Shallow Groundwater Monitoring at the American Electric Power Plant CO2 Product Validation Facility

Monitoring and Verification: ENOS WP3 Workshop

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AEP AMERICAN ELECTRIC POWER

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Project Timeline

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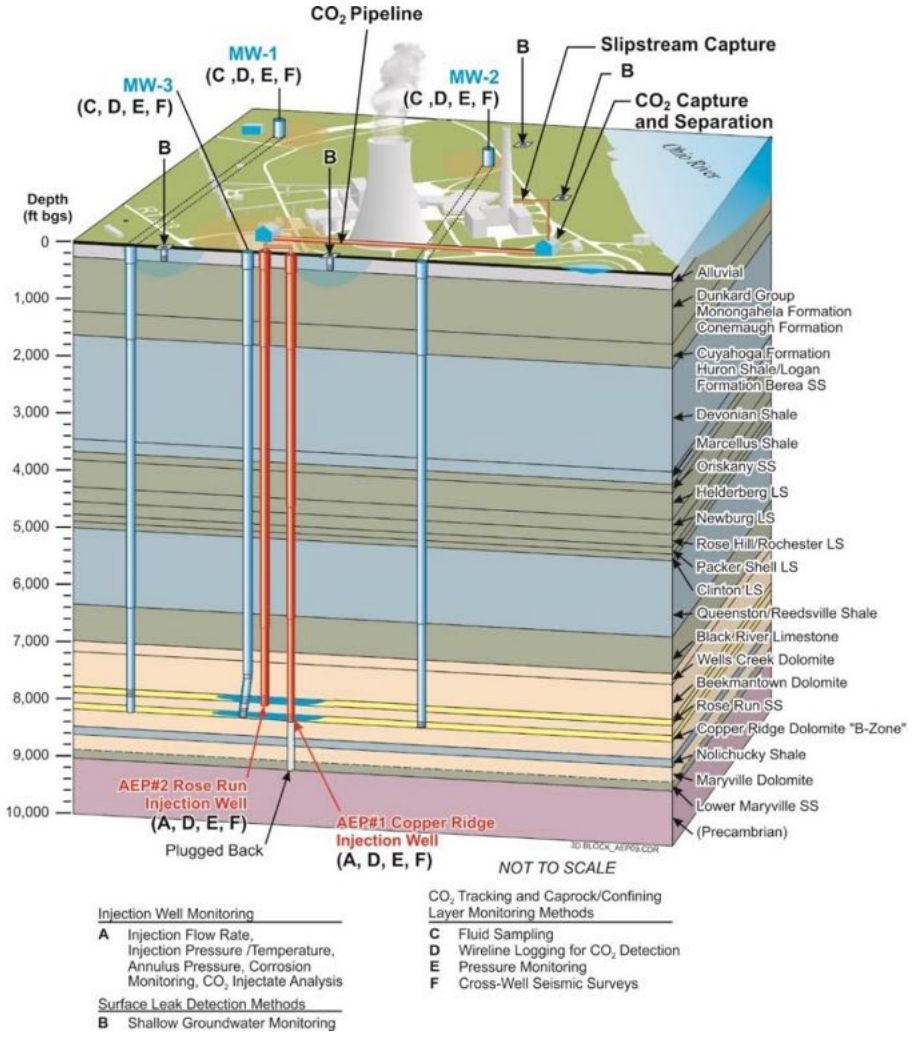
The Monitoring Program at the AEP PVF Site was a Comprehensive, Integrated Program



The PVF project at the AEP Mountaineer Power Plant consisted of a 20 MW CO_2 Capture and Storage System

CO_2 Capture and Injection took place from October 2009 - May 2011

Well network of 2 injection wells and 3 reservoir monitoring wells

Injection into two reservoirs, the Rose Run Sandstone and the Copper Ridge Dolomite

Monitoring Goals & Requirements	Program Approach
Leak detection and protection of the USDW	Shallow and deep groundwater sampling and analysis
Differential reservoir pressure monitoring	Downhole pressure / temp. data collection
CO_2 plume assessment through modeling	Reservoir pressure data analysis
Well network mechanical integrity and well condition maintenance	Frequent well observation/ maintenance surface & well

