Impact of CO_2 Intrusion into USDWs, the Vadose Zone, and Indoor Air

DOE/EPA Collaborative Review
Tracking Geologically Sequestered CO2:
Monitoring, Verification, & Accounting (MVA), Simulation and Risk Assessment

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United States Environmental Protection Agency

1. Development of Methods to Evaluate Gas Intrusion into Buildings from Geological Sequestration of CO_2 Using Natural and Anthropogenic Analogues

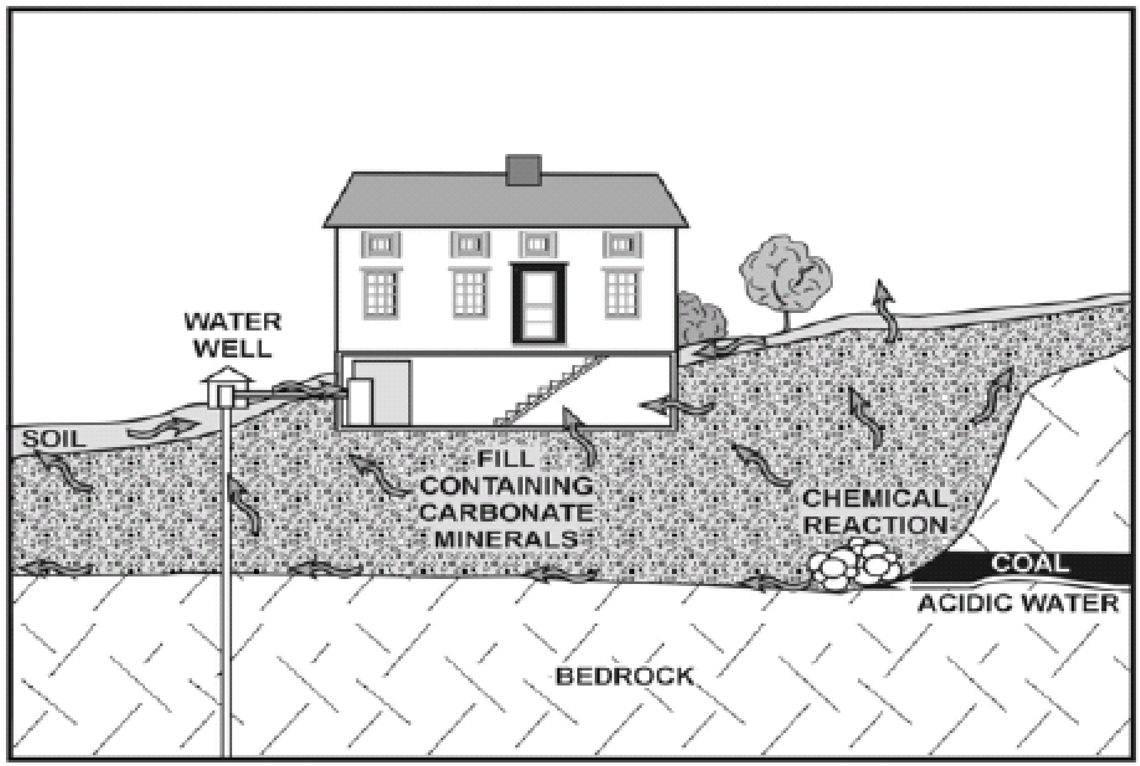
Elevated levels of CO_2 in ground water and the vadose zone will cause displacement of O_2 and intrusion of CO_2 into buildings.

$$4\,FeS_2 + 15\,O_2 + 14\,H_2O \rightarrow 4\,Fe(OH)_3 + 8\,H_2SO_4$$

(Pyrite + oxygen + water → "yellowboy" + sulfuric acid)

$$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO_2$$

(Sulfuric acid + lime → gypsum + water + carbon dioxide)



Overall Objective

Develop a protocol to distinguish natural and anthropogenic causes of CO_2 intrusion into buildings.

Increase public acceptance?

Source: Pittsburgh Geologic Survey

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Study Location - Valley Center, KS

During a period of heavy precipitation on September 13, 2008, low O_2 and elevated CO_2 levels were measured in indoor air in a number of homes in and around Valley Center, Kansas. The lowest and highest O_2 and CO_2 concentration measured in indoor air was 10% and 7%, respectively.

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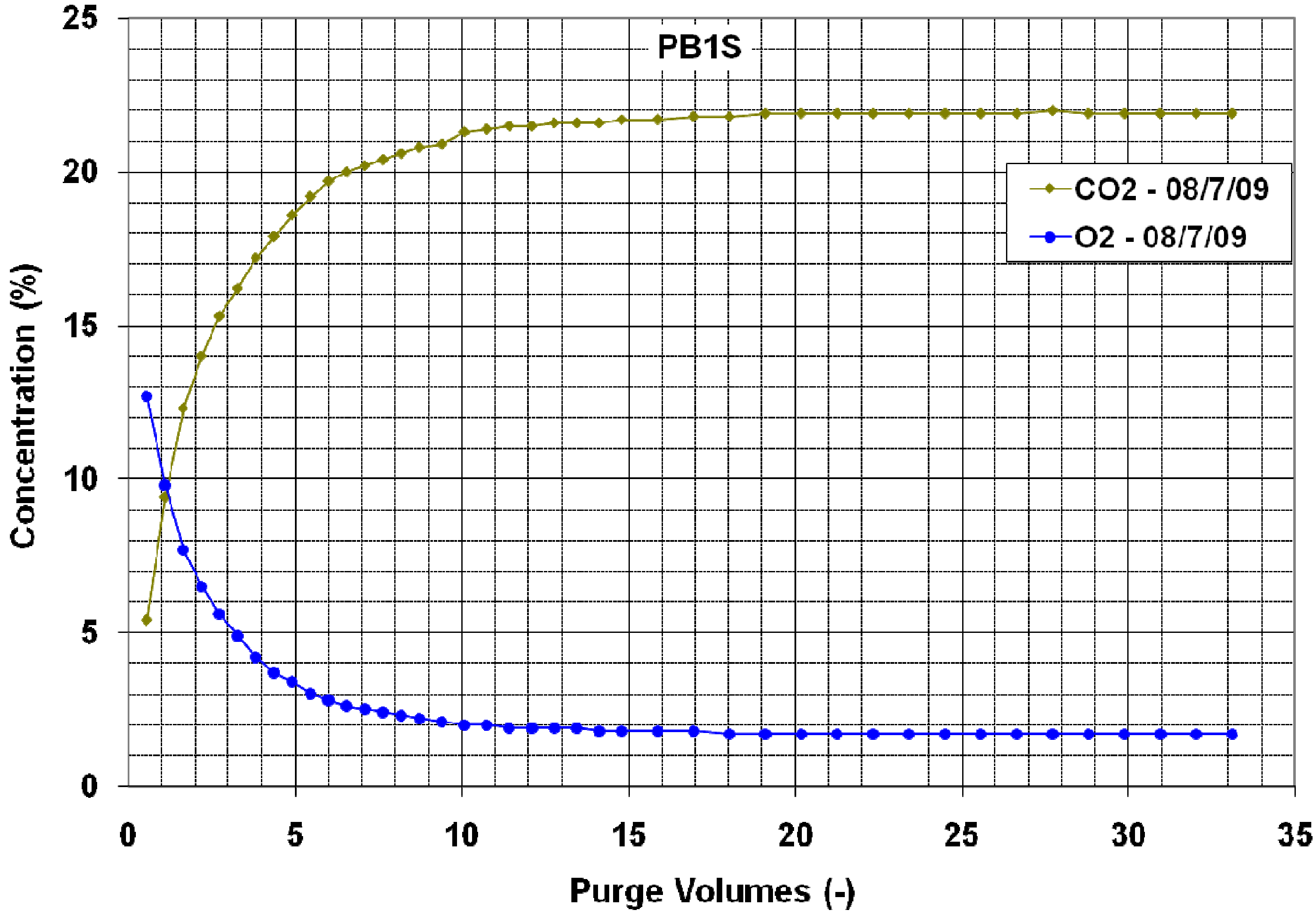
Site-Specific Objectives

