CHARACTERIZATION AND MODELING OF THE WILLISTON BASIN FOR POTENTIAL CO_2 EOR AND STORAGE A CASE STUDY OF THE RIVAL FIELD

EERC Energy & Environmental Research Center

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ABSTRACT

The Plains CO_2 Reduction (PCOR) Partnership team at the Energy and Environmental Research Center (EERC) has conducted a study Williston Basin oil fields suitable for CO_2 storage and enhanced oil recovery (EOR). The potential for incremental oil production from CO_2 floods and CO_2 storage capacities of oil fields were estimated as part of Phases I and II of the PCOR partnership regional characterization activities. Phase III activities are focused on more detailed studies of selected oil fields. In contrast with the reconnaissance level study conducted in Phases I and II, Phase III studies intend to use available geophysical data to characterize the pore system and understand features of fluid transport in the reservoirs under consideration. This is achieved by building a static geological model and simulating dynamic processes of CO_2 injection coupled with ongoing oil and/or gas production. This case study describes an approach that can be applied to other oil fields in the region for the purpose of large-scale CO_2 EOR and storage operations.

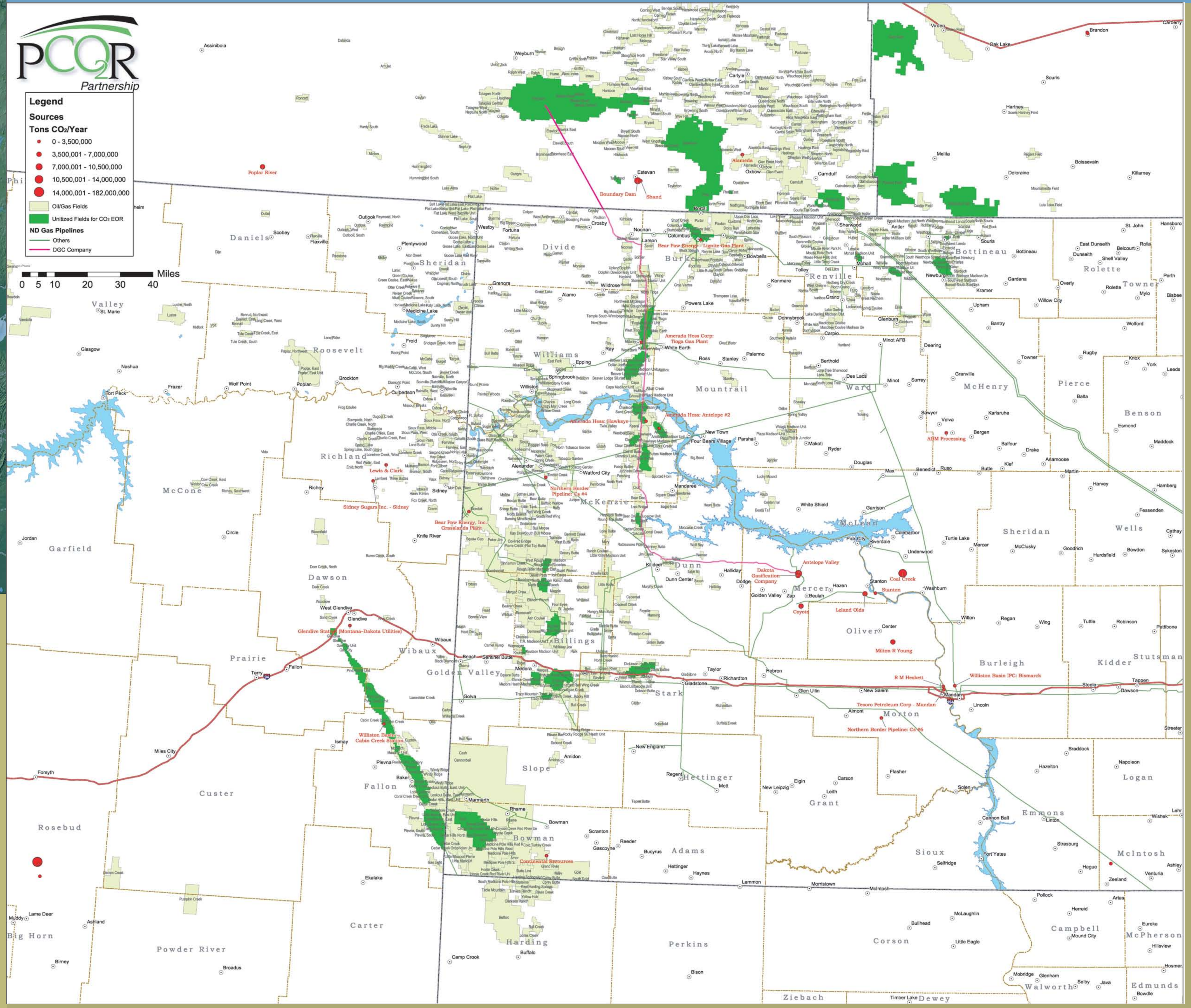
METHODOLOGY

The following characteristics are of particular interest in a CO_2 EOR and storage project: incremental oil recovery, CO_2 required for providing the targeted incremental recovery and the amount of CO_2 permanently trapped in the reservoir after the project completion. Shaw and Bachu (2002) noted that oil production could be increased from 7% to 23% of the original oil in place (OOIP) through successful miscible flooding techniques, while Nelms and Burke (2004) suggested a value of 7% to 11%. This study uses an average value of 12% recovery of the OOIP. The quantity of CO_2 necessary to recover incremental oil has been estimated through the evaluation of historica CO_2 EOR floods while this will always be a site specific value, as approximately a thousand standard cubic feet (mcf) of CO_2 for every incremental stock tank barrel (stb) of oil recovered can be used as a starting point to estimate purchase quantities of CO_2.