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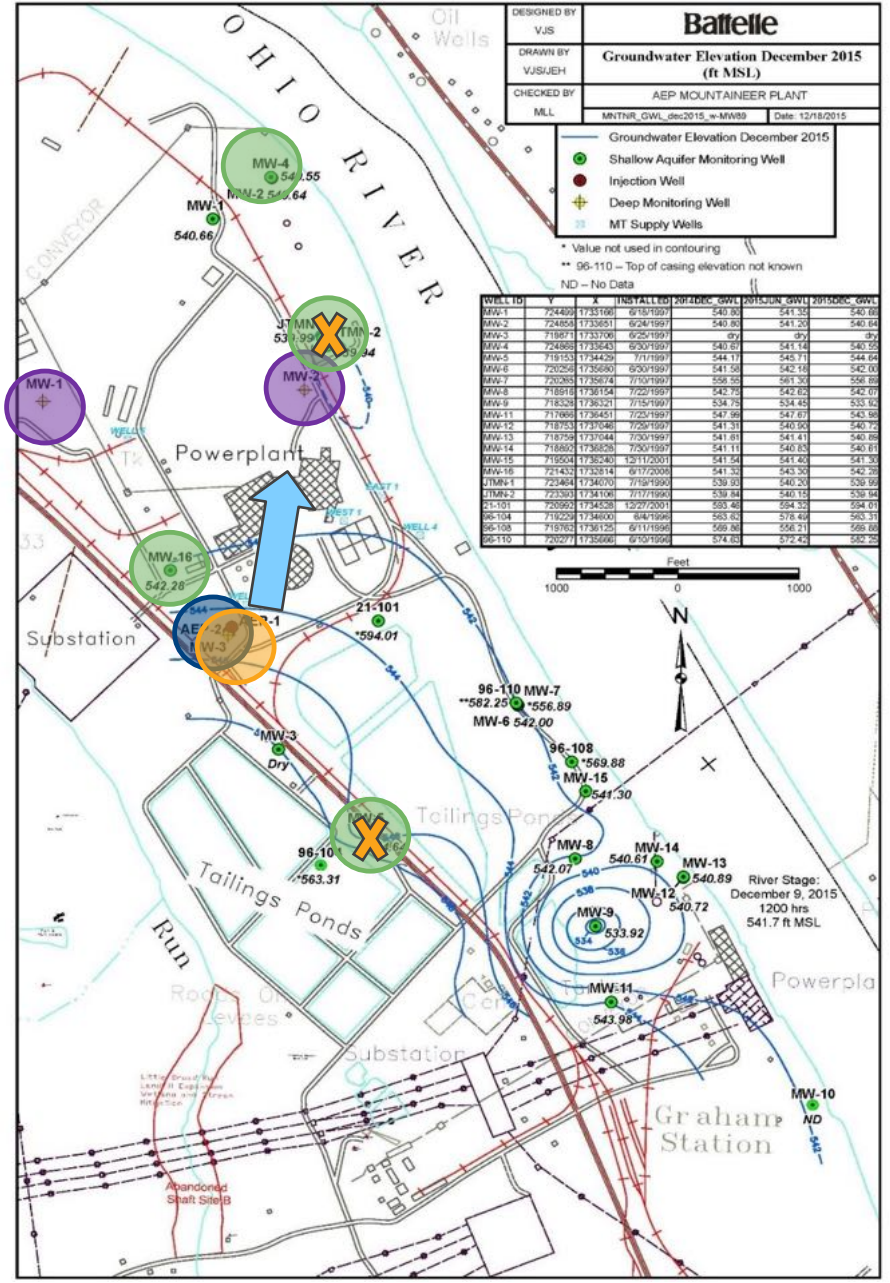
Site Layout Showing Well Proximities

Groundwater Monitoring Wells Surround the Deep Injection and Monitoring Wells.

Deep Monitoring Wells completed approx. 7,800 – 8,000 ft.

Injection Wells completed approx. 7,800 – 8,000 ft.

Direction of shallow groundwater flow



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Monitoring parameters – shallow groundwater

Cations	Anions	Physical Parameters	Other[b]
Potassium Sodium Calcium Magnesium Iron Manganese Aluminum Barium Boron Lithium[b] Strontium Dissolved Silica	Chloride Sulfate Bromide Fluoride	pH[a] Alkalinity (Bicarbonate) Alkalinity (Carbonate) Total Dissolved Solids Specific gravity/ Density[b] Dissolved Organic Carbon Specific conductance[a] Temperature[a] Turbidity[a]	Stable hydrogen isotopes (D/H) Stable oxygen isotopes (^{18}O /^{16}O) Stable carbon isotopes (^{13}C/^{12}C) Dissolved CO_2

(a) Field parameter

(b) Optional parameter, may be done at AEP's discretion

How to detect a leak signal?

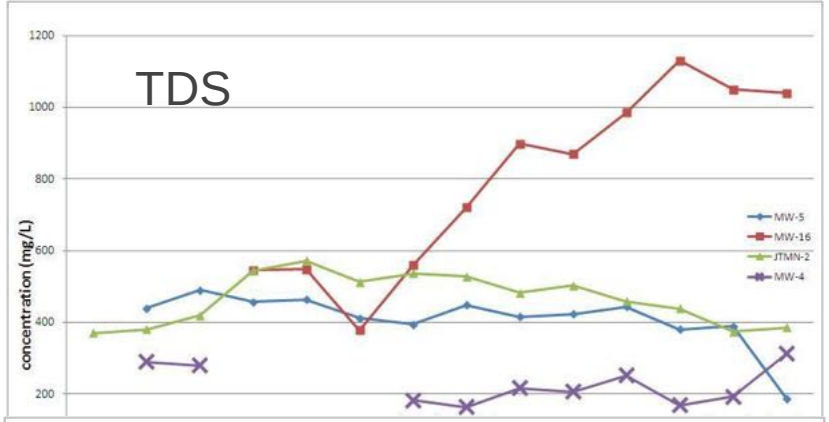
- Change in chemical parameters, e.g.
  - decreased pH caused by dissolution of CO_2
  - increase in alkalinity - dissolution of carbonate minerals by acidic fluids
  - increase in TDS - mineral dissolution and increase in cations such as Ca^{+2} and Mg^{+2}
  - Increase in acid-soluble metals such as iron and manganese