- Determine geochemical reactions causing observation of elevated CO_2 and depressed O_2 in soil gas;
- Determine the primary point(s) of entry (e.g., sump basins) of soil gas into homes;
- Determine an effective means of eliminating or minimizing intrusion of oxygen displacing soil-gases (N_2 and CO_2) during heavy precipitation events.

Typical Soil-Gas Profile at Valley Center



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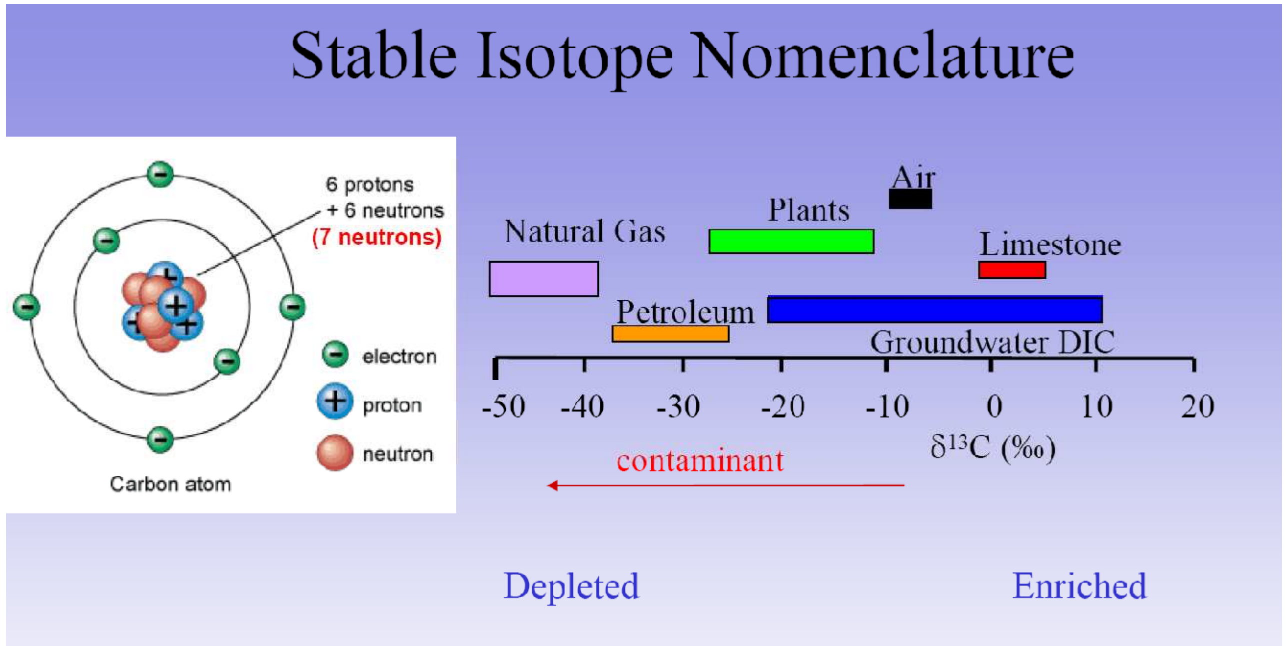
Use of Carbon Isotopes to Identify Thermogenic/Microbial Origin of CO_2 in Ground Water and Soil Gas



Source: Fessenden et al. (2008)

$$\delta 13C_{CO_2}\,(‰) = \left[\frac{\left({}^{13}C/{}^{12}C\right)\text{sampled}}{\left({}^{13}C/{}^{12}C\right)\text{standard}} - 1\right] x1000$$

$$\Delta 14C_{CO_2}\,(‰) = \left(\frac{\left({}^{14}C/{}^{12}C\right)\text{sample}}{\left({}^{14}C/{}^{12}C\right)\text{standard}} - 1\right) x1000$$

Primary Points of Entry – Tile Drains/Sump-Basin ?

Tile Drains Connected to Sump Basins

Primary Points of Entry/Evaluation of Mitigation Techniques

- Install radon mitigation systems
- Conduct blower door tests

2. *Use of Soil-Gas and Ground-Water Monitoring to Evaluate Leakage from Well Penetrations and Faults at Anthropogenic Analogues*

The objective of this research effort is to evaluate the usefulness of near-surface (< 1000 ft) soil-gas and ground-water measurements to detect the potential for leakage from well penetrations prior to injection and leakage during injection of CO_2.

Gas and brine migration through well penetrations would have a spot anomaly whereas gas migration through faults and fractures would be expressed as a linear trend or diffuse anomaly.

