Above Zone Pressure Interpretation for Leaky Well Characterization and Its Identification from Leaky Caprock/Fault

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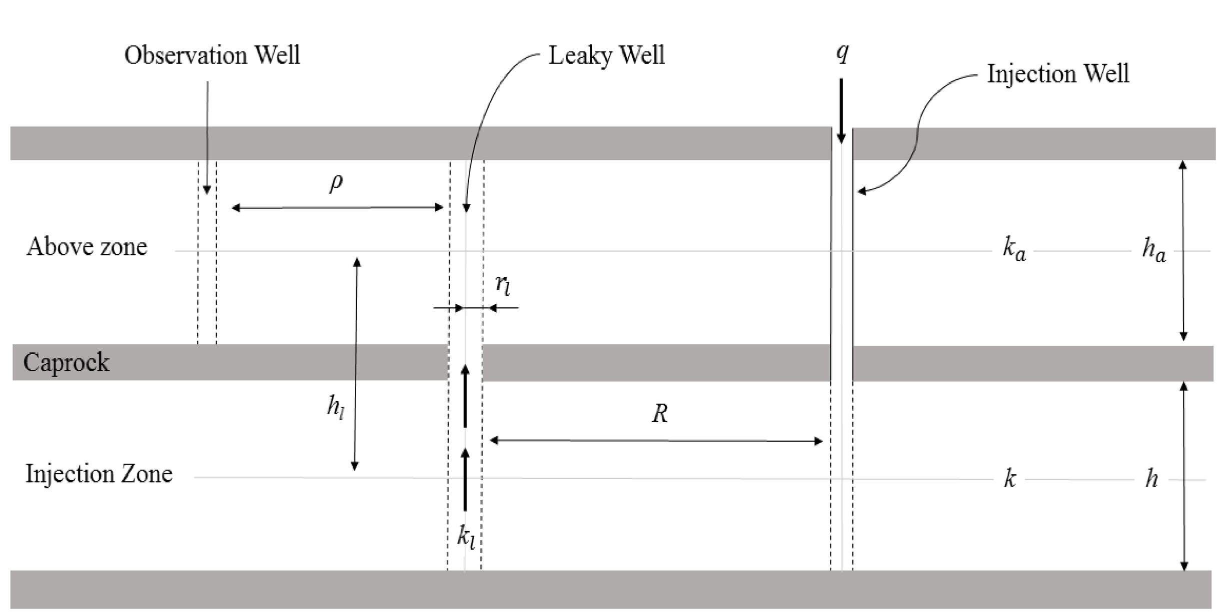
Abstract

Pressure transient analysis has long been used for reservoir characterization. Above-zone (AZ) pressure has been investigated for inferring leakage pathway characteristics in leakage events from subsurface injection operations. The recorded pressure in the AZ should be purely related to leakage and therefore it can be safely inverted to deduce leakage characteristics.

Identification of leakage feature and spatial investigation of leakage is required for leakage evaluation. In this study, we propose a pressure interpretation method for early detection of leaky pathways, applying two observation points in the AZ. We distinguish leaky well, fault and caprock based on their corresponding flow regime identification. We show that the pressure difference of the two observation wells can be applied as a proxy for unknown leakage rate, which is crucial for leakage identification as well as characterization.

Model Description



Methodology

Applying Zeidouni and Vilarrasa (2016) analytical solution, we derive the following equation:

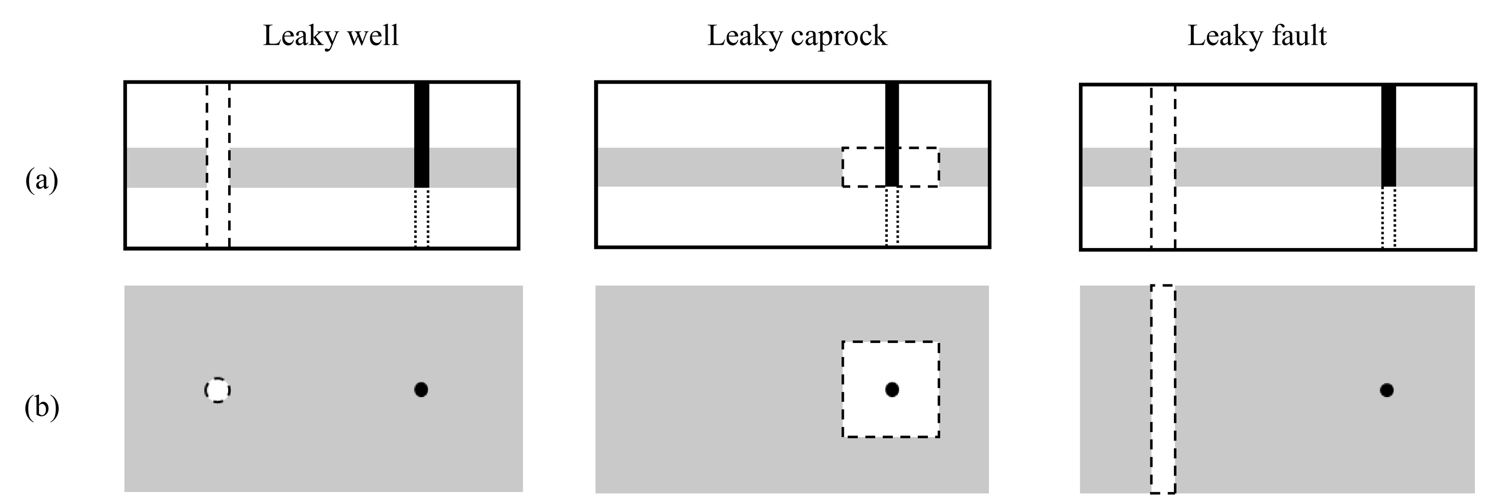
$$\Delta p_{a1}(t,\rho_1) - \Delta p_{a2}(t,\rho_2) = \frac{\mu B}{2\pi k_a h_a} \ln\left(\frac{\rho_2}{\rho_1}\right) q_l(t)$$