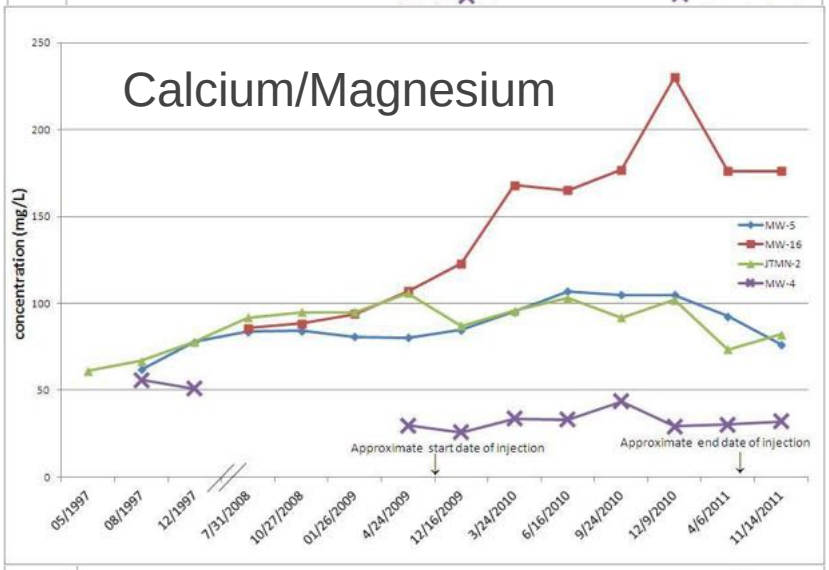
- Isotopes
  - Stable oxygen and hydrogen isotopes ($\delta^{18}O$ and δD) of shallow groundwater differ characteristically from deep brines.
  - Stable carbon isotopes ($\delta 13C$) of shallow groundwater (CO_2) differ from $\delta 13C$ of anthropogenic CO_2 from coal combustion

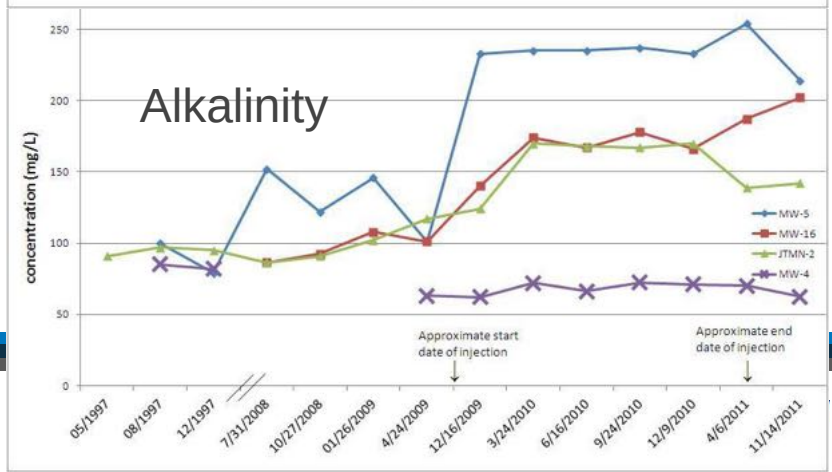
Chemical Parameter Monitoring

Several chemical parameters increased in concentration starting around the same time that injection started

Possible indicators of upward CO2 leakage?

