Modeling and Mapping the Area of Potential Impact (AoPI) for Class VI CO_2 Injection Wells

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https://envext02.rti.org/geoseq/ordgstools.htm

Abstract

The EPA Underground Injection Control (UIC) Program geological carbon sequestration rule requires applicants to model and map an area of review (AoR) about the CO_2 injection well(s). The AoR focuses the geological and geographical survey for compromises to the sealing layers, such as from fractures or abandoned wells, which might provide migration pathways for CO_2 or displaced native brines and threaten the quality of Underground Sources of Drinking Water (USDWs). Therefore, the mapping of the AoR may be based on the projection of subsurface zones of potential endangering influence. Given that supercritical phase CO_2 is less dense than the saline fluids in the receiving zone, it is important for the sealing layer(s) to physically contain the buoyant CO_2, especially during the lifetime of the injection. The sealing layer is also expected to contain the saline fluids displaced by the injection of CO_2. It is not pressure influence that contributes to endangerment, but the critical threshold pressure that could support upward flow of saline fluids from the injection zone to the USDW through a hypothetical unplugged well. Permit applicants are required to use computational (meaning numerical) models to map the maximum extent of separate phase CO_2 and the threshold pressure front. This research project is evaluating simpler area of potential impact (AoPI) tools for regulators to evaluate the complex numerical models associated with the permit applications. The AoPI tools are based on semi-analytic solutions for modeling and mapping the zone of pressure influence, the threshold pressure front, and the CO_2 front. The AoPI tools support conceptual model testing, and their computational efficiency allows for probabilistic uncertainty analysis. Comparisons to the TOUGH2 numerical model support the testing and verification of definitions of critical pressure. Products from the research will be web and desktop-based GIS tools for modeling and mapping the AoPI based on the projection of the outer envelope containing maximum extent threshold pressure and CO_2 fronts. The research and development team includes support from Lawrence Berkeley National Lab, Princeton University, S.S. Papadopulos and Associates, and RTI International.

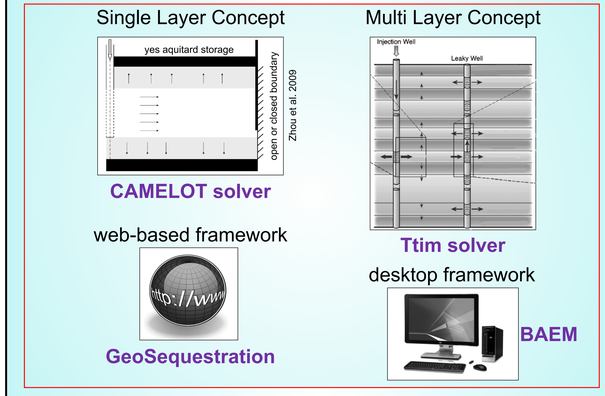


Figure 1: Project overview

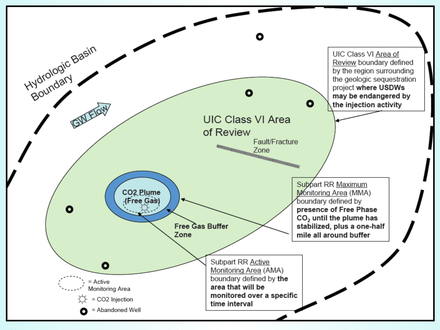


Figure 2: Monitoring areas - UIC class VI and subpart RR requirements

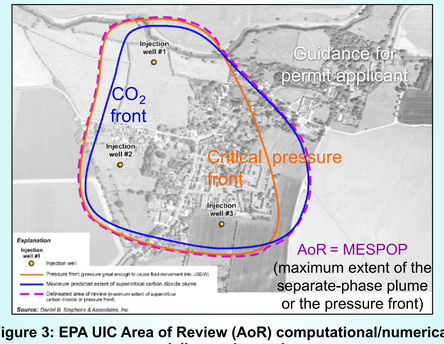


Figure 3: EPA UIC Area of Review (AoR) computational/numerical modeling and mapping

