Engineer).**
- The combination of filling the mine void space, providing a new pathway for the CO<sub>2</sub> gas, and **increasing the ventilation with fans was effective at remediating this relatively large site (~ 1 acre).**
- This successful remediation was unique since historically PADEP-BAMR has had successful remediation from only filling in the void space at smaller sites (~ 0.5 acres).



# References

- [Zehnder, Caralyn; Manoylov, Kalina; Mutiti, Samuel; Mutiti, Christine; VandeVoort, Allison; and Bennett, Donna, "Introduction to Environmental Science: 2nd Edition" \(2018\). Biological Sciences Open Textbooks. 4. https://oer.galileo.usg.edu/biology-textbooks/4](https://oer.galileo.usg.edu/biology-textbooks/4)
- Environmental indoor air quality testing & consulting. Oxygen Levels - Indoor Air Quality (IAQ) Testing in Dallas Austin Houston, February 24, 2023. [indoorairqualitytestingdallas.com](http://indoorairqualitytestingdallas.com).
- United States, Department of Labor, Mine Safety and Health Administration. "Air Quality." 30 CFR 75.321
- Erdmann, Christine A., Kate C. Steiner, and Apte, Michael G. Indoor carbon dioxide concentrations and sick building syndrome symptoms in the base study revisited: analyses of the 100 building dataset. Proceedings: Indoor Air 2002, [www.epa.gov/sites/production/files/2014-08/documents/base\\_3c2o2.pdf](http://www.epa.gov/sites/production/files/2014-08/documents/base_3c2o2.pdf)
- H. Wang, B.Z. Dlugogorski, E.M. Kennedy, Kinetic modeling of low-temperature oxidation of coal, Combustion and Flame, Volume 131, Issue 4, 2002, Pages 452-464, ISSN 0010-2180, [https://doi.org/10.1016/S0010-2180\(02\)00416-9](https://doi.org/10.1016/S0010-2180(02)00416-9).
- Yuan, L., and A. C. Smith. "Mining Publication: Modeling the Effect of Barometric Pressure Changes on Spontaneous Heating in Bleederless Longwall Panels." 2010. <https://www.cdc.gov/niosh/mining/works/cover-sheet1571.html>.
- EPA, 2015. Carbon Dioxide Acute Health Effects EPA (Environmental Protection Agency): Appendix B. Source: Compressed Gas Association 1990. <https://www.epa.gov/sites/production/files/2015-06/documents/co2appendixb.pdf>.
- EPA, 1991. Building Air Quality: A Guide for Building Owners and Facility Managers. [Document Display | NEPIS | US EPA](https://www.epa.gov/nepis/epa-1991-building-air-quality-a-guide-for-building-owners-and-facility-managers)
- EPA. 1994. Indoor air Facts No. 4 Sick Building Syndrome. [000002JA.PDF \(epa.gov\)](https://www.epa.gov/iaq/indoor-air-facts-no-4-sick-building-syndrome)



# THANK YOU!

# QUESTIONS?

Omar Beckford, Ph.D., P.E.  
Hydrologist  
obeckford@osmre.gov

Paul Huemmrich, P.E.  
Civil Engineer  
phuemmrich@osmre.gov

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