Integrated Approach to Carbon Management and CO$_2$-Based EOR in the Williston Basin
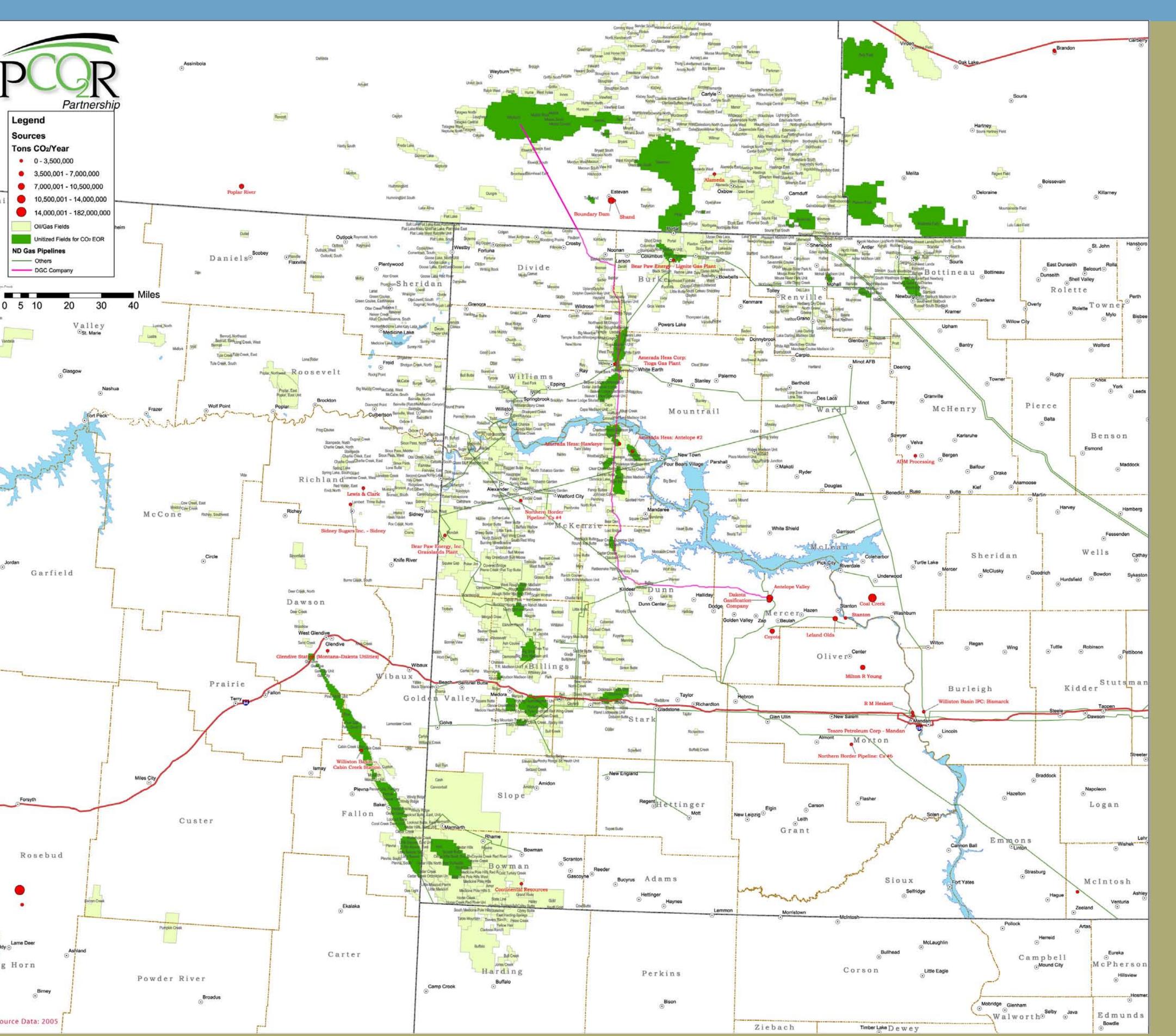
EERC Energy & Environmental Research Center