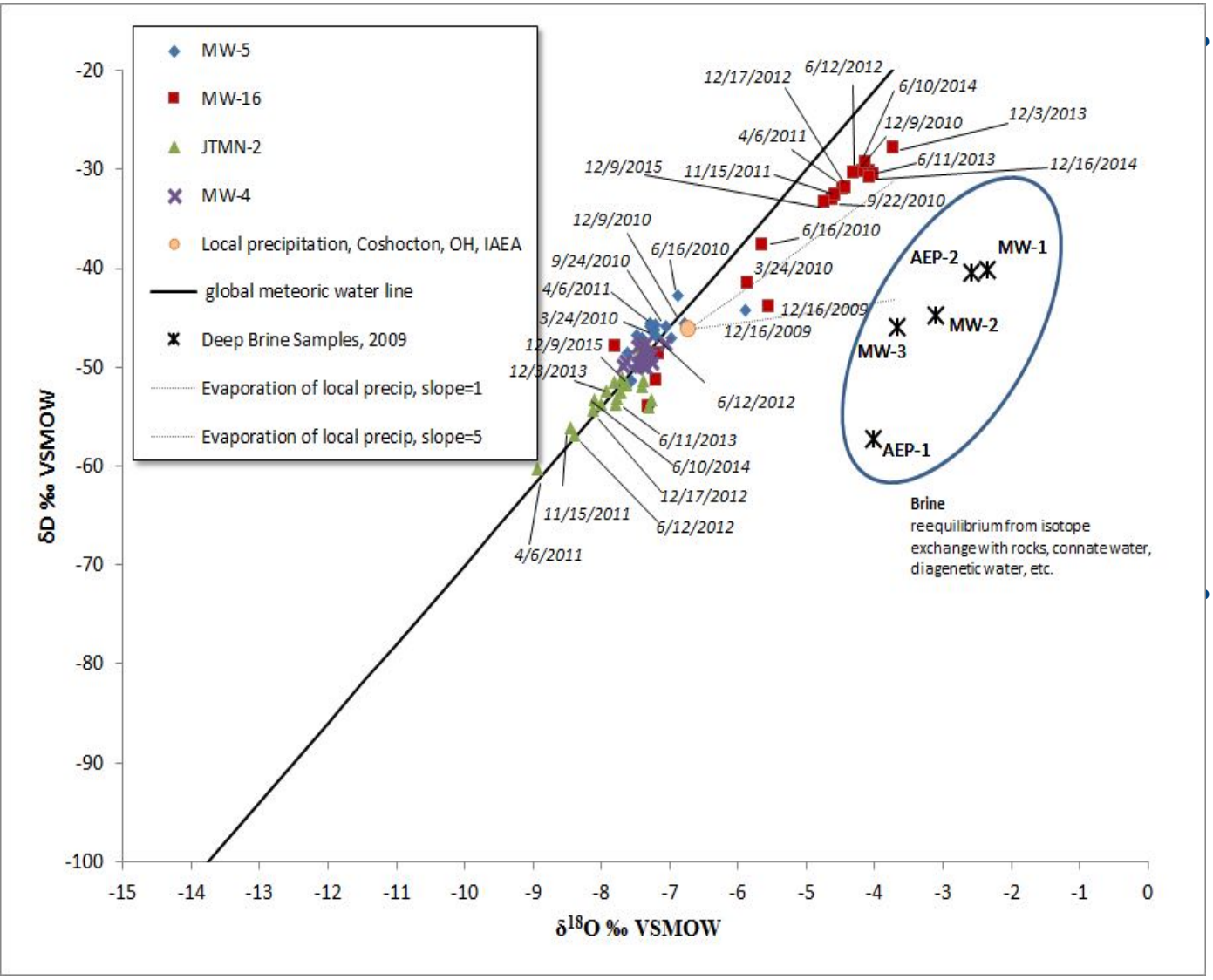






Stable Oxygen and Hydrogen Isotopes

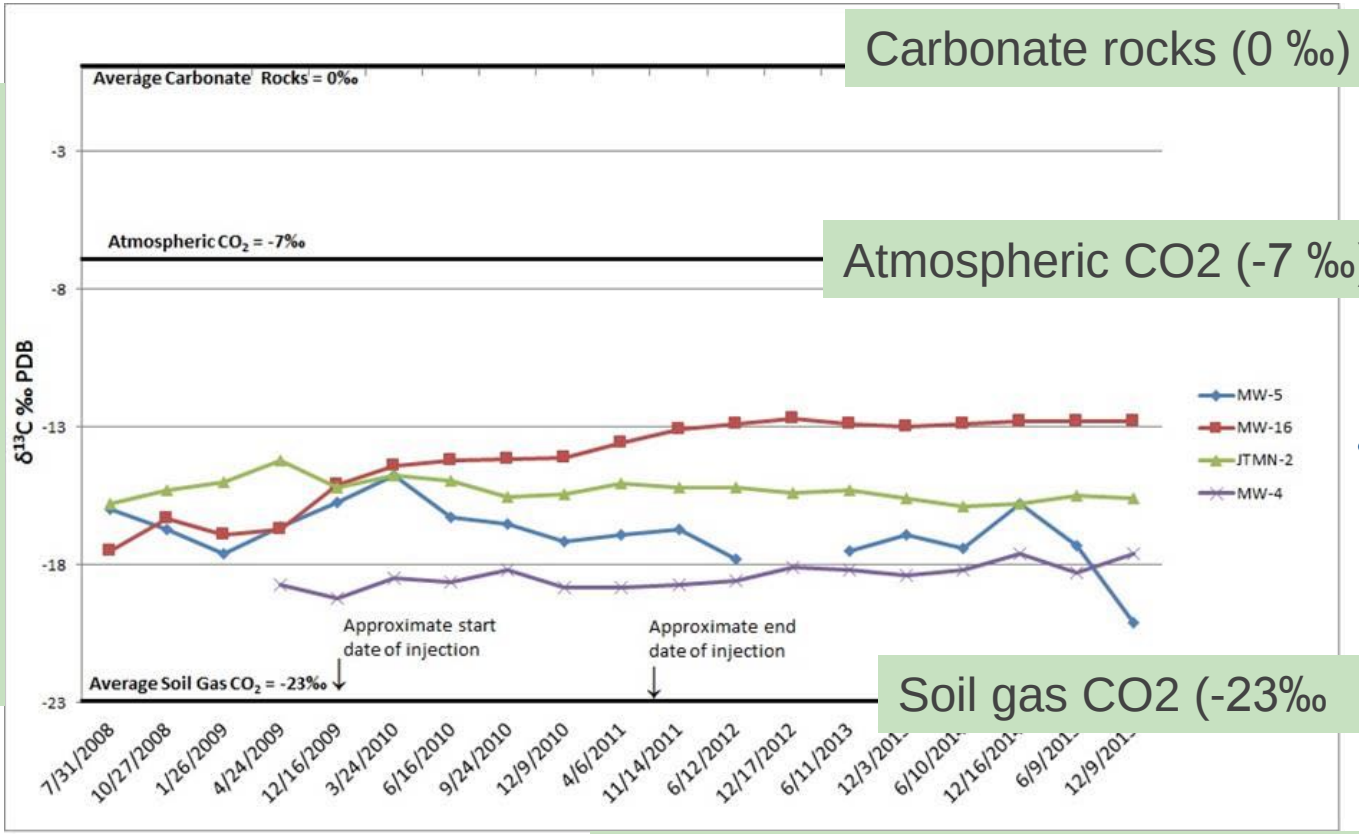
Possible upward brine migration?