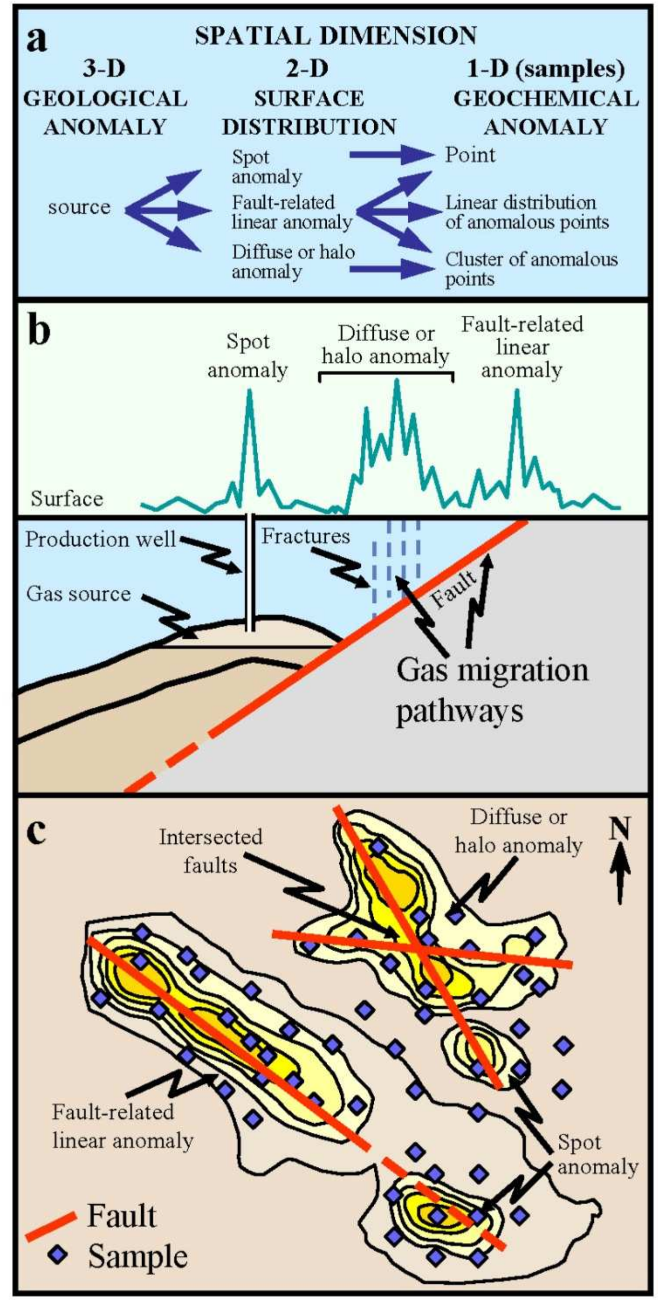


Figure modified from Ciotoli et al., (2004).

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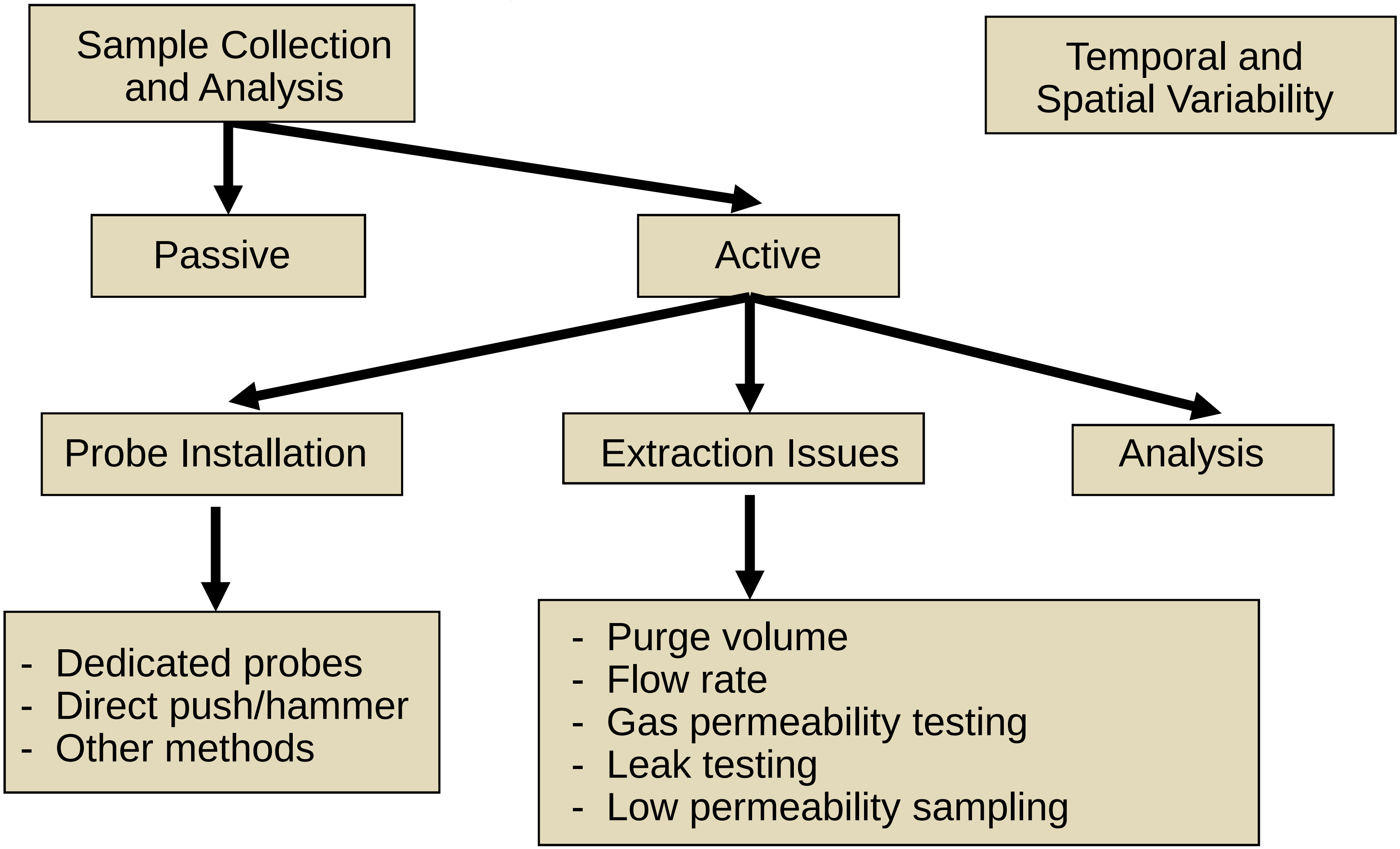
Soil-Gas Sampling Near Well Penetrations

Gas and brine migration into a USDW could be accompanied by measurable alteration in pH, major ions, and potential mobilization of hazardous inorganic compounds.

Release of gas into the vadose zone could be accompanied by compositional changes in soil gas (e.g., CH_4, C2-C4 hydrocarbons, CO_2, δ13C, Δ14C, H_2, He, H_2S, ^{222}Rn).

