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Using Analytical and Numerical Modeling to Assess the Utility of Groundwater Monitoring Parameters at Carbon Capture, Utilization, and Storage Sites

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Carbon capture, utilization, and storage (CCUS) is becoming an important bridge to commercial geologic sequestration (GS) to help reduce anthropogenic CO_2 emissions. While CCUS at brownfield sites (i.e. mature oil and gas fields) has operational advantages over GS at greenfield sites (i.e. saline formations) such as the use of existing well infrastructure, previous site activities can add a layer of complexity that must be accounted for when developing groundwater monitoring protection networks.

Extensive work has been done on developing monitoring networks at GS sites for CO_2 accounting and groundwater protection. However, the development of appropriate monitoring strategies at commercial brownfield sites continues to develop. The goals of this research are to address the added monitoring complexity by adapting simple analytical and numerical models to test these approaches using two common subsurface monitoring parameters, pressure and aqueous geochemistry. The analytical pressure model solves for diffusivity in radial coordinates and the leakage rate derived from Darcy's law. The multi component groundwater flow and solute-transport simulator PHAST solves the advection-reaction-dispersion equation for 3-D transport and mixing of fluids .The research was conducted at a CO_2 enhanced oil recovery (EOR) field on the Gulf Coast of Texas. We modeled the performance over 50 years of one monitoring well from the EOR field using physical and operational data including lithology and water chemistry samples, and formation pressure data. We explored through statistical analyses the threshold of leakage detection using the analytical and numerical methods by varying select geologic reservoir properties, and the monitoring well location spatially and vertically with respect to a leaky fault. Preliminary results indicate that a pressure based subsurface monitoring system provides a better probability of fluid migration detection at greater depths (e.g. 1300 meters) than at shallower depths (e.g. 500 meters). For geochemistry based subsurface monitoring, the probability of detection displays a more complex relationship and depends largely on the hydraulic properties of the monitoring interval (e.g. permeability). These preliminary results demonstrate that an integration of these monitoring parameters at different depths can improve the overall chances of fluid migration detection. By assessing the probability of fluid migration detection, an initial finding on the use and implementation of each monitoring technique can be made at this field and realistically extrapolated to other CCUS fields.

Keywords: Carbon Capture Utilization and Storage, CO_2 Enhanced Oil Recovery, Groundwater Hydrology, Monitoring Networks, Analytical Modeling, Numerical Modeling