- Stable oxygen and hydrogen isotopes were monitored in the groundwater and compared with deep brine pre-injection samples to detect upward migration of deep brine from injection reservoirs
- Post baseline MW-16 (red squares) deviates from meteoric line where other shallow water samples plot.

Stable Carbon Isotope Monitoring

- Stable carbon isotope activities detected in all 4 wells fall between atmospheric and soil gas as expected



- Levels remained consistent in pre-injection, during-injection and post-injection monitoring events

No indicators of upward CO2 leakage?

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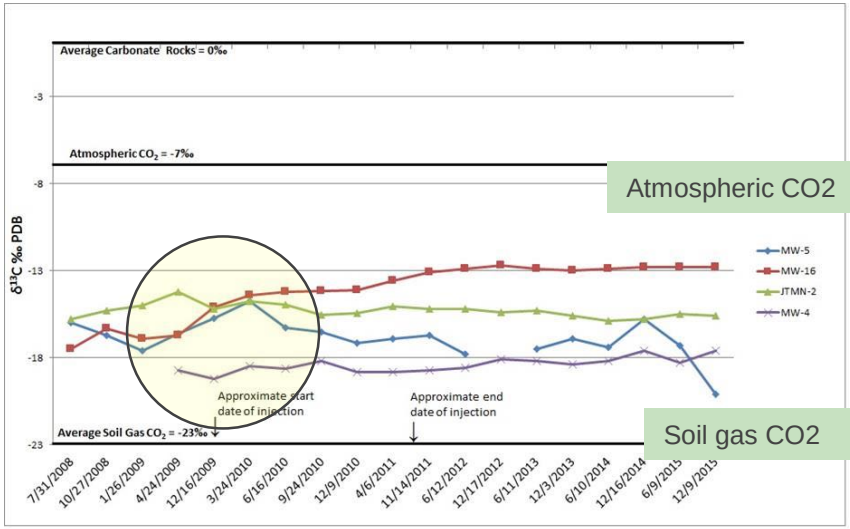
- Further analysis indicated that the observed concentration increases in chemical indicator parameters were not due to upward migration of CO_2 from the injection reservoirs.

- Further analysis of the Stable oxygen and hydrogen isotopes indicated that the deviations in mw-16 are probably not due to upward migration of brine from the injection reservoirs.

Chemical Parameter Monitoring

Possible indicators of upward CO2 leakage?