3. Method Development on Soil-Gas Sampling to Support Research Objectives on GS



Simultaneous Leak, Purge, and Gas Permeability Testing

Heuristic Model of Leakage During Soil-Gas Sampling

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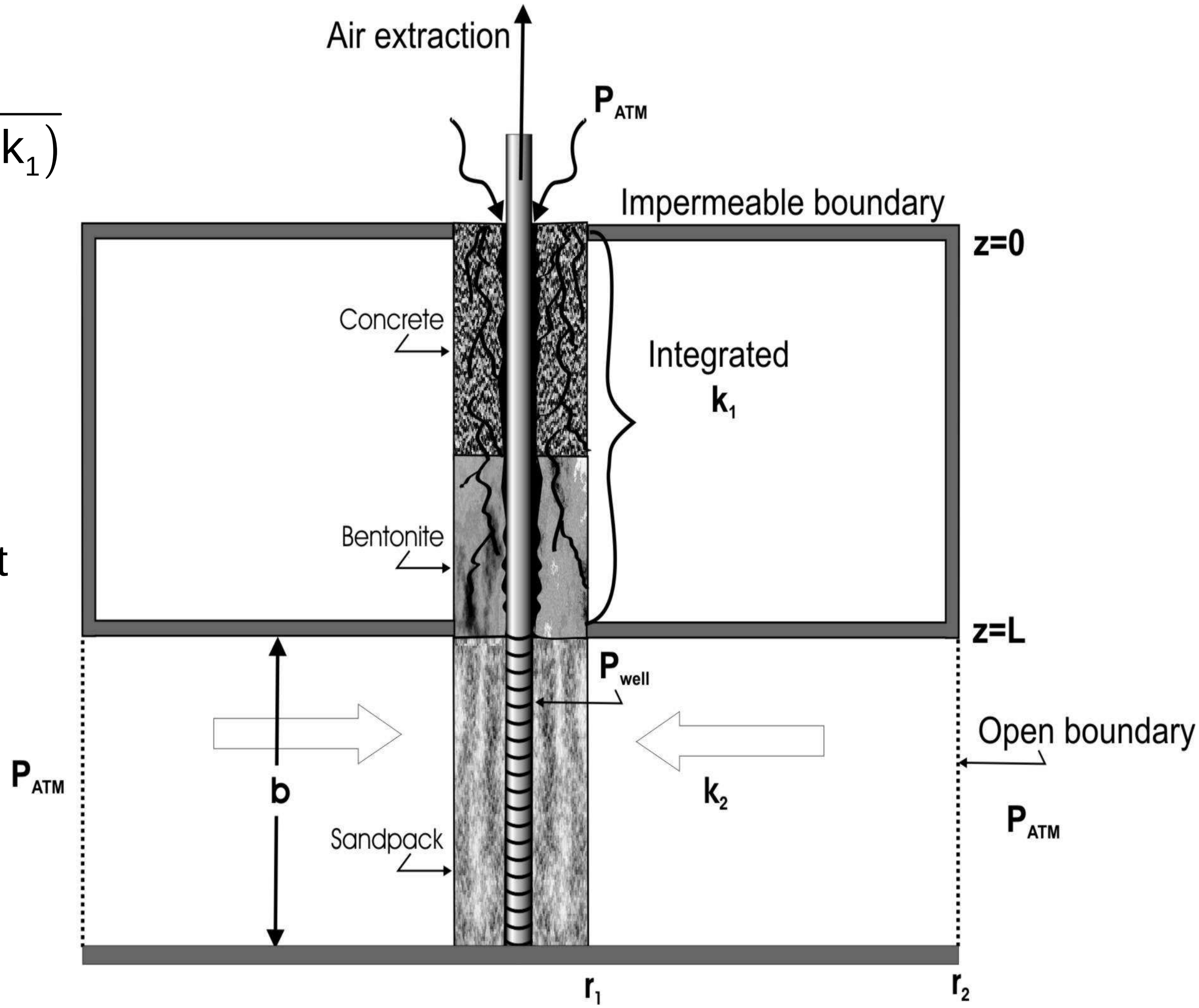
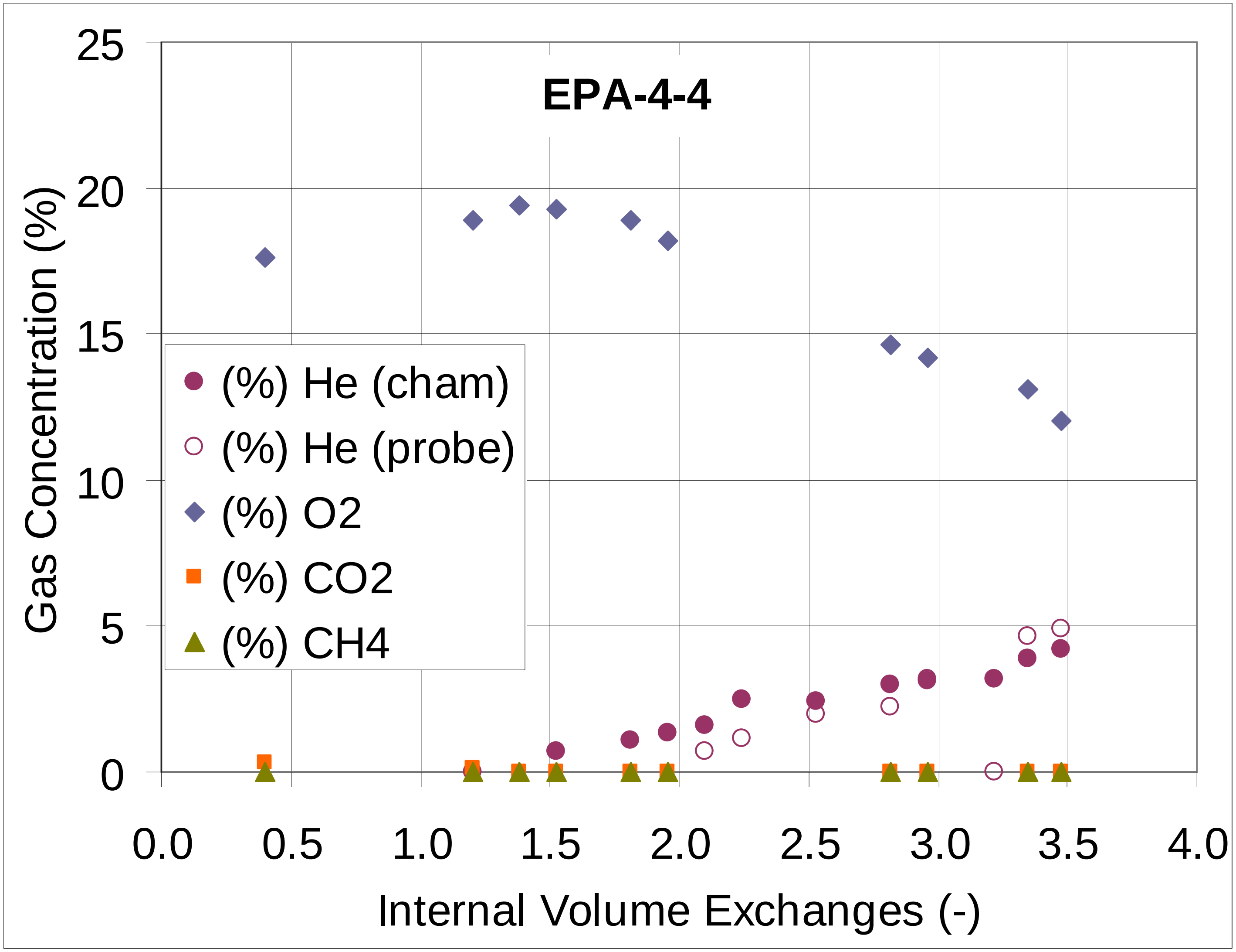
$$\xi = \frac{Q_z}{Q_z + Q_r} = \frac{1}{1 + C(k_2/k_1)}$$