$$\text{Incremental oil recovered } \mathit{(stb)} = \mathit{OOIP(stb)} \cdot 12\% \text{ recovery factor}$$
$$CO_2 \text{ required} = \text{Incremental oil recovery}\mathit{(stb)} \cdot 8\ \mathit{Mcf/stb} \qquad (1)$$

It is expected that dynamic simulations of the injection and production processes will allow for deriving site specific values of the parameters used in formulae (1). They also will aid in estimating the amount of CO_2 permanently trapped in the reservoir.

WILLISTON BASIN ENHANCED OIL RECOVERY POTENTIAL



The Williston Basin extends over parts of North Dakota, South Dakota, Montana, Saskatchewan, and Manitoba. As part of the site selection process, CO_2 sources and candidate oil fields are evaluated and matched according to CO_2 output, storage capacity and incremental oil recovery potential. Results of the evaluation are listed below:

Montana

Sources (Coal-fired power plants)

- One coal fired power plant in southeastern Montana
- Annual CO_2 emissions = 265 Bcf

Sinks (Selected Fields)

- Ten unitized fields for CO2 EOR
- Total OOIP = 3250 million bbl
- Potential Incremental Oil = 390 million bbl
- Total CO_2 needed for EOR = 3120 Bcf

North Dakota

Sources (Coal-fired power plants)

- Six coal fired power plant in central North Dakota
- Annual CO_2 emissions = 682 Bcf

Sinks (Selected Fields)

- 28 unitized fields for CO_2 EOR
- Total OOIP = 2183 million bbl
- Potential Incremental Oil = 262 million bbl
- Total CO_2 needed for EOR = 2,095 Bcf

Manitoba

Sinks (Selected Fields)

- Three unitized fields for CO_2 EOR
- Total OOIP = 332 million bbl
- Potential Incremental Oil = 39 million bbl
- Total CO_2 needed for EOR = 319 Bcf

Saskatchewan

Sources (Coal-fired power plants)

- Two coal fired power plant in southeastern Saskatchewan
- Annual CO_2 emissions = 161 Bcf