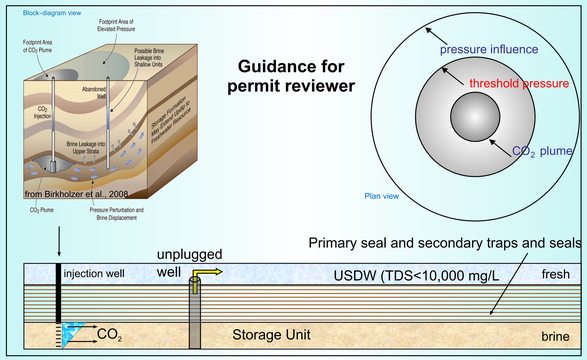


Figure 4: Area of Potential Impact (AoPI) semi-analytical modeling and mapping

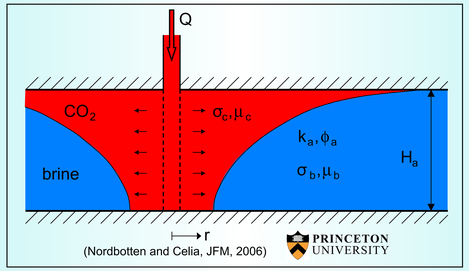
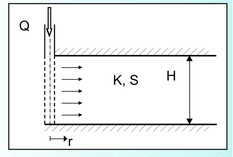


Figure 5: Maximum extent CO_2 front - vertically integrated approach

$$\Delta p = \frac{Q}{4\pi KH} W(u): \quad u = \frac{S\, r^2}{4KHt}$$



Δp is the change in pressure [FL^{-2}]
Q is the injection rate (positive into the aquifer) [L^3T^{-1}]
K is the hydraulic conductivity of the aquifer [L^2]
S is the storativity of the aquifer [-]
r is the radial distance from the center of the injection well [L]
H is the aquifer thickness [L]
t is time since injection started [T]
$W()$ is the well function

Note: an equivalent injection volume rate of brine is computed by dividing CO_2 mass rate of injection by CO_2 density @ pressure, temperature. (Altunin, 1975).

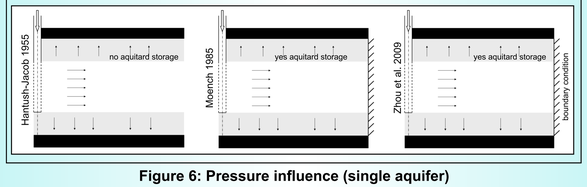


Figure 6: Pressure influence (single aquifer)

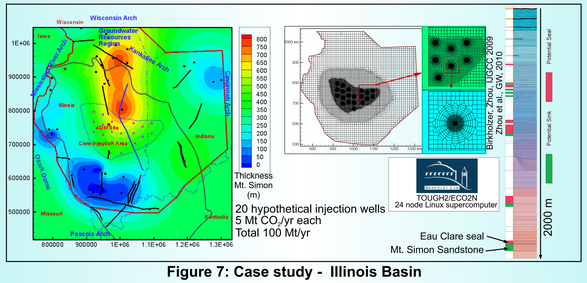


Figure 7: Case study - Illinois Basin

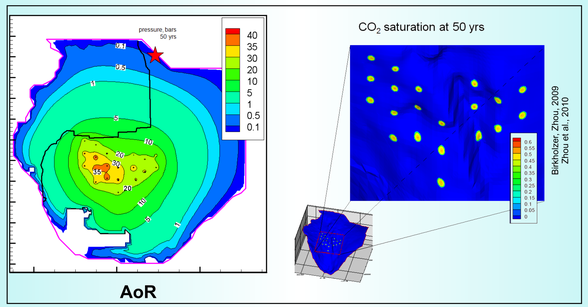


Figure 8: Pressure fronts --- basin scale; CO_2 fronts --- local scale

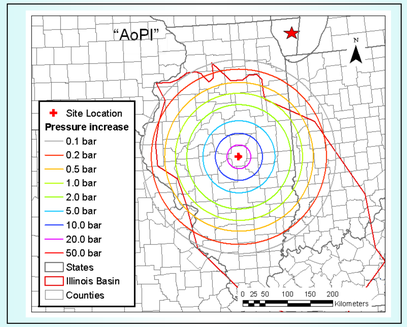


Figure 9: Pressure influence, Mt. Simon fm, 50 yrs, semi-analytical, single phase solution, single layer