Therefore, we can normalize the pressure with respect to the difference between pressure changes measured at two observation wells in the above zone. Applying straight-line semi-log method for infinite acting radial flow, we characterize leaky well.

$$\Delta p_1(t) \big/ \left(\Delta p_1(t) - \Delta p_2(t)\right) = m \ln(t_D) + b$$

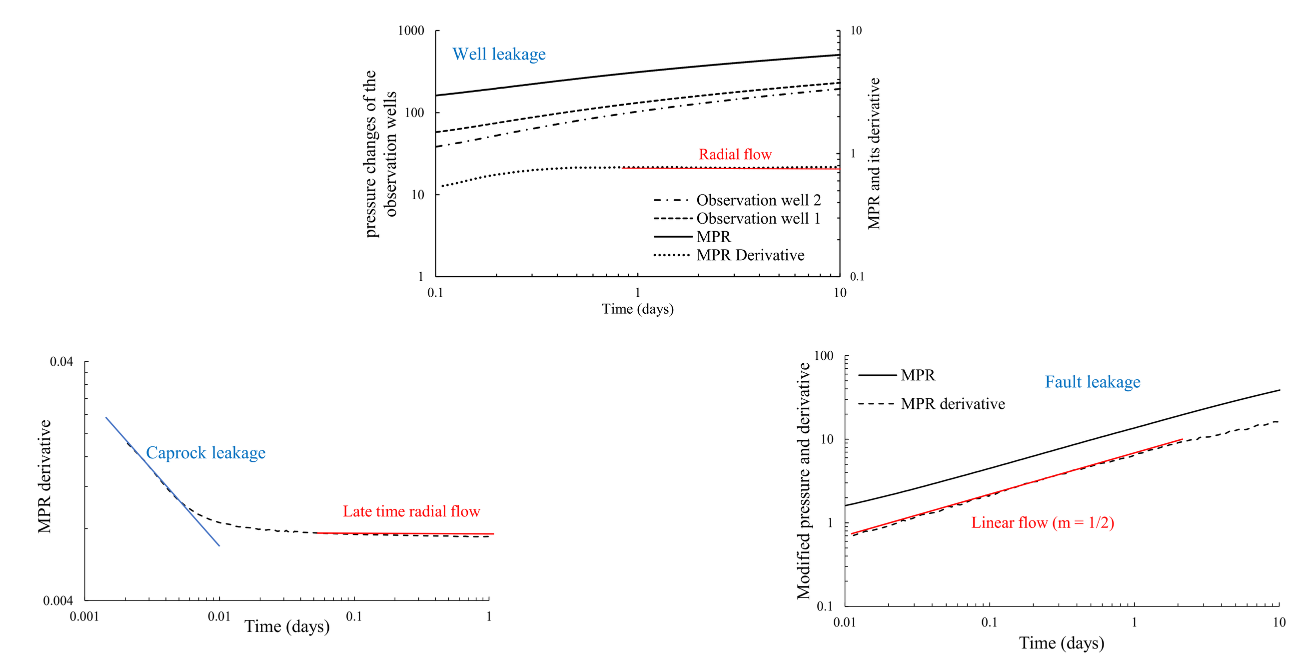
Methodology

Pressure change in the above zone is not necessarily related to focused leakage through a well. Diffuse leakage through a local/regional weakness in the caprock is another possibility. The diffusive nature of the caprock leakage induces spherical stabilization in the above zone, because the normalized pressure ($\Delta P/q_l$) is relatively constant in the leaky region of the caprock layer during the diffuse leakage. A leaky fault is a planar interface that causes linear flow geometry.