$$C = \frac{2bL}{r_w^2 \ln(r_{atm}/r_w)}$$

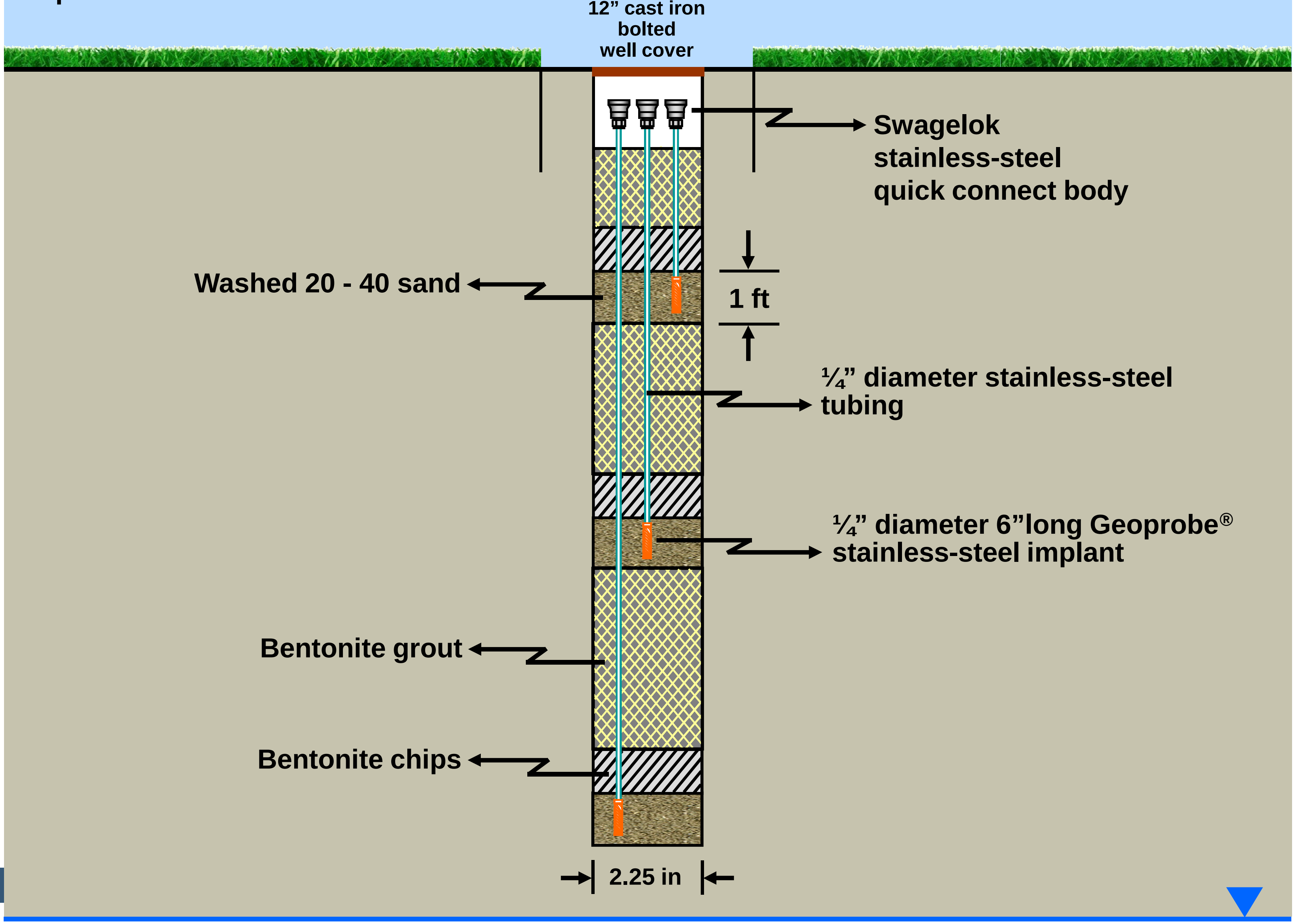
Leakage is a function of the permeability contrast between the borehole and surrounding media and geometric factors.