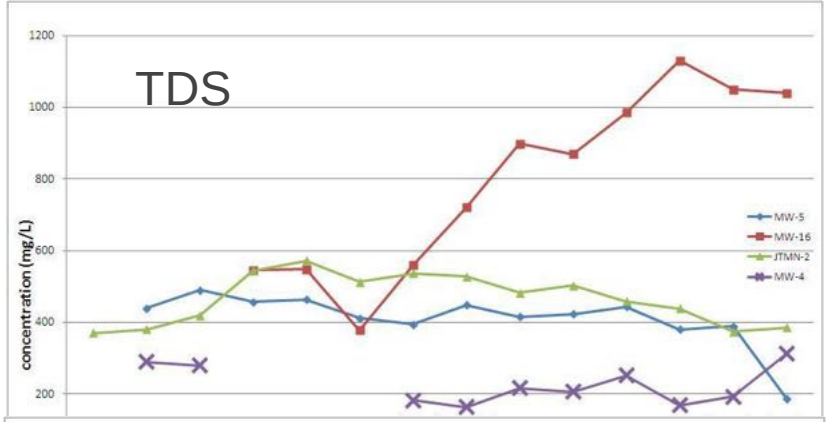
Probably not

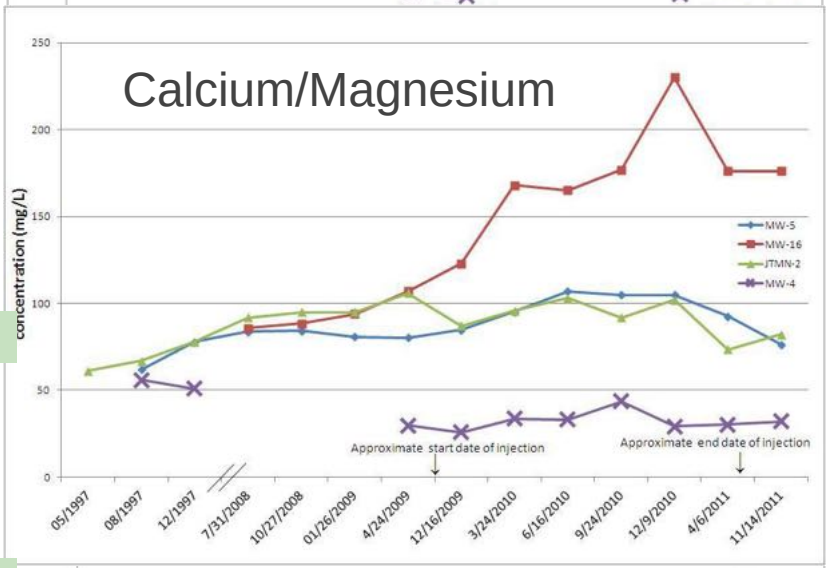


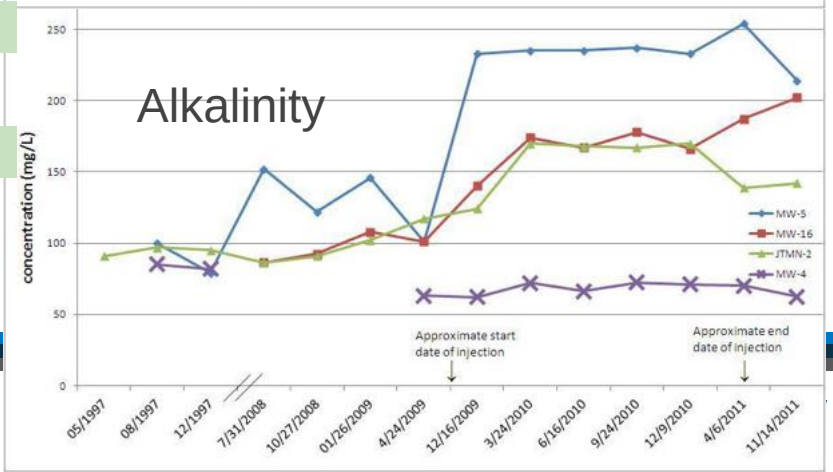
Atmospheric CO2

Soil gas CO2

CO2 from coal combustion (-20 to -30‰)