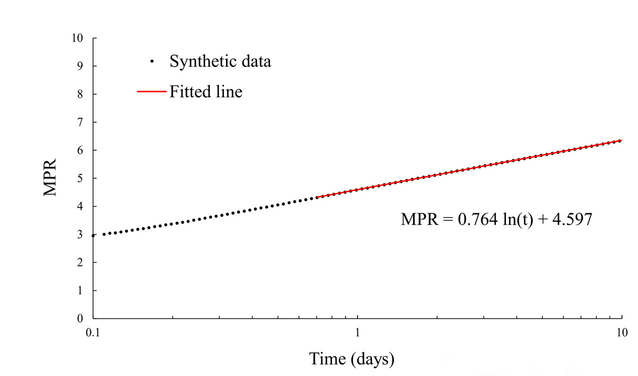


Characterization procedure and example

1. Flow regime identification:



2. Semi-log radial flow characterization:

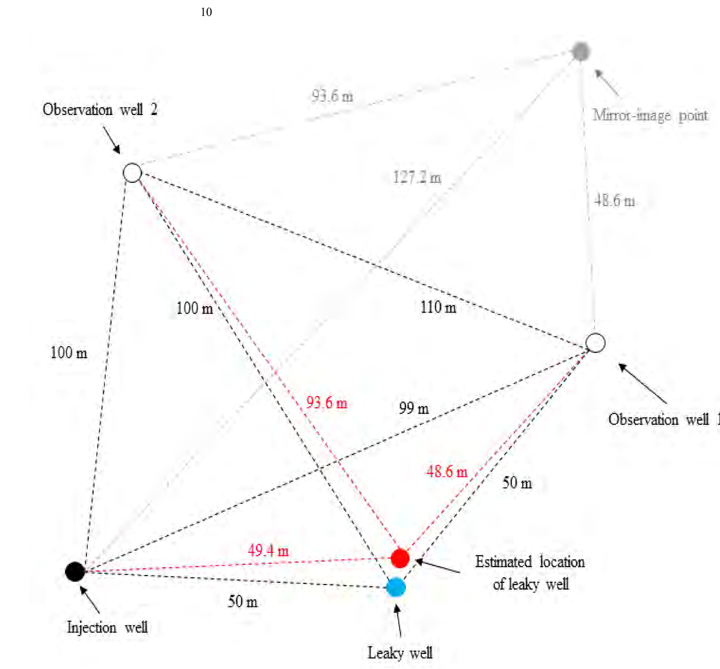


2.1. Estimation of leaky well location:

$$\rho_{D1} = 2\sqrt{e^{-(b/m)-\gamma}} \qquad \rho_1 = 48.6\ m$$

$$\rho_{D2} = \rho_{D1} e^{0.5/m} \qquad \rho_2 = 93\ m$$

$$R = 49.38$$

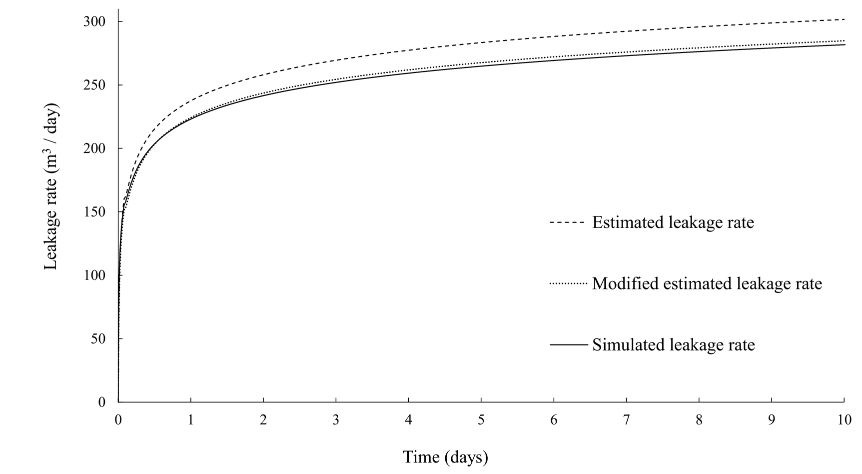


Characterization procedure and example

2.2. Estimation of leakage rate and hydraulic conductivity of the leaky well:

$$q_l = \frac{2\pi k_a h_a (\Delta P_{a1} - \Delta P_{a2})}{\mu B \ln\left(\frac{\rho_2}{\rho_1}\right)}$$

$\alpha = 0.0225$



Conclusions

1. The derivative curve for diffuse leakage shows spherical stabilization (-3/2 slope derivative line) while that for focused well leakage shows radial flow characterized by zero-slope derivative. Fault leakage causes linear flow, which is shown by 1/2 slope line at derivative curve.
2. We applied pressure difference of the two observation wells as an alternate of unknown leakage rate for pressure normalization.
3. We estimated the location, leakage rate, and leakage coefficient of the leaky well. The estimated leakage rate can be more accurate applying the actual location of the leaky well if known in the field instead of estimated location of the leaky well.

References

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