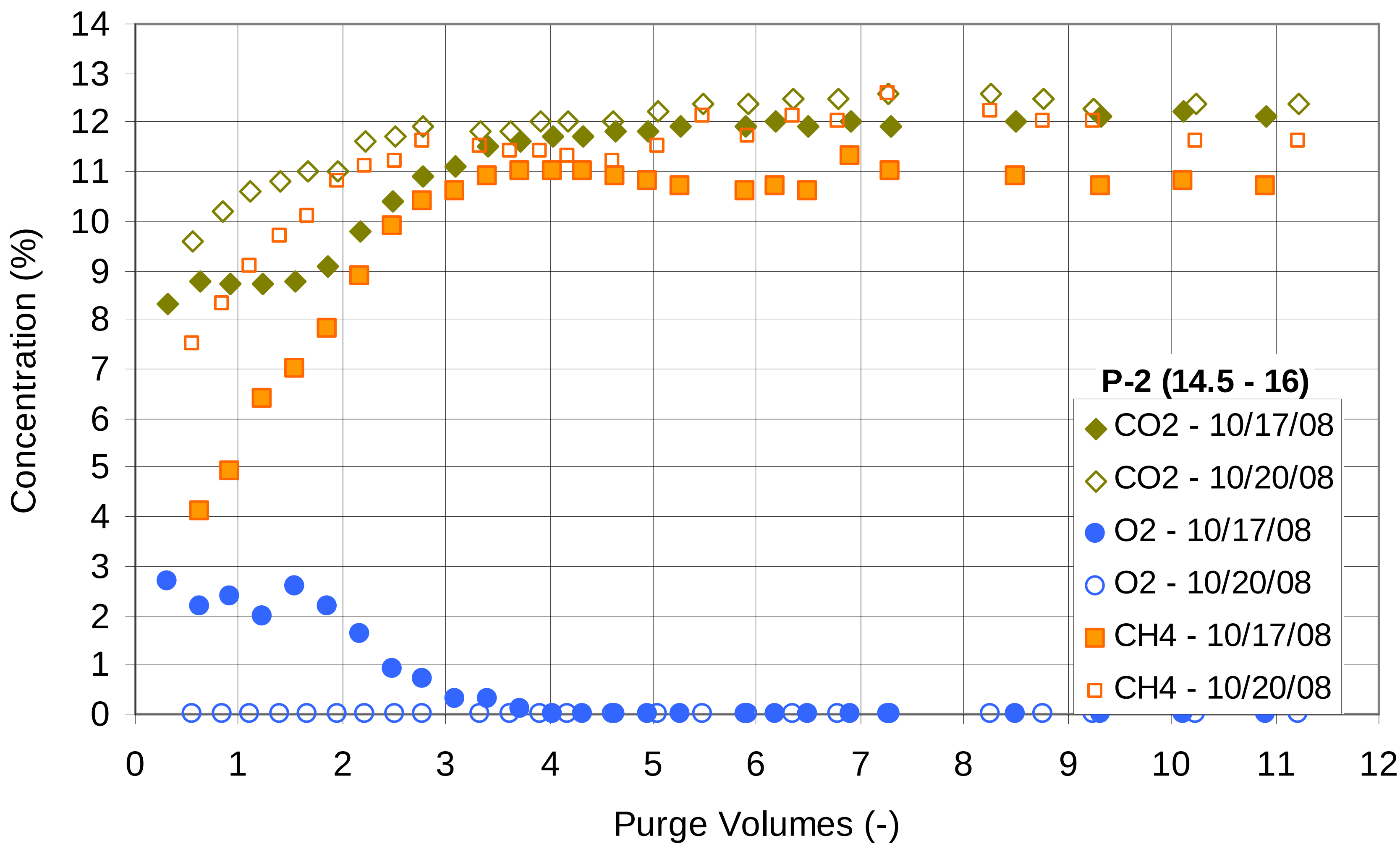
Leak Testing in Green River, UT



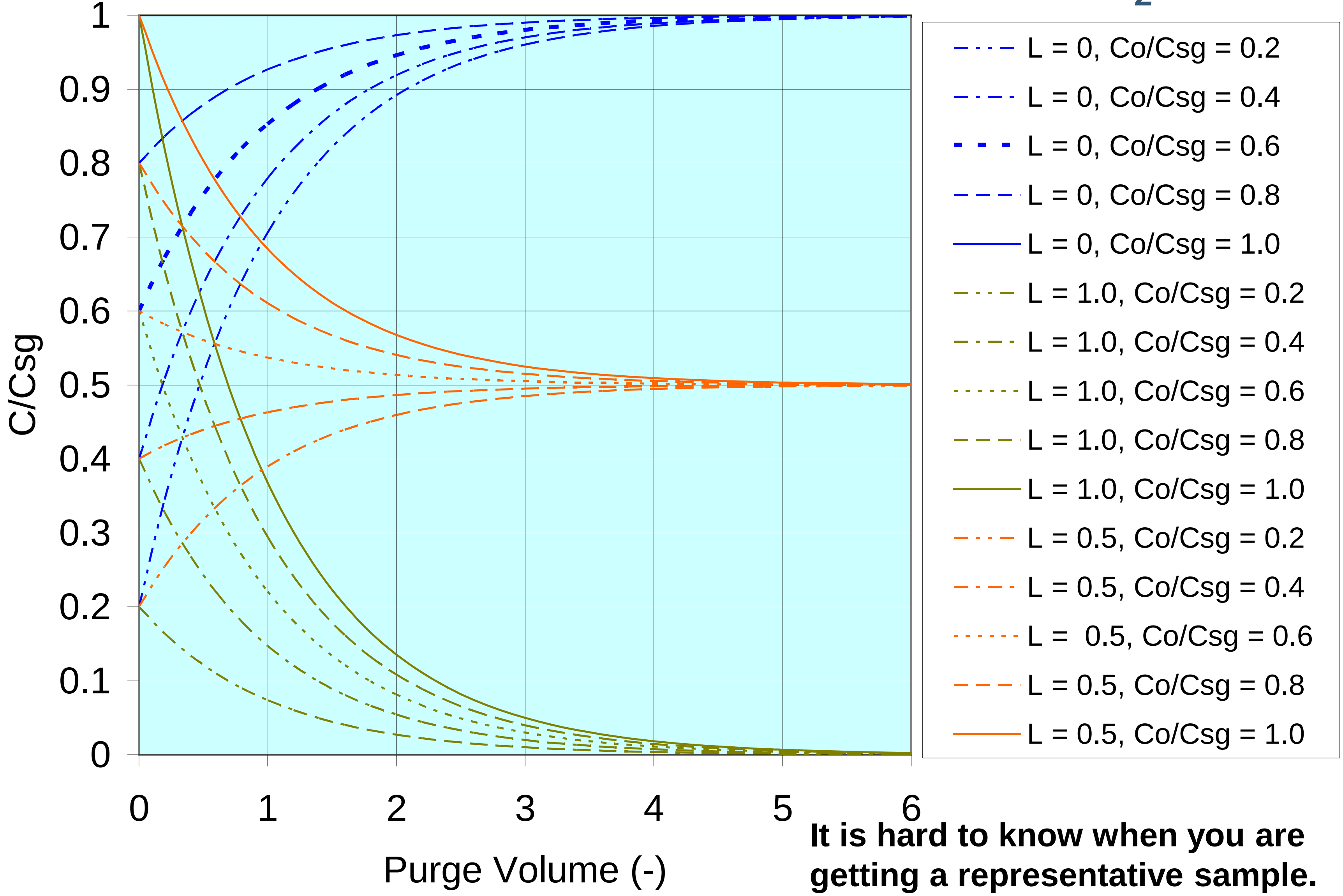
Vapor Probe Installation



Purge Testing

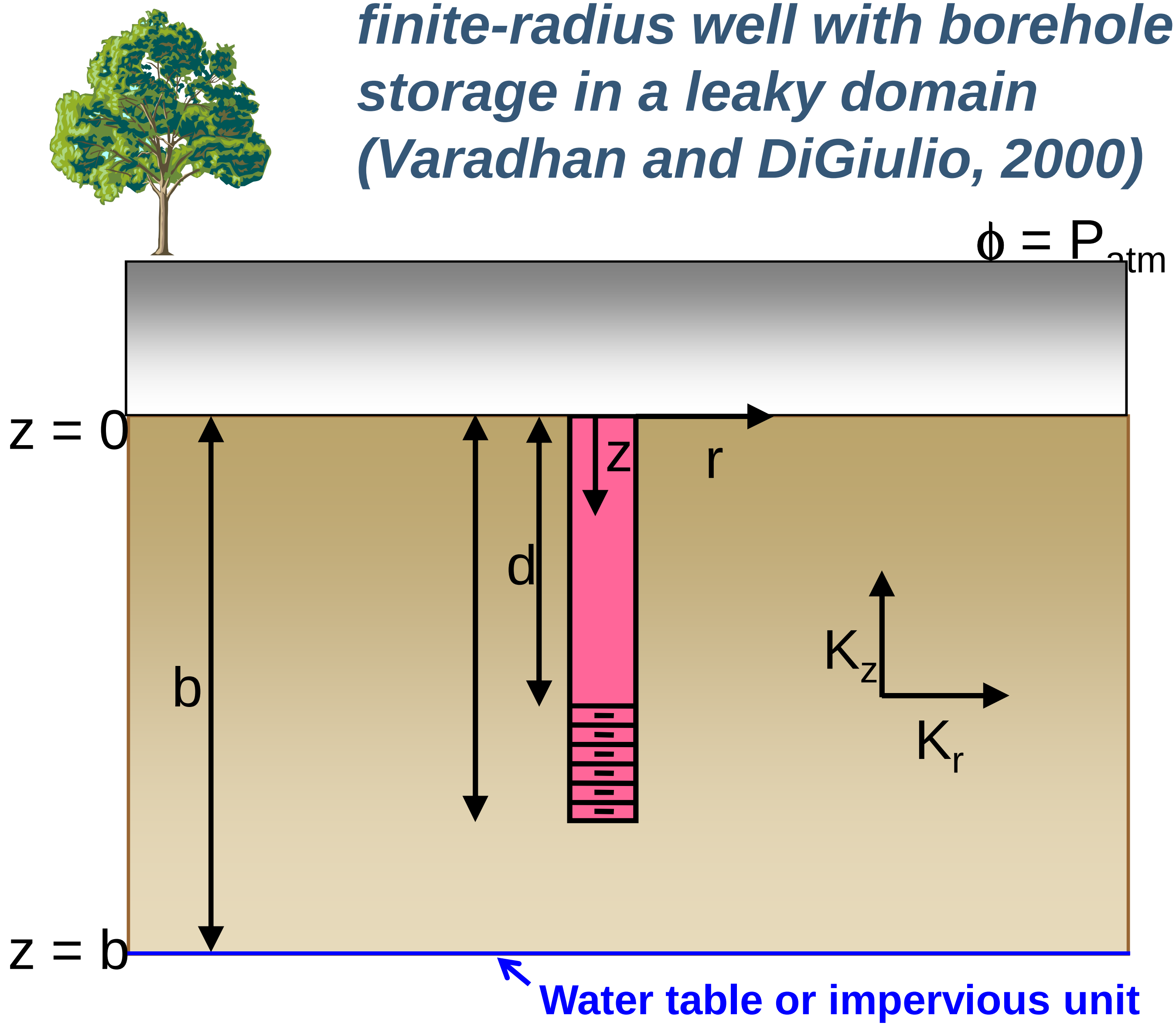


Sample Concentration as a Function of Leakage, Initial Probe Concentration, and Soil-Gas Concentration for CO_2