PCOR Partnership

UNIVERSITY of North Dakota Grand Forks

WILLISTON BASIN ENHANCED OIL RECOVERY POTENTIAL

Current PCOR Partnership Partners

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$_2$.
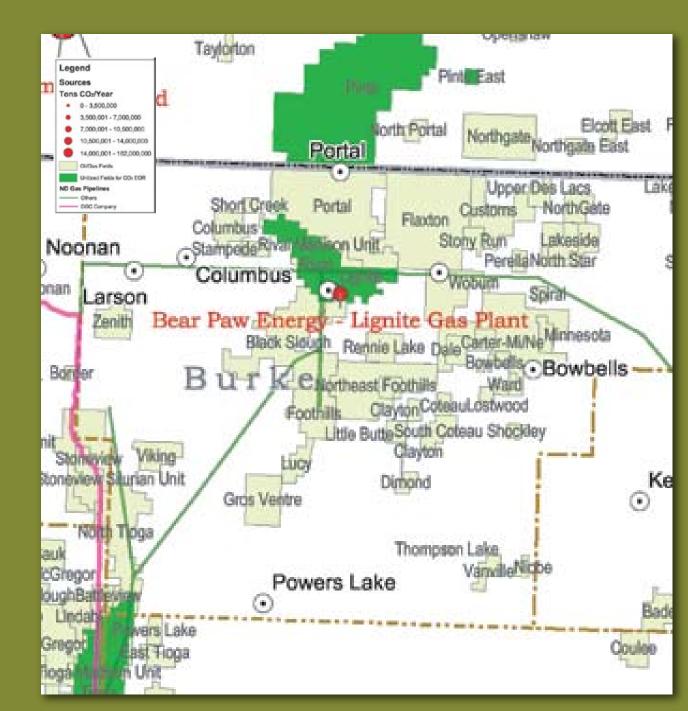
$$\text{Incremental oil recovered (stb)} = \text{OOIP(stb)} \cdot .12\% \text{ recovery factor}$$
$$\text{CO}_2 \text{ required} = \text{Incremental oil recovery(stb)} \cdot .8 \text{ Mcf/stb} \quad (1)$$

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.

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 in the table below.

In recent years most of the activity in the Williston Basin has been focused on the unconventional Bakken oil resources. With the continued development of technologies such as horizontal well drilling, multi-staged fracture jobs and other development strategies; the Bakken oil production has continued to rise and is on the verge of becoming the basins largest oil producer. Since the Bakken has such great reserves, with much of the original oil in place (OOIP) being left behind after primary production, it may become a future target for CO$_2$ enhanced oil recovery. This technology has not yet been proven in the Bakken but may prove to be a very useful tool for increasing field life, oil production, as well as sequestering CO$_2$.
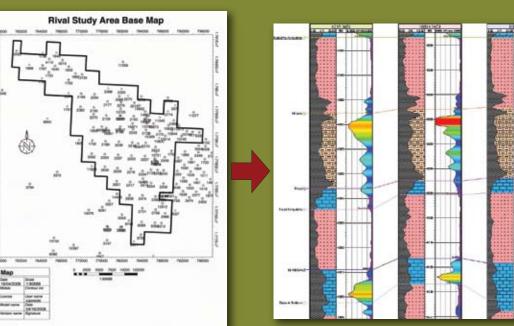
DETAILED EVALUATION TECHNIQUES

Oil fields are selected for detailed evaluation based on a number of evaluation criteria; in this case the Rival Field in Burke County, North Dakota was selected for further evaluation because:

- It is a maturing oil field which has been produced since the late 50's with a cumulative production of more than 16 million bbls of oil
- Most of the current production is the result of a successful water flooding plan
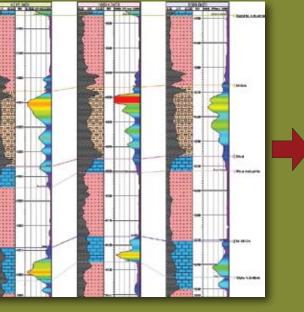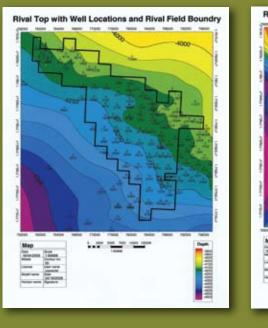- The Bear Paw Gas Processing Plant is located on the edge of the Rival and Lignite fields and could supply some of the CO$_2$ nessessary for EOR
- The Original Oil in Place (OOIP) of more than 80 million bbl in the Rival field makes it a good candidate for EOR with an estimated incremental recovery 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
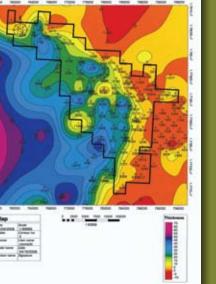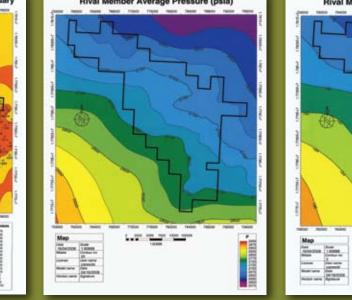
STATIC MODELING WORKFLOW

