Monitoring a large volume CO_2 injection: Year two results from SECARB project at Denbury's Cranfield, Mississippi, USA

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Abstract:

The Southeast Regional Carbon Sequestration Partnership (SECARB) early project in western Mississippi has been testing monitoring tools and approaches to document storage efficiency and storage permanence under conditions of CO2 EOR as well as downdip injection into brine. Denbury Onshore LLC is host for the study and has brought a depleted oil and gas reservoir, Cranfield Field, under CO2 flood. Injection was started in July 2008 and has now achieved injection rates greater than 1.2 million tons/year though 23 wells, with cumulative mass injected as of August, 2010 of 2.2 million metric tons. Injection is into coarse grained fluvial deposits of the Cretaceous lower Tuscaloosa Formation in a gentle anticline at depths of 3300 m. A team of researchers from 10 institutions has collected data from five study areas, each with a different goal and different spatial and temporal scale.

The Phase 2 study began at the start of injection and has been using pressure and temperature as a tool for assessing permanence mostly in the oil productive interval. Real-time read-out shows high sensitivity to distant changes in injection rate and confirms the geologic model of reservoir compartmentalization. Above-zone pressure monitoring ~120 m above the injection interval is used to test the sensitivity of this approach for documentation of integrity of the confining system in an area of numerous well completions as pressure increase is induced in the reservoir by more than 70 bar.

Monitoring of the High Volume Injection Test (HiVIT) area includes repeat measurements of aqueous geochemistry in the injection zone. Rock-water-CO2 interactions in the reservoir as CO2 dissolves are minimized by mineral "armoring" by abundant chlorite cement in high permeability reservoir sandstone. Geochemical monitoring of confined freshwater aquifers at depths of 70-100 m is underway. Groundwater analysis focuses on assessment of the sensitivity of this method to detect leakage above background variability. A repeat seismic survey of the HiVIT is planned for late 2010 to assess saturation change especially in downdip brine-only areas.

A study focused on feasibility of monitoring the shallow subsurface to separate leakage from normal complex surface fluxes is underway at an monitoring array installed in October 2009 to assess the interactions of recharge, soil gas, and shallow groundwater aquifers. Recent well re-entry and tracer injection will provide further information to interpret observed elevated deep-sourced methane.

The Detailed Area Study (DAS) is collecting dense time-lapse data from closely-spaced three well array of an injector and two observation wells. The observation wells were completed with fiberglass casing to facilitate electrical resistance tomography (ERT) measurements, and a diverse array of instrumentation was both cemented behind casing and suspended on tubing. Injection started at the DAS December 1, 2009. We have measured pulsed neutron and resistivity via wireline, downhole and above-zone pressure, distributed temperature, and fluid chemistry including introduced pulses of perfluorocarbons, noble gases, and SF6 as tracers. Between wells, time-lapse crosswell seismic and electrical resistance tomography (ERT) are used to measure saturation change. The goals are to

measure changes as fluids evolve from single phase (brine) to two phase (CO_2–brine) in order to document linkages between pressure and sweep efficiency. A time-lapse VSP survey bridges the vertical resolution and areal coverage between cross-well and surface seismic. The repeat surveys for many tools are scheduled for September, 2010.

Reservoir characterization based on cores, historic and new wireline log data, production history, hydrologic tests, fluid analysis, and a three-D seismic survey have been used in multiple numerical models to predict reservoir response in order to design effective monitoring strategies and optimize deployment. History matching of observed response to predicted response is used to interpret results and improve confidence in conceptual models and numerical approaches. Probabilistic methods have been used to assess the significant uncertainties resulting from reservoir heterogeneity.

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