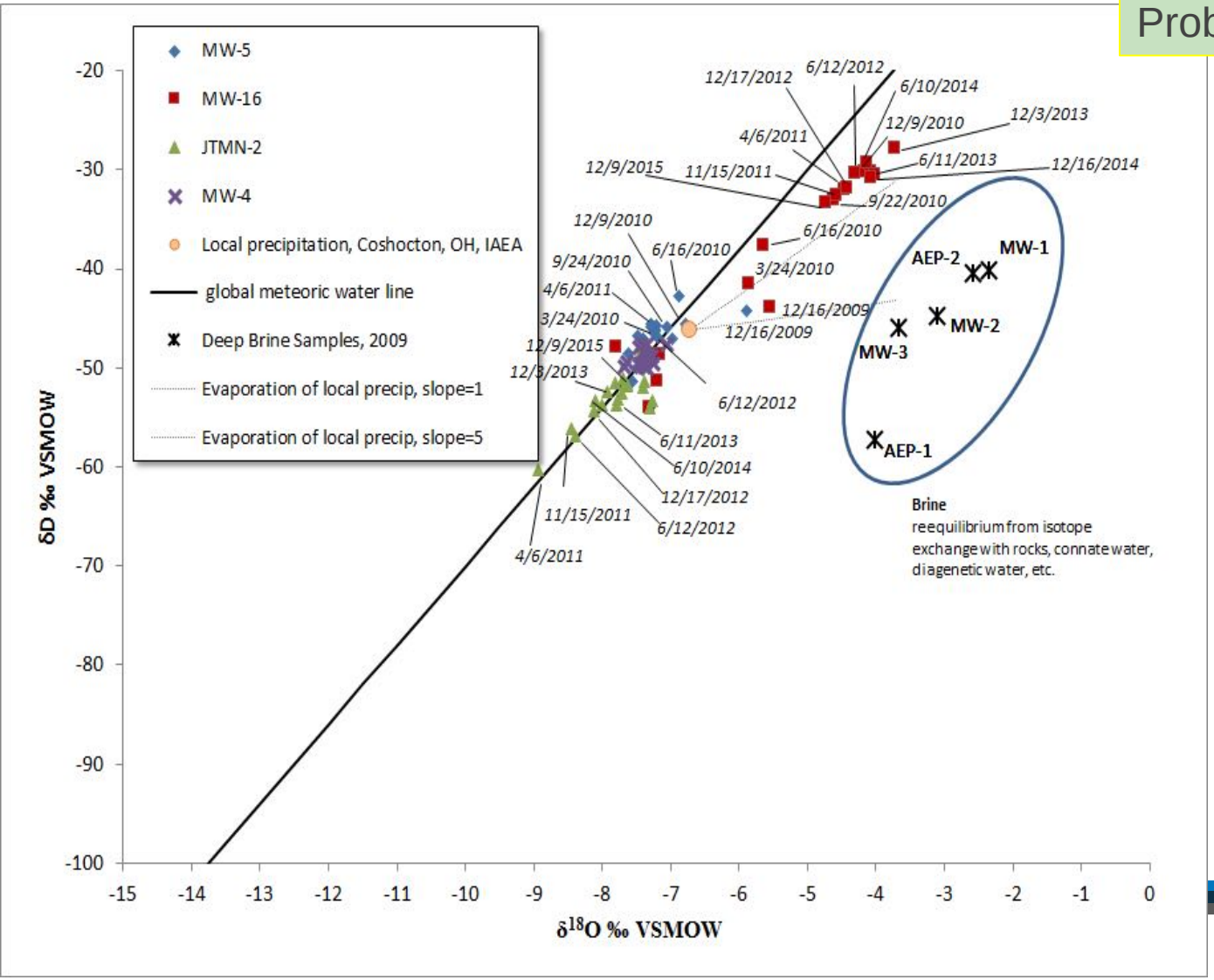




Stable Oxygen and Hydrogen Isotopes

Possible upward brine migration?

Probably not



- MW-16 (red squares) follows a line representing evaporated precipitation – not on mixing line with deep brine.

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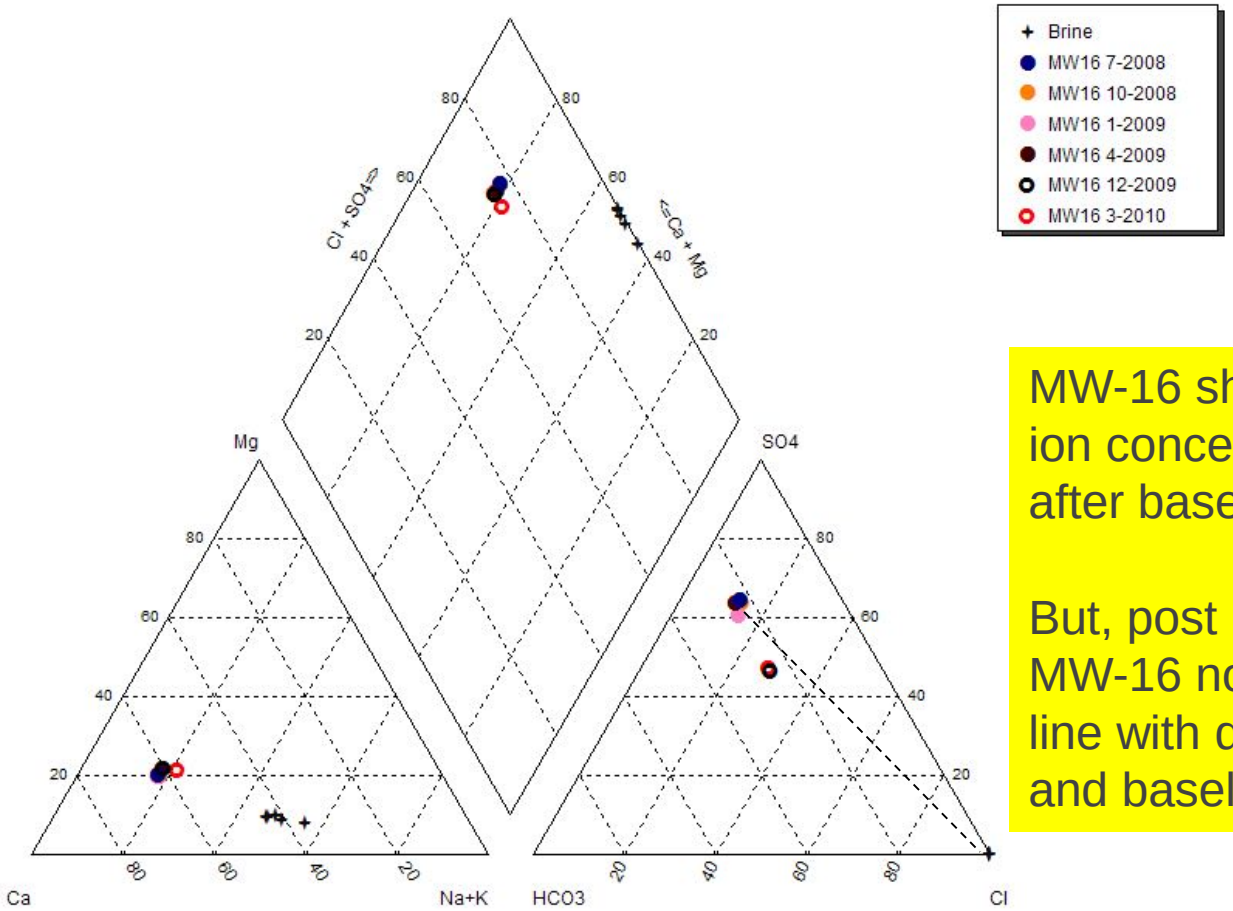

MW-16 shows shift in ion concentrations after baseline period.