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.
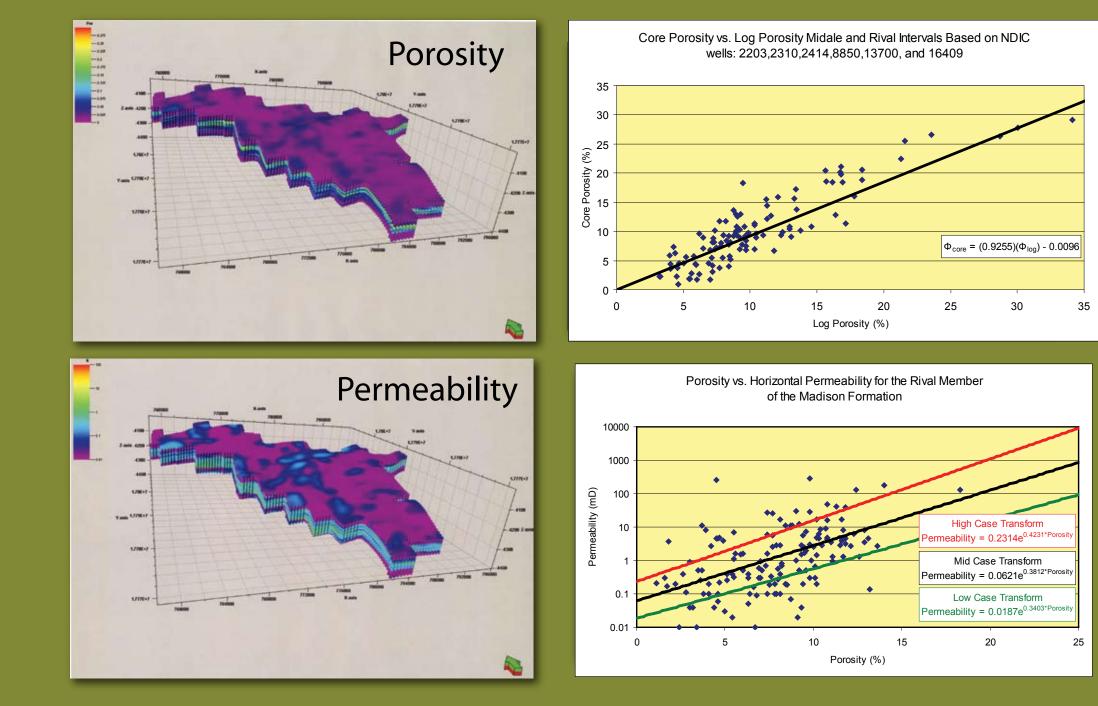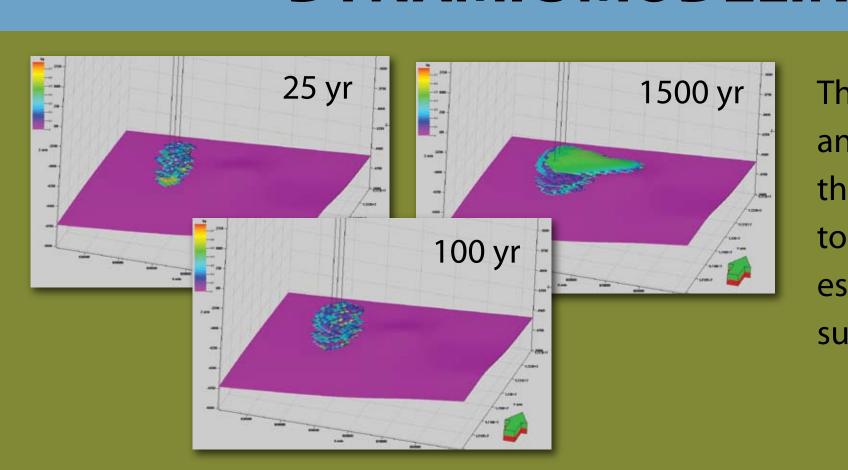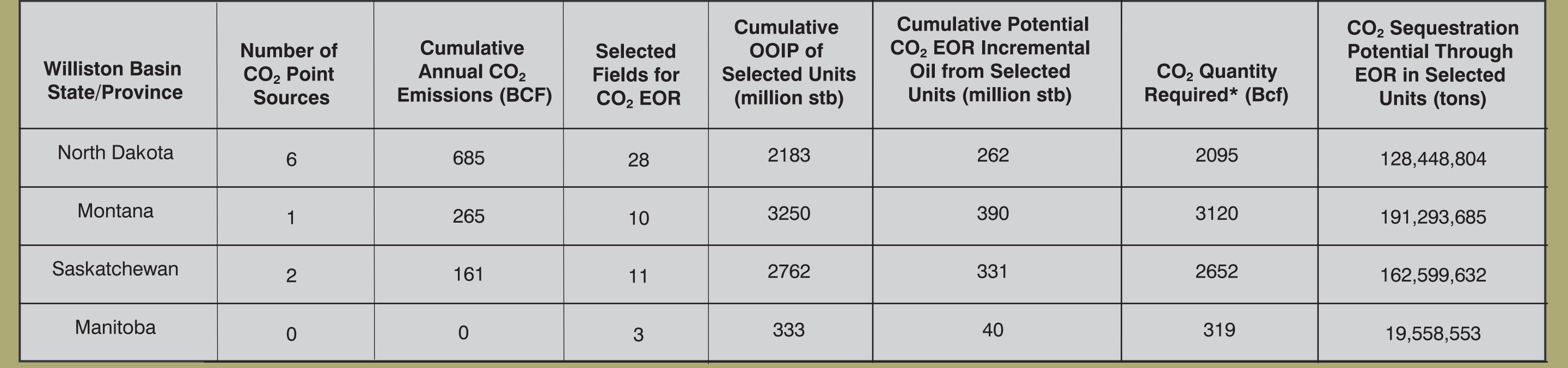

