# Southwest Regional Partnership Farnsworth Unit EOR Field Project – Development Phase

## Background

The U.S. Department of Energy Regional Carbon Sequestration Partnership (RCSP) Initiative consists of seven partnerships. The purpose of these partnerships is to determine the best regional approaches for permanently storing carbon dioxide ($CO_2$) in geologic formations. Each RCSP includes stakeholders comprised of state and local agencies, private companies, electric utilities, universities, and nonprofit organizations. These partnerships are the core of a nationwide network helping to establish the most suitable technologies, regulations, and infrastructure needs for carbon storage. The partnerships include more than 400 distinct organizations, spanning 43 states and four Canadian provinces, and are developing the framework needed to validate geologic carbon storage technologies. The RCSPs are unique in that each one is determining which of the numerous geologic carbon storage approaches are best suited for their specific regions of the country and are also identifying regulatory and infrastructure requirements needed for future commercial deployment. The RCSP Initiative is being implemented in three phases, the Characterization Phase, Validation Phase, and Development Phase. In September 2003, the Characterization Phase began with the seven partnerships working to determine the locations of $CO_2$ sources and to assess suitable locations for $CO_2$ storage. The Validation Phase (2005–2012) focused on evaluating promising $CO_2$ storage opportunities through a series of small scale field projects in the seven partnership regions. Finally, the Development Phase (2008-2020+) activities are proceeding and will continue evaluating how $CO_2$ capture, transportation, injection, and storage can be achieved safely, permanently, and economically at large scales. These field projects are providing tremendous insight regarding injectivity, capacity, and containment of $CO_2$ in the various geologic formations identified by the partnerships. Results and assessments from these efforts will assist commercialization efforts for future carbon storage projects in North America.

The Southwest Regional Partnership on Carbon Sequestration (SWP) is led by the New Mexico Institute of Mining and Technology and represents a coalition comprising a diverse group of experts in geology, engineering, economics, public policy, and outreach. Stakeholders in SWP projects include private industry, non-governmental organizations, government entities, and most importantly, the general public. The SWP region encompasses Arizona, Colorado, Oklahoma, New Mexico, Utah, Kansas, Nevada, Texas, and Wyoming and contains plentiful supplies of oil, natural gas, and coal. Combustion of these fuels for electricity, transportation, and other industrial processes, produces $CO_2$. The 10 largest coal-fired power plants in the SWP region emit

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## PARTNERS

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Pacific Northwest National Laboratory
Utah Geological Survey
University of Missouri
University of Utah
Sandia National Laboratories
Schlumberger Carbon Services

## PROJECT DURATION

**Start Date** 10/01/2007
**End Date** 07/31/2022

## COST

**Total Project Value**
$82,910,800

**DOE/Non-DOE Share**
$57,318,771 / $25,592,029

## PROJECT NUMBER

FC26-05NT42591

125 million metric tons of $CO_2$ per year, approaching half of the total point-source emissions of the region. In addition to electrical plants and other stationary sources of anthropogenic $CO_2$ (natural gas processing plants, refineries, ammonia/fertilizer plants, ethylene and ethanol plants, and cement plants). The SWP region produces and transports more than 27 million metric tons of naturally sourced $CO_2$ per year from vast geologic reservoirs and about 2 million metric tons of anthropogenic $CO_2$ from gas, ethanol, and fertilizer plants. One option the SWP is exploring is the viability of supplanting the $CO_2$ currently produced from natural $CO_2$ reservoirs used for enhanced oil and natural gas recovery with anthropogenic $CO_2$ from power plants. A significant network of $CO_2$ pipelines bridge $CO_2$ sources and potential $CO_2$ storage units significantly improve the viability of this option.

## Project Description

As part of its Development Phase efforts, the SWP is characterizing, modeling, monitoring, and tracking at least 1 million metric tons of $CO_2$ at an ongoing oil recovery operation in Ochiltree County, northern Texas. The primary target reservoir is the Pennsylvanian-age Morrow Sandstone Formation within the Farnsworth Unit (FWU) of the Anadarko Basin (Figure 1). A particularly important research focus for this project is to develop portability or transferability of site-specific results to other sites. The project is being performed in two phases: (1) Characterization and Active Monitoring, Verification, Accounting, (MVA) and Assessment; and (2) Post-injection Monitoring, Verification, Accounting, and Assessment.

The project includes several key aspects that are being emphasized as necessary components for wide deployment of carbon capture and storage (CCS). These include (1) meaningful public outreach and education, (2) effective storage site selection and characterization protocols; (3) quantitative monitoring, simulation, and risk assessment of injected and stored $CO_2$; (4) a project assessment for storage efficacy and management, and (5) accounting protocols for both $CO_2$ sources and storage sites.