But, post baseline MW-16 not on mixing line with deep brine and baseline MW-16

Figure 9-10. Well MW-16 Piper Diagram of Pre-Injection and Post-Injection Shallow Groundwater Data (Equivalents)
(Open symbols represent post-injection data. Deep brine fluid from well AEP-1 plotted for reference)

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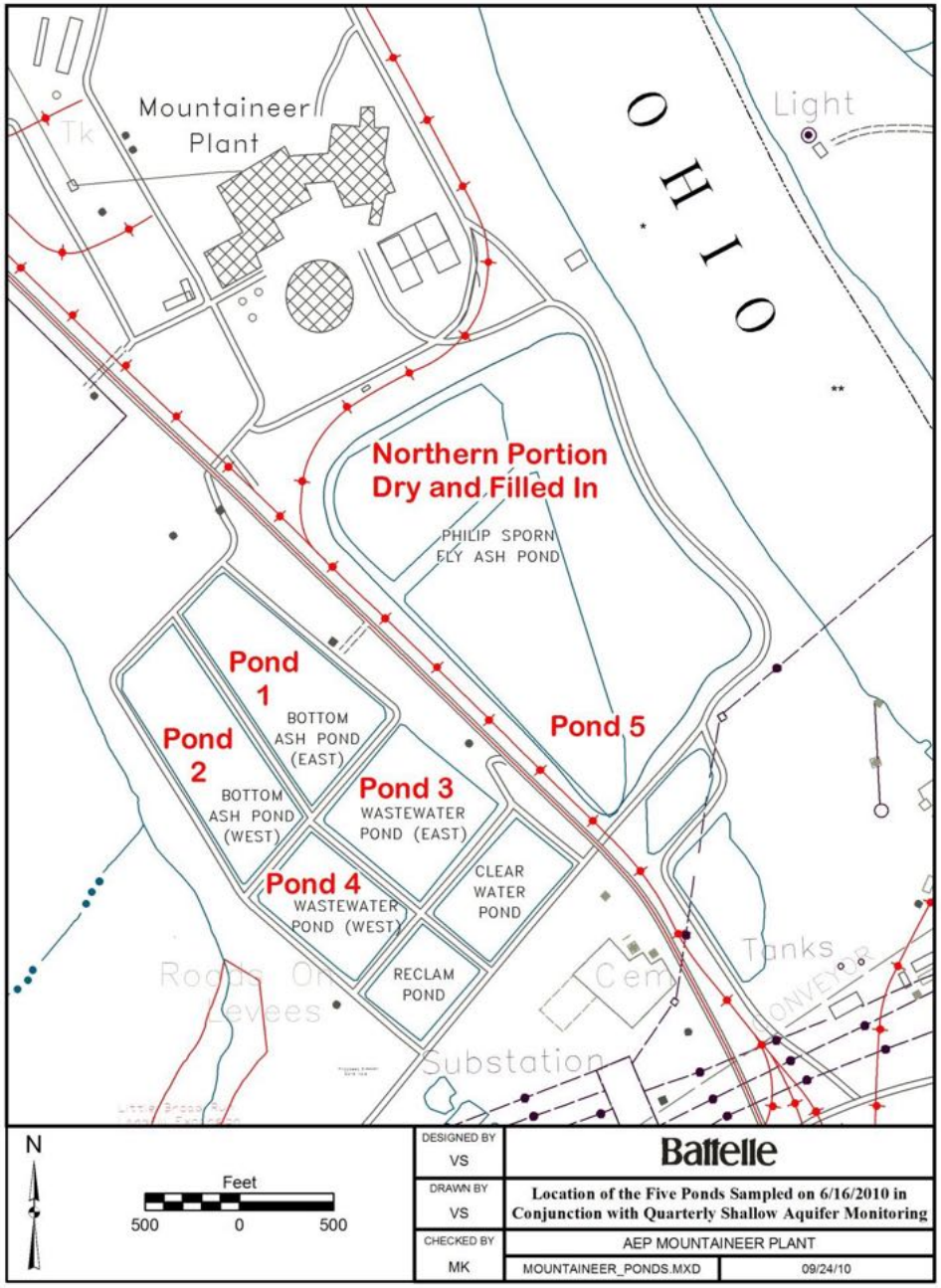
Stable Oxygen and Hydrogen Isotope data

- The changes seen in post-injection Stable Oxygen and Hydrogen Isotope data from well MW-16 appears to be due to mixing of shallow aquifer water with a highly evaporated water, which has higher TDS and is isotopically significantly heavier than meteoric water. This could be due to a number of plant activities,
- Other possible sources of water and solutes around the plant were investigated to attempt to explain the geochemical changes observed in the shallow aquifer during post-injection sampling.

- **Leaky pond hypothesis** - water from the nearby bottom ash ponds or wastewater ponds may have leached into the shallow groundwater and caused the observed composition changes at MW-16C

- 5 ponds were sampled and compared to groundwater data

- Mixing models show that major ion ratios are not consistent with a simple mixing ratio, and different proportions of pond water were required to simulate observed δ18O values than chloride concentrations.



Summary

- It isn't easy to identify an impact to shallow groundwater, especially at industrial sites
- False positives are possible, especially with cation/anion data
- Use statistics to analyze data
- Isotope data can help explain apparent leakage signals
- If signals are detected, focus on disproving CO2/brine leakage rather than proving the cause, which may require additional data and much greater effort…and still not find the cause…

Gaps in shallow groundwater monitoring methodology

- Need protocol(s) for analyzing sampling data to discern evidence for CO2 or brine leakage…