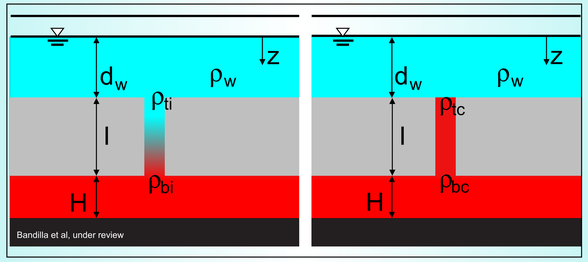


Figure 10: Maximum extent thresh pressure - static calculations based on assuming equilibrium density or uniform density in unplugged well

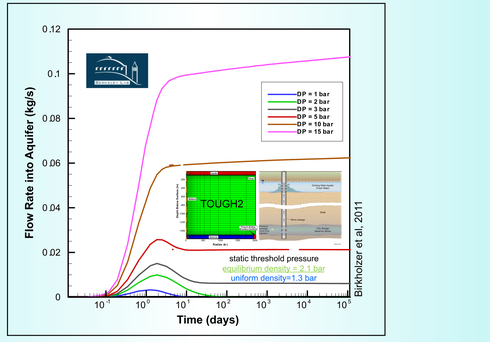


Figure 11: Dynamic vs. static threshold pressure

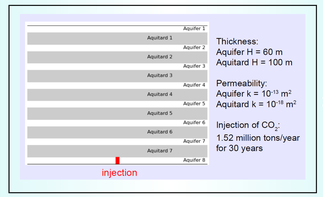


Figure 12: TTim is introduced through an example of a system with eight layers
Example: Jens T. Birkholzer, Quanlin Zhou, Chin-Fu Tsang, 2009, International Journal of Greenhouse Gas Control 3 181-194

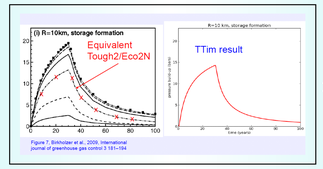


Figure 13: Pressure build-up in injection layer, 10km from injection well
TTim gives almost same results as Tough2/ECO2n

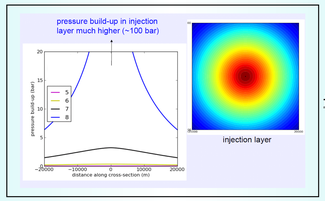


Figure 14: TTim contour plot and cross-section along line through injection well, after 30 years of injection

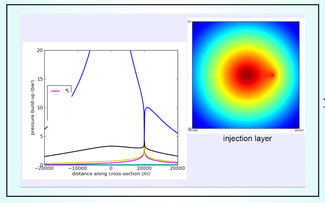


Figure 15: TTim pressure distribution with abandoned well 10km from injection well screened in layers 5-8 1919

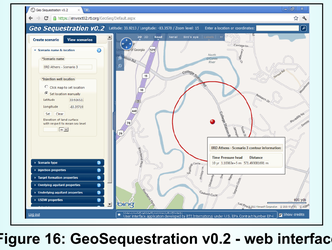


Figure 16: GeoSequestration v0.2 - web interface

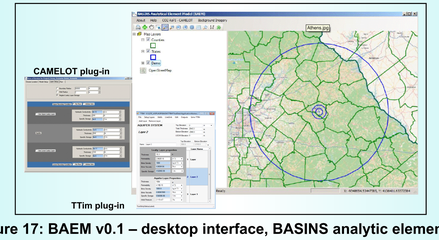


Figure 17: BAEM v0.1 – desktop interface, BASINS analytic element model