*Figure 1. Map depicting the location of the Farnsworth Unit (red diamond) within the Anadarko Basin. Potential $CO_2$ storage resources for the Morrow within the FWU exceed 10 million metric tons based on rough estimates of formation volume and porosity.*

The first phase of the project includes all aspects required to prepare for and track subsurface $CO_2$ during the active injection and monitoring period. The site, an active $CO_2$ injection petroleum recovery site, is managed by Chaparral Energy, L.L.C. (CELLC). SWP efforts include (1) performing baseline surface and subsurface characterization using both existing and new data, (2) evaluating and quantifying potential risks associated with injection operations; (3) developing and updating site models, injection simulations, and risk assessment evaluations; (4) assessing and drilling characterization wells and monitoring/observation wells; (5) designing, developing, and implementing MVA plans to monitor and track injected $CO_2$; and (6) continuing to refine storage estimates.

The second phase includes all aspects of post-injection monitoring that will be required once active $CO_2$ injection and monitoring operations cease. The post-operation period for the SWP FWU project will commence after at least 1 million metric tons of $CO_2$ have been injected. During this period SWP will continue to (1) perform MVA activities and track $CO_2$ plume movement using in-place facilities and wells, (2) conduct simulation analysis and risk assessment activities, and (3) make improvements to area and regional models and $CO_2$ storage estimates.

## Description of Geology

The Anadarko Basin is approximately 50,000 square miles in size and primarily located in the northern Texas panhandle and western Oklahoma, extending into eastern Colorado and western Kansas. The basin is known to contain significant reserves of oil and gas and has been extensively developed for recovery.

The SWP Development Phase effort is examining the Morrow Formation (Figure 2), which is undergoing active EOR operations that began in December 2010. The field is divided into sections based on injection and recovery wells in place. Additional sections are added as tertiary injection expands across the field. The Morrow Formation comprises incised valleyfill sandstone that contains oil, and the formation lies at an average depth of 7,750 feet. Formation permeabilities range from 10 to 500 mD (average ~54mD), which is within the range for $CO_2$ injection and storage. A conservative estimate of $CO_2$ storage capacity of the Morrow within the FWU exceeds 10 million metric tons of $CO_2$ based on estimated formation volume and porosity. As the SWP acquires production and other reservoir data, more refined storage capacity estimates can be made.

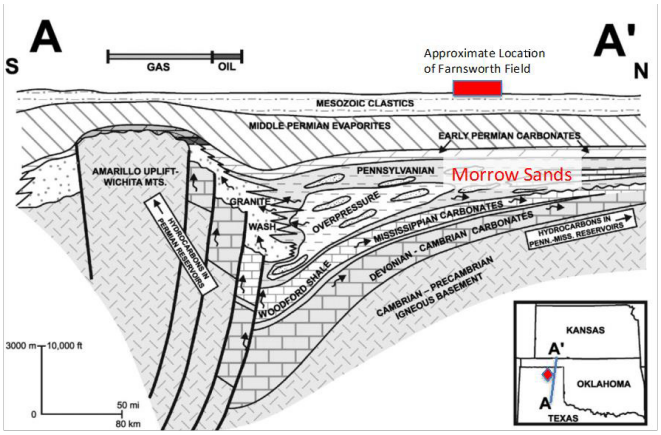


*Figure 2. Cross section schematic of the Anadarko Basin depicting the FWU and underlying Morrow Sands (in red)*

## Sources of $CO_2$

The project involves modeling, monitoring, and tracking the injection of approximately 0.2 million metric tons of $CO_2$ per year over multiple years. The $CO_2$ will be obtained from two anthropogenic sources: (1) the Arkalon Ethanol Plant in Liberal, Kansas and (2) the Agrium Fertilizer Plant in Borger, Texas. The $CO_2$ is transported by pipeline from the sources, which are located less than 100 miles from the site.

## Injection Monitoring Operations

The site is located within an active oilfield where $CO_2$ injection has been ongoing prior to this project's monitoring and tracking efforts. Injection is being performed by CELLC in five-spot injection patterns where four oil recovery wells surround a central injection well. Injection operations expand to adjacent five-spot patterns as operations continue. The SWP will begin monitoring and tracking activities on active five-spot patterns and continue to monitor additional patterns as they come online.