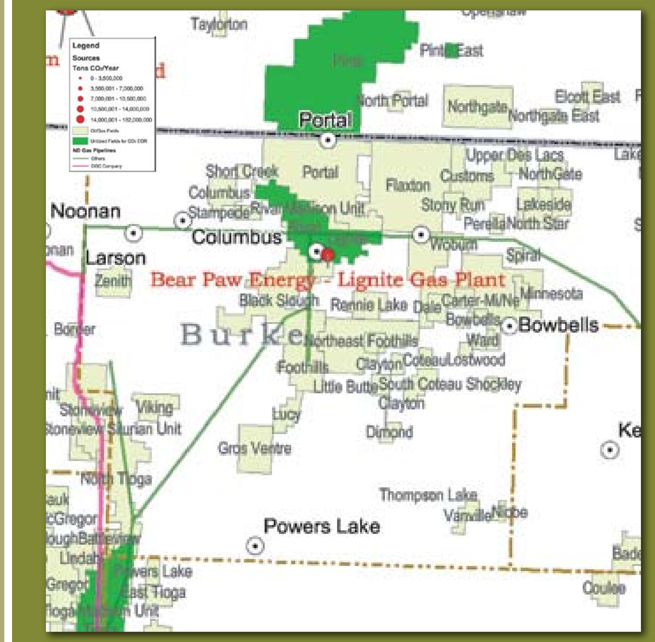
Sinks (Selected Fields)

- 11 unitized fields for CO_2 EOR
- Total OOIP = 2762 million bbl
- Potential Incremental Oil = 331 million bbl
- Total CO_2 needed for EOR = 2,652 Bcf

Williston Basin State/Province	Cumulative OOIP of Selected Units (million stb)	Cumulative Potential CO_2 EOR Incremental Oil from Selected Units (million stb)	CO_2 Quantity Required* (Bcf)	CO_2 Sequestration Potential Through EOR in Selected Units (Bcf)	CO_2 Sequestration Potential Through EOR in Selected Units (tons)
North Dakota	2183	262	2095	2095	128,448,804
Montana	3250	390	3120	3120	191,293,685
Saskatchewan	2762	331	2652	2652	162,599,632
Manitoba	333	40	319	319	19,558,553
South Dakota	High-Pressure Air Injection Currently Ongoing in Buffalo Units				

CO_2 quantity required is the total purchase amount and does consider recycling of CO_2 from the tertiary recovery operation.

SITE SELECTION

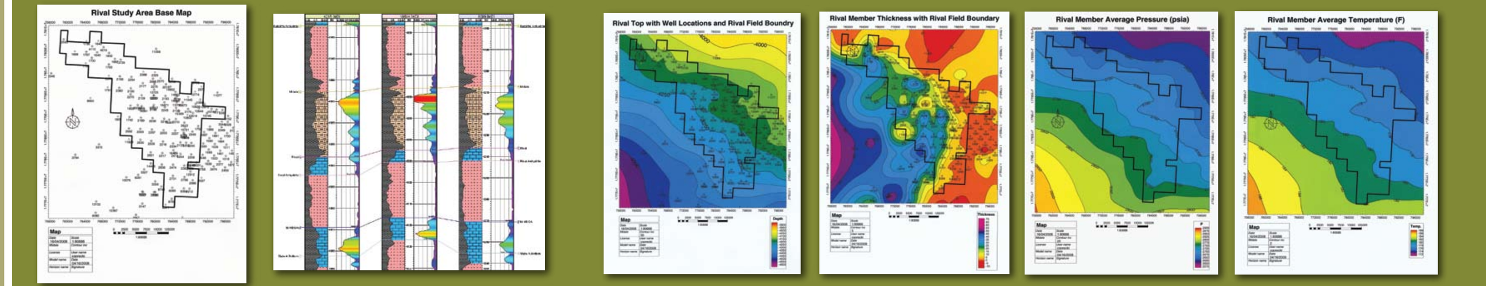


The Rival Field was selected for dynamic CO_2 Enhanced Oil Recovery (EOR) modeling because:

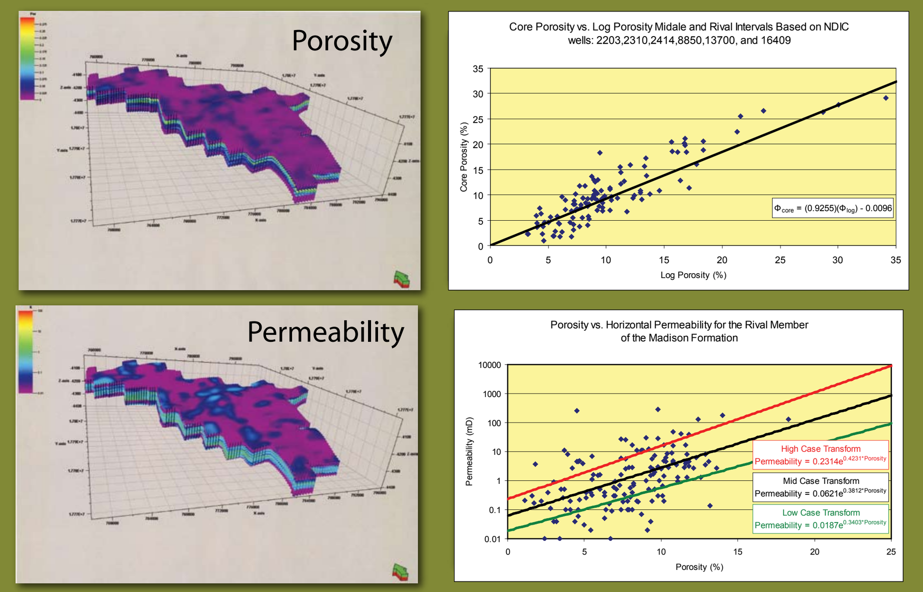
- It is a maturing oil field which has been produced since the late 50's with a cummulative production of more than 16 million bbls of oil
- Most of the current production is the result of a successful water flooding plan
- The Bear Paw Gas Processing Plant is located on the edge of the Rival and Lignite fields and could supply some of the CO_2 nessessary for EOR
- The Original Oil in Place (OOIP) of more than 80 million bbl in the Rival field makes it a good candidate for EOR with an estimated incremental recovery of 10 million bbls of oil at a 12% recovery factor
- The productive zones in the Rival Field are the Midale and Rival members of the Madison Formation and these zones are sandwiched between two thick and laterally extensive anhydrites, which will enhance sweep efficiency

STATIC MODELING WORKFLOW

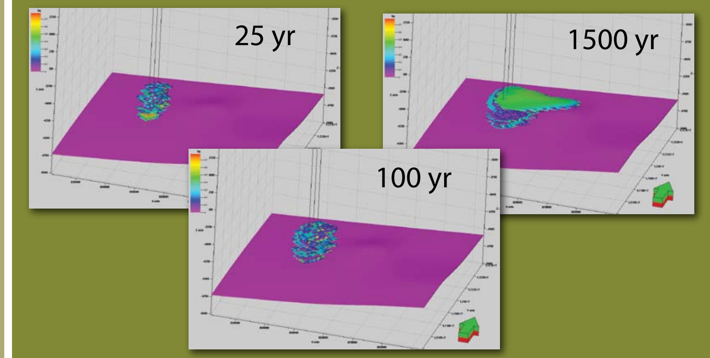
After the field has been selected, all of the available oil, gas, and water well data are brought into the modeling software so the structure, thickness, and other properties can be mapped. The pressure and temperature T (°F) distributions are calculated from standard gradients of the area, based on the formation depth.



Porosity was calculated based on log and core measurements and then adjusted to reservoir conditions and populated through the model. Permeability was calculated based on a transform developed from core analyses and a low, mid, and high case was developed.



DYNAMIC MODELING WORKFLOW



The fluid model is created based on the formation water, oil and gas analyses and is applied to the static model. After the fluid model is developed a history match is preformed to check the validity and prediction simulations are run to estimate the potential incremental oil recovery and the subsequent CO_2 sequestered.of the model.