Porosity was calculated based on log and core measurements and then adjusted to reservoir conditions and populated through the model. Permeability was calculated based on a transform developed from core analyses and a low, mid, and high case was developed.

Porosity

Permeability

Map legend

1. Phase II Zama Acid Gas Injection Site
2. Phase II Lignite CO$_2$ Sequestration ECBM Site
3. Phase II Prairie Pothole Wetlands Terrestrial Sequestration Site
4. Phase II CO$_2$ Sequestration in Deep Saline Formation/EOR Site
5. Phase III Western Canadian Basin Demonstration
6. Phase III Williston Demonstration

1. CO$_2$-Rich Gas in a Pinnacle Reef Structure – Acid gas (approximately 70% CO$_2$, 30% H$_2$S) from a natural gas processing plant in northern Alberta, Canada, is being injected into an oil-producing zone in an underground pinnacle reef structure. Results will help to determine the best practices to support sequestration in these unique geologic structures as well as further the understanding of H$_2$S on tertiary oil recovery and CO$_2$ sequestration.

2. CO$_2$ in an Unminable Lignite Seam – CO$_2$ will be injected into unminable lignite seams in northwestern North Dakota. The injected CO$_2$ will be trapped by naturally bonding to the surfaces of the fractured lignite. The injected CO$_2$ also has the potential to displace methane occupying the coal fractures. This validation test will provide valuable information regarding lignites for both CO$_2$ sequestration and enhanced coalbed methane production.

3. Out of the Air – Into the Soil – A wetland in north-central South Dakota is being managed to demonstrate practices that will improve CO$_2$ uptake. The results will help to optimize terrestrial CO$_2$ uptake and facilitate the monetization of terrestrial CO$_2$ credits.

4. CO$_2$ in a Deep Oil Reservoir – CO$_2$ will be injected into an oil-bearing zone at great depth in the Williston Basin in western North Dakota. The activity will be used to determine the efficiency of CO$_2$ sequestration and the use of CO$_2$ to produce additional oil from other deep carbonate source rocks.

5. Fort Nelson Demonstration – Injection of acid gas into a saline formation in British Columbia, Canada, for acid gas disposal, and carbon sequestration.

6. Williston Basin Demonstration – Injection of anthropogenically sourced CO$_2$ into a carbonate reservoir in North Dakota for enhanced oil recovery (EOR) and carbon sequestration.

Williston Basin State/Province	Number of CO$_2$ Point Sources	Cumulative Annual CO$_2$ Emissions (BCF)	Selected Fields for CO$_2$ EOR	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 (tons)
North Dakota	6	685	28	2183	262	2095	128,448,804
Montana	1	265	10	3250	390	3120	191,293,685
Saskatchewan	2	161	11	2762	331	2652	162,599,632
Manitoba	0	0	3	333	40	319	19,558,553

CO$_2$ quantity required is the total purchase amount and does consider recycling of CO$_2$ from the tertiary recovery operation.

DYNAMIC MODELING WORKFLOW

25 yr   1500 yr   100 yr

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.