

# **Sixth Annual Conference on Carbon Capture & Sequestration**

*Geologic Storage - EOR*

## **Results of Integrated Biofuels and Value-added Sequestration Project in Russell, Kansas**

*Timothy R. Carr and Martin K. Dubois*

*University of Kansas*

*Kansas Geological Survey*

*785.550.8302*

*tcarr@sunflower.com*

May 7-10, 2007 • Sheraton Station Square • Pittsburgh, Pennsylvania

# Pittsburgh Facts

- Pittsburgh is home to 466 bridges — more than any other city in the world.
- Pittsburgh is the only city with an airport displaying the skeleton of a 15-foot T. rex.
- In 1967 the Big Mac was invented in a McDonald's in Pittsburgh.
- Pittsburgh is the number one city for the consumption of Hostess Ho Ho's

Joanne G. Sujansky's *Pittsburgh Will Steel Your Heart: 250 Reasons to Love Pittsburgh*

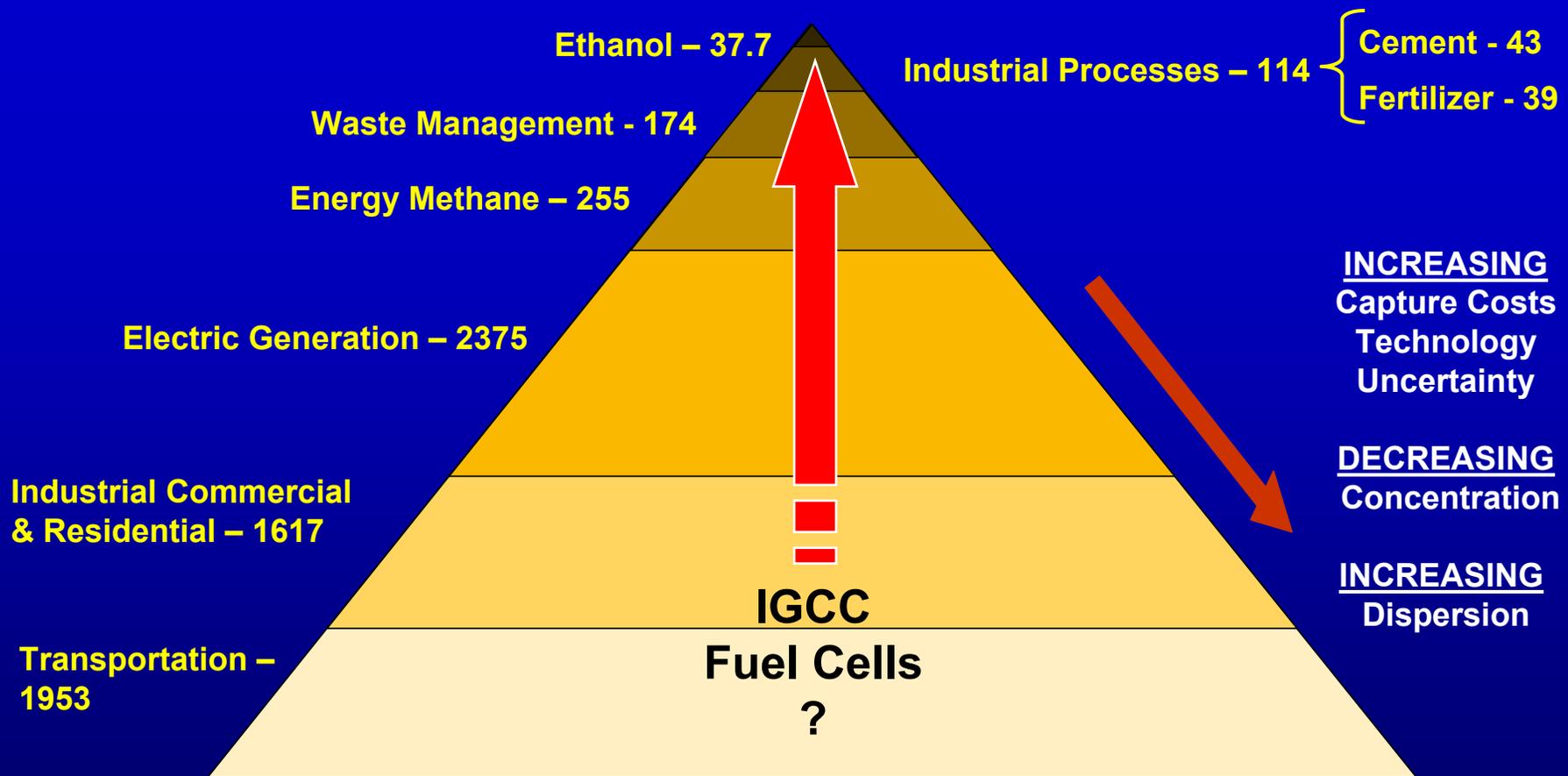
# Outline

- **Approach to Value-Added Sequestration**
- **Integrated Energy Systems**
  - **Sources of Greenhouse Gas (GHG)**
    - **Operating Costs for Capture and Compression**
  - **Carbon Credits**
- **Russell, Kansas Project**
  - **Results of Pilot**
  - **Economics**
  - **Sequestration Potential**
- **Other Potential Projects**

# Approach

- **Viewing CO<sub>2</sub> as a Resource**
  - Looking for Value-Added Sequestration Opportunities
  - Path to the Future ⇒ Carbon Management
- **Inventory & Evaluate Greenhouse Gas Resources**
  - Multiple Scales (Nation – Regional – Local – Single Source)
- **Inventory & Evaluate Sequestration Opportunities**
  - Multiple Scales (Nation – Regional – Local – Wellbore)
- **Guiding Principles**
  - Economically Viable
  - Environmentally Sound
- **Integrated Energy Systems**
  - Ethanol Plants
  - Other High-Purity Sources

# Greenhouse Gas Resource

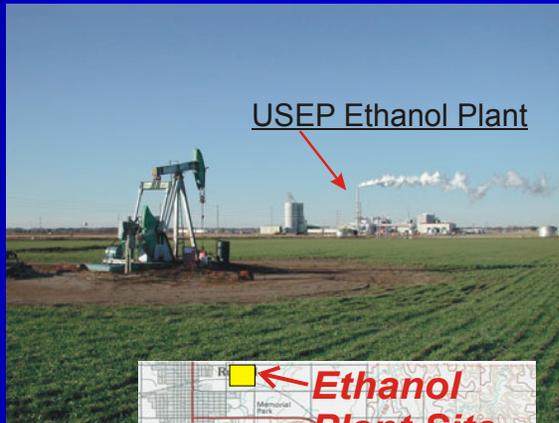


Agricultural Methane – 183  
Nitrous Oxides – 367  
HFC, PFC, SF<sub>6</sub>, etc. - 132

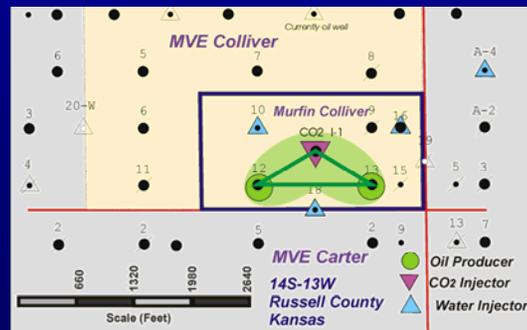
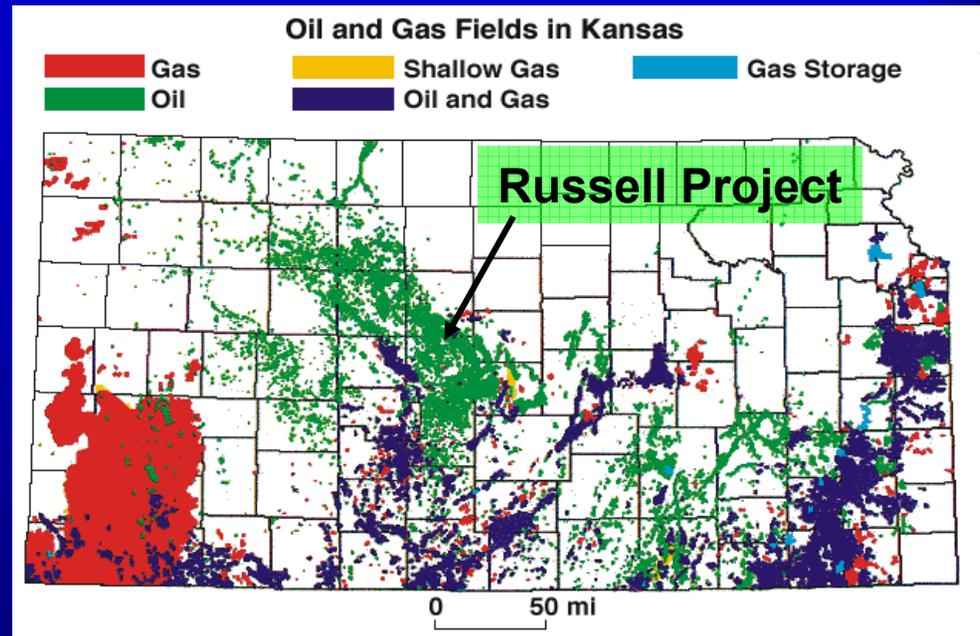
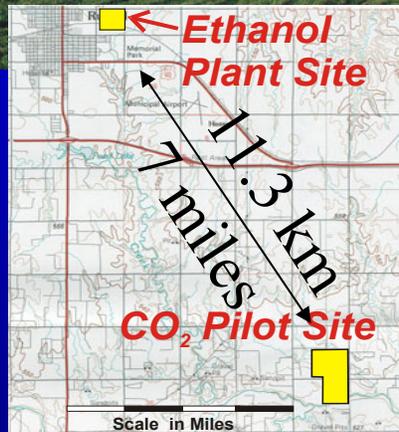
**Total GHG Emissions 7,147 Million Metric Tons**

*Data: Year 2005 Energy Information Agency and Renewable Fuels Assos.*

# Russell, Kansas Project



First Sequestration  
of Agricultural CO<sub>2</sub>



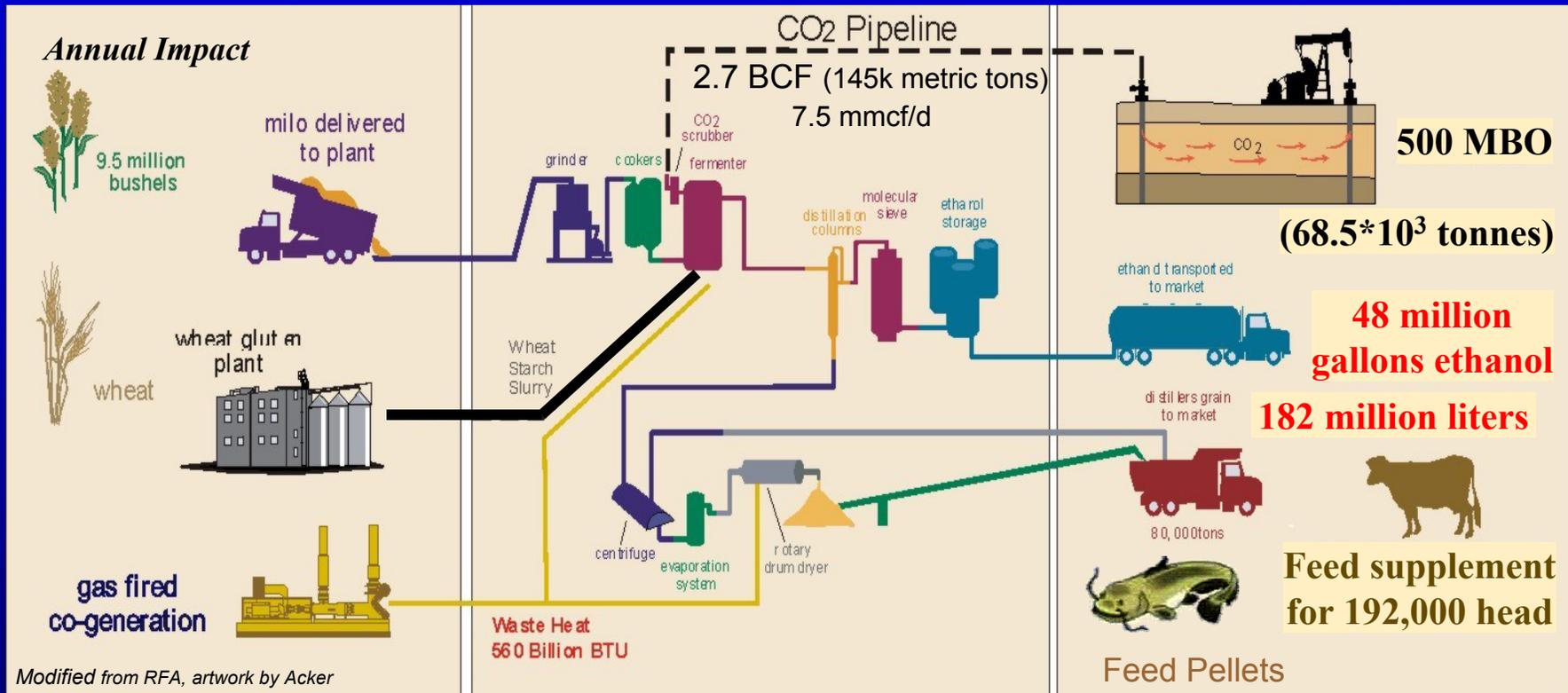
Russell is centered in oil,  
grain and cattle region

# Integrated Energy Systems

## Raw Materials

## Ethanol Plant

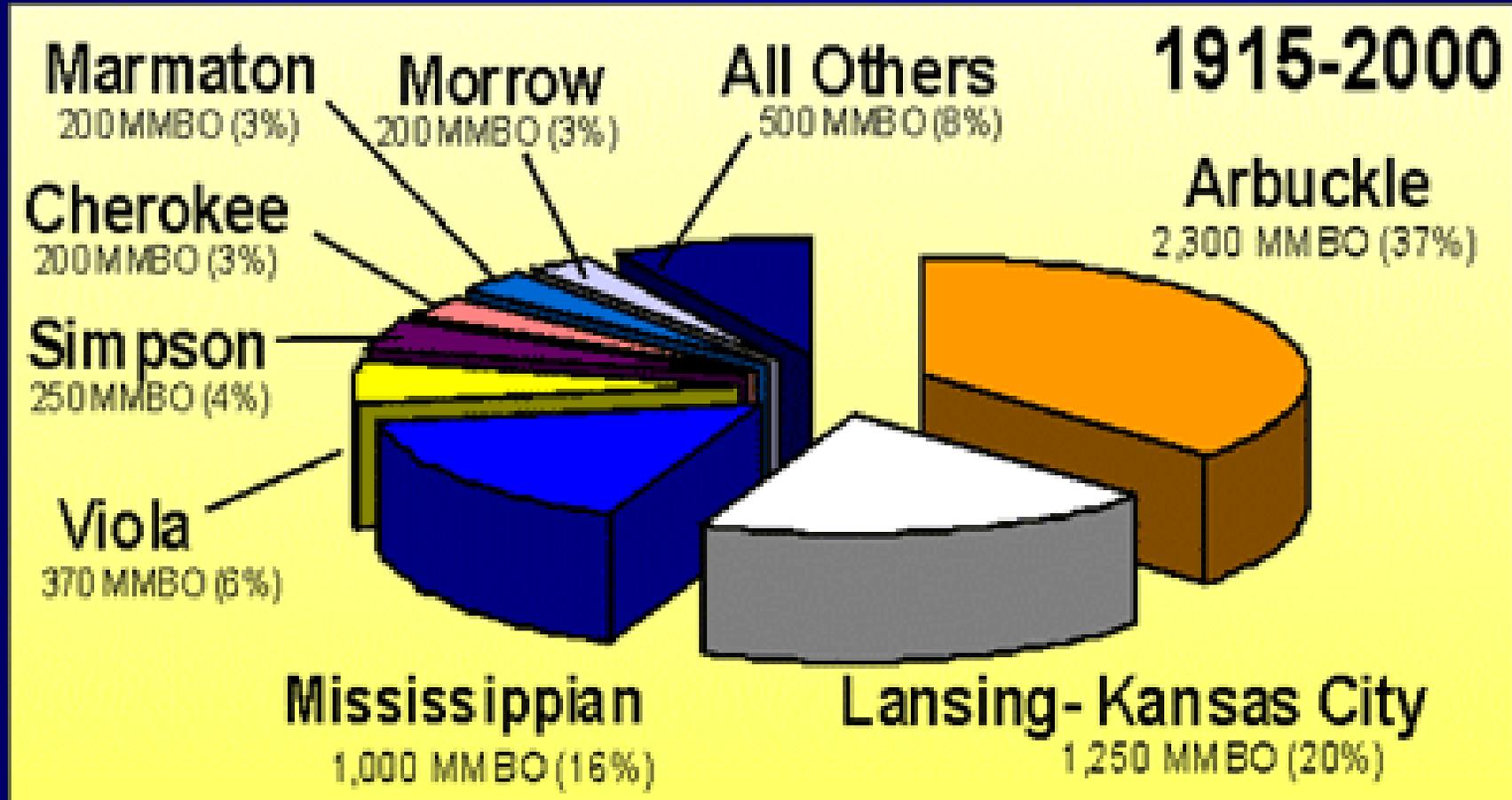
## Products



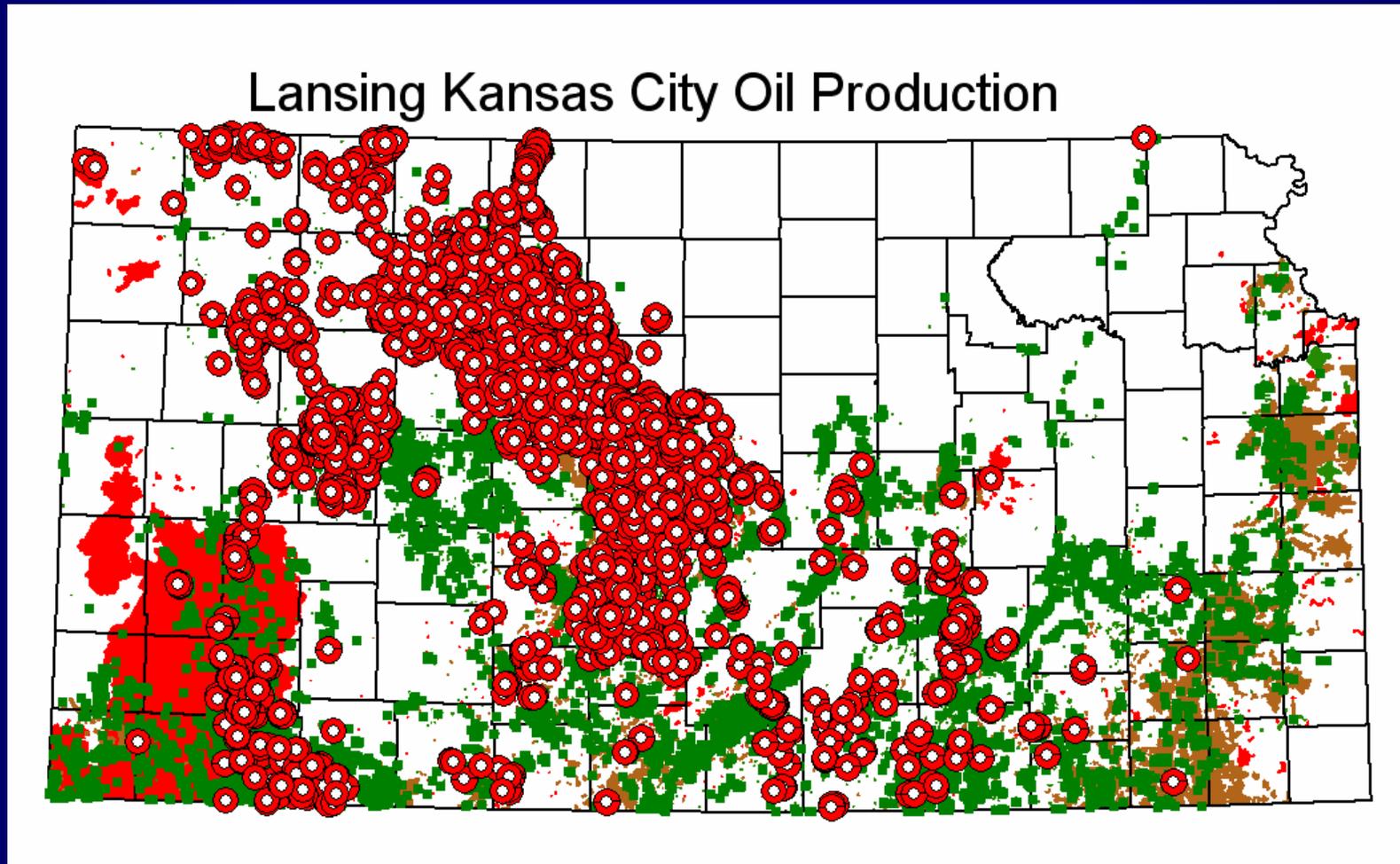
1 metric ton CO<sub>2</sub> = 19 mcf



# Lansing-Kansas City Production

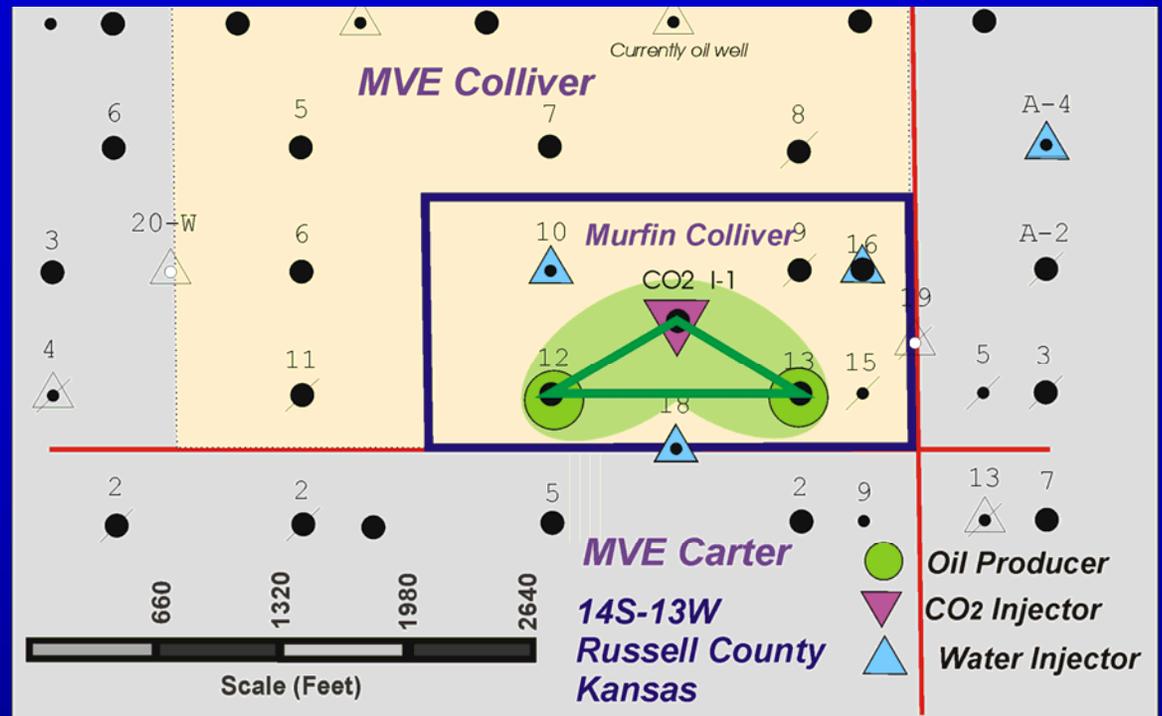


# Lansing-Kansas City Production

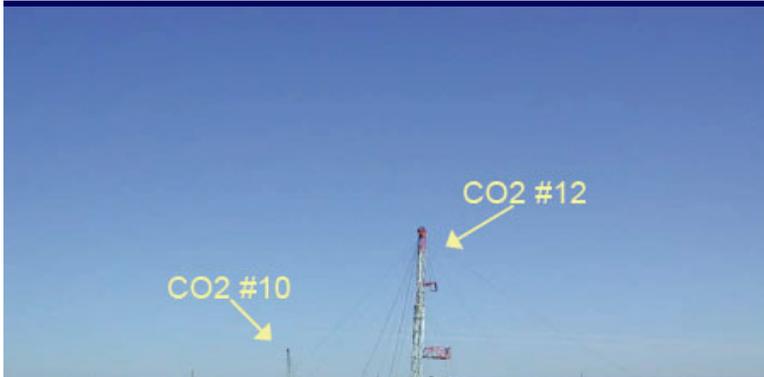


# CO<sub>2</sub> Miscible Flood Demonstration Pilot