The injection process being used by CELLC is referred to as a hybrid water alternating with $CO_2$ gas injection (WAG). An initial 'dry slug' ($CO_2$ only) is injected during the process followed by a 'wetter' combination of an increasing ratio of water to $CO_2$ as the process matures. The initial $CO_2$ slug is planned to be about 15 percent of the original hydrocarbon pore volume (volume in a formation available to hydrocarbon intrusion). The slug size may vary depending on breakthrough time and gas production. The water and gas ratio and injection rates are controlled by CELLC and determined by reservoir response (such as oil and gas production) and available $CO_2$.

## Simulation and Monitoring of Carbon Dioxide

Initial site characterization activities and a review of historical data are being used to develop preliminary interpretations of structure, reservoir, and caprock stratigraphy; fluids and facies distributions; and pressure and temperature data. Characterization activities include a 3-D seismic survey, vertical seismic profiling, crosswell tomography seismic, downhole logging and coring, and geophysical and geochemical analysis. The information from these efforts is being used to develop a series of models for use in initial flow modeling and sensitivity studies. An initial stratigraphic model is being generated for the reservoir and overlying strata, incorporating information from interpretations of formation lithology that can then be used to build a baseline geomodel.

The ultimate goal of the preliminary interpretations of the subsurface is to develop a 3-D, fully coupled process model of the injection site. Simulation models are based on information obtained from baseline data and newly-collected data from pre-monitoring efforts, including drilling activities, initial seismic surveys, and initial sample analyses. The comprehensive simulation model facilitates risk assessment and evaluation of storage capacity, injectivity, $CO_2$ fate, $CO_2$ transport, and trapping mechanisms. The model will be revised throughout the project as new data are obtained from MVA efforts.

The goal of the simulation and monitoring efforts is to create an improved reservoir model. Understanding reservoir lithology, heterogeneity, and architecture is critical to building a reservoir model for prediction of fluid flow, sweep efficiency, oil recovery, and storage potential. The information gained from the creation and modification of the reservoir model is expected to be applicable to similar basins that may be studied as potential $CO_2$ storage locations.

## Goals and Objectives

The primary objective of the DOE's Carbon Storage Program is to develop technologies to safely and permanently store $CO_2$ and reduce greenhouse gas emissions without adversely affecting energy use or hindering economic growth. The programmatic goals of Carbon Storage research are to (1) develop and validate technologies to ensure 99 percent storage permanence; (2) develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness; (3) support industry's ability to predict $CO_2$ storage capacity in geologic formations to within 30 percent; and (4) develop Best Practices Manuals (BPMs) for monitoring, verification, accounting, and assessment; site screening, selection, and initial characterization; public outreach, well management activities, and risk analysis and simulation.

The primary objective of the SWP development effort is to demonstrate the successful reservoir characterization, modeling, monitoring, and tracking of at least 1 million metric tons of $CO_2$ used for EOR at a mature and active oil field as part of CCS deployment. This work has two primary objectives, with the first focusing on geologic and reservoir characterization and the second focusing on accurately predicting and monitoring $CO_2$ movement and storage within, and recovery from, the reservoir for the duration of the project.

Characterization and modeling efforts are creating an improved model of the reservoir and overlying seals. Understanding reservoir lithology, heterogeneity, and architecture is critical for prediction of fluid flow, sweep efficiency, oil recovery, and storage potential for this site and is contributing to our understanding of similar geologic settings within the United States. Monitoring technologies are being compared and contrasted during operational and post-operational monitoring efforts to determine the ultimate fate of injected $CO_2$. It is anticipated that this work may identify the most effective and least expensive monitoring technologies. Additionally, it may improve our understanding of reactive transport of $CO_2$ in EOR projects through detailed characterization and modeling, allowing for less expensive monitoring of $CO_2$ in subsequent EOR projects.

## Accomplishments

The following accomplishments have been achieved:

- Completed acquiring and processing field data from an initial 3-D seismic imaging survey.
- Geologic characterization of the site is underway and has included investigation of petrophysical properties and performance of a literature review, initial risk assessment analysis.

## Benefits

This effort is improving techniques needed for future commercial carbon storage projects in the United States by demonstrating that $CO_2$ used at active EOR sites can be successfully modeled, monitored, and tracked using techniques refined through large-scale CCS efforts. The effort will contribute to the Carbon Storage Division goals of developing technologies for ensuring 99 percent storage permanence and predicting reservoir storage capacity to within 30 percent. This effort is optimizing monitoring design and improving identification and reduction of potential risks associated with $CO_2$ injection and storage. The knowledge gained will help develop a 'blueprint' for CCS at similar sites in the southwestern United States.

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