It is hard to know when you are getting a representative sample.

Analytical solution for transient axi-symmetric gas flow for a finite-radius well with borehole storage in a leaky domain (Varadhan and DiGiulio, 2000)



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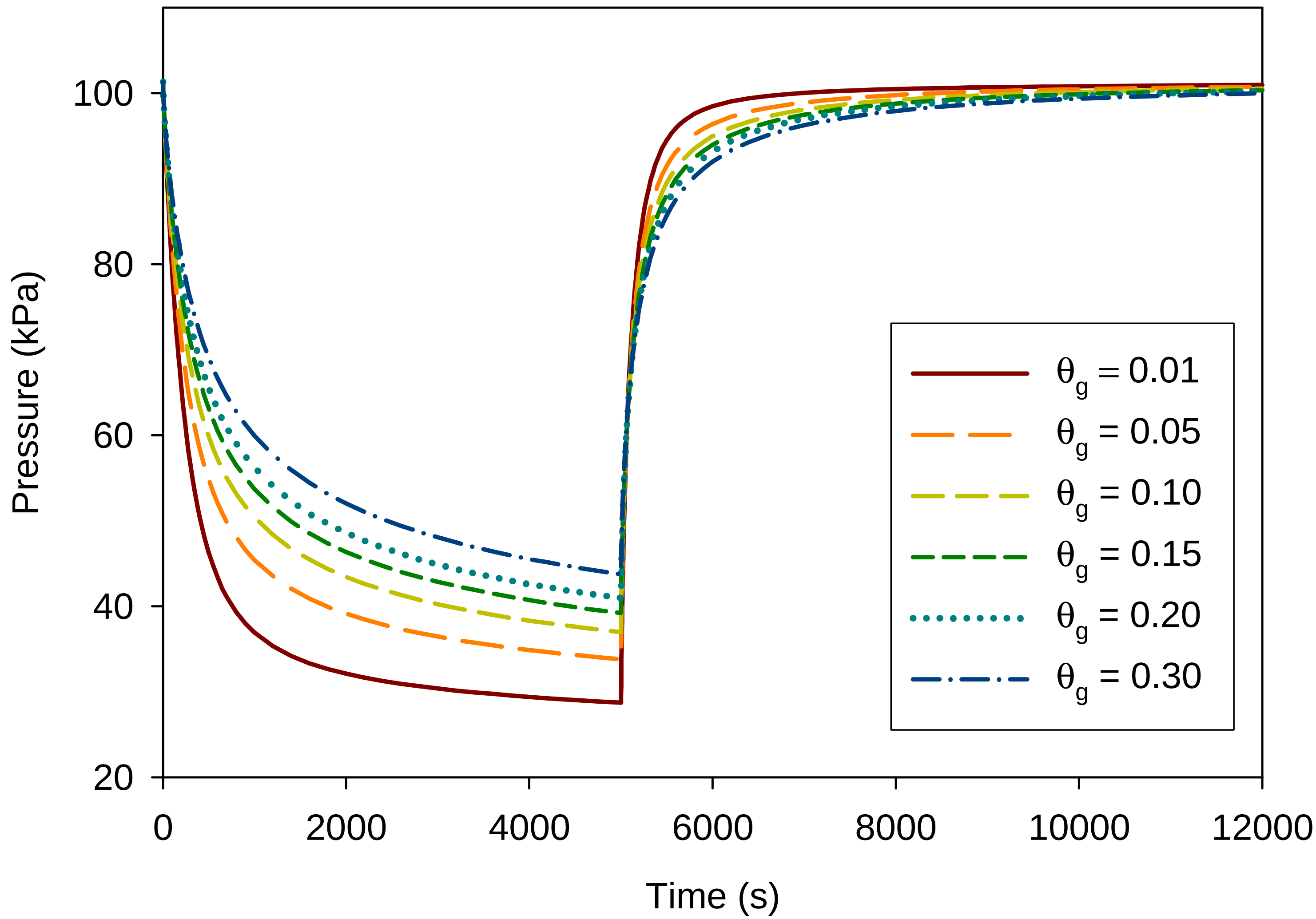

Gas Flow During Soil-Gas Sampling

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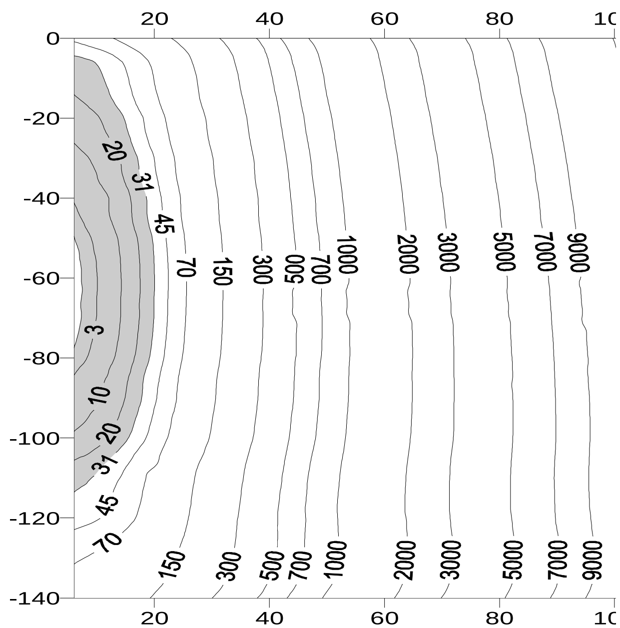
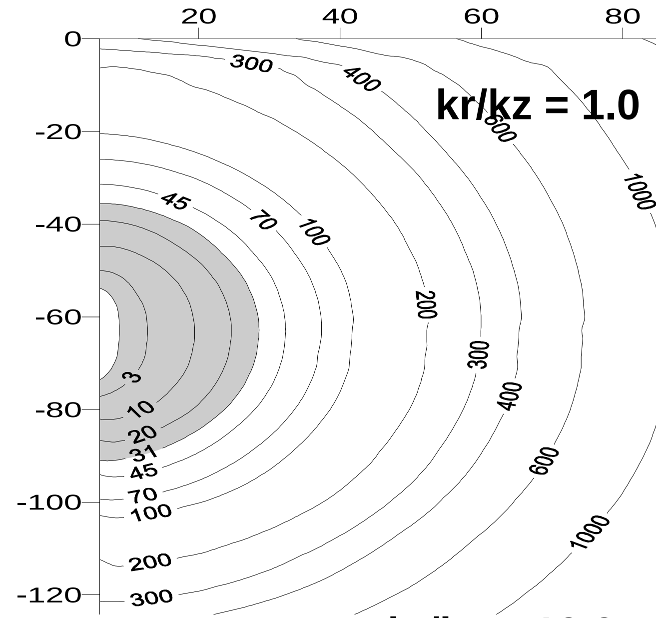
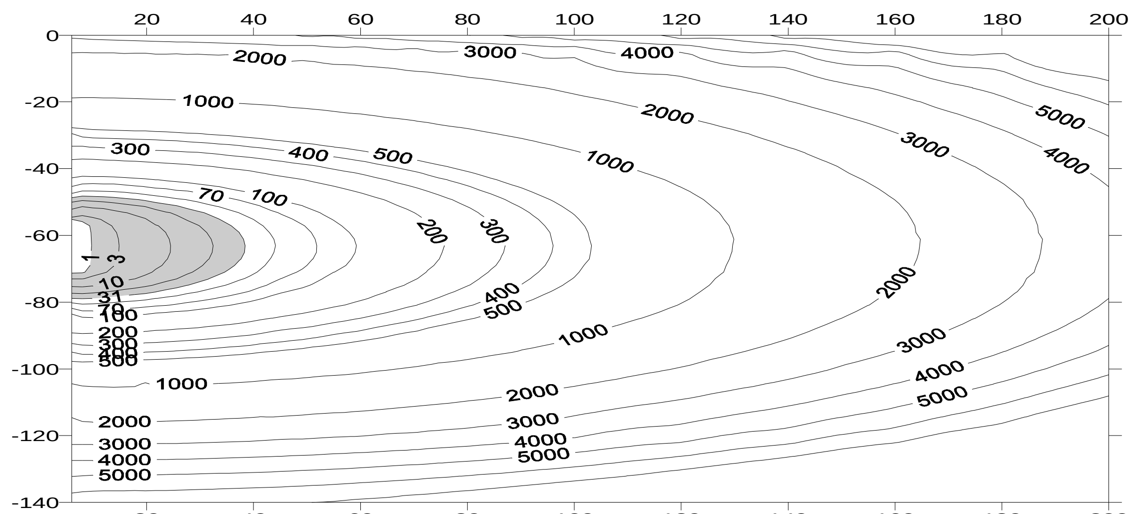
kr/kz = 0.1



kr/kz = 1.0



kr/kz = 10.0



Model Input for Particle Tracking	
283.0	temperature (K)
-0.00641	pumping rate (300 sccm)
1.1e-10	radial permeability (cm^2)
0.1	air-filled porosity (-)
520.0	thickness of formation (cm)
56.0	top of well screen (cm)
71.0	bottom of well screen (cm)
3.81	nominal well radius (cm)

From DiGiulio et al., (2007)

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Questions?

caglecartoons.com

"HOW ON EARTH DO WE TURN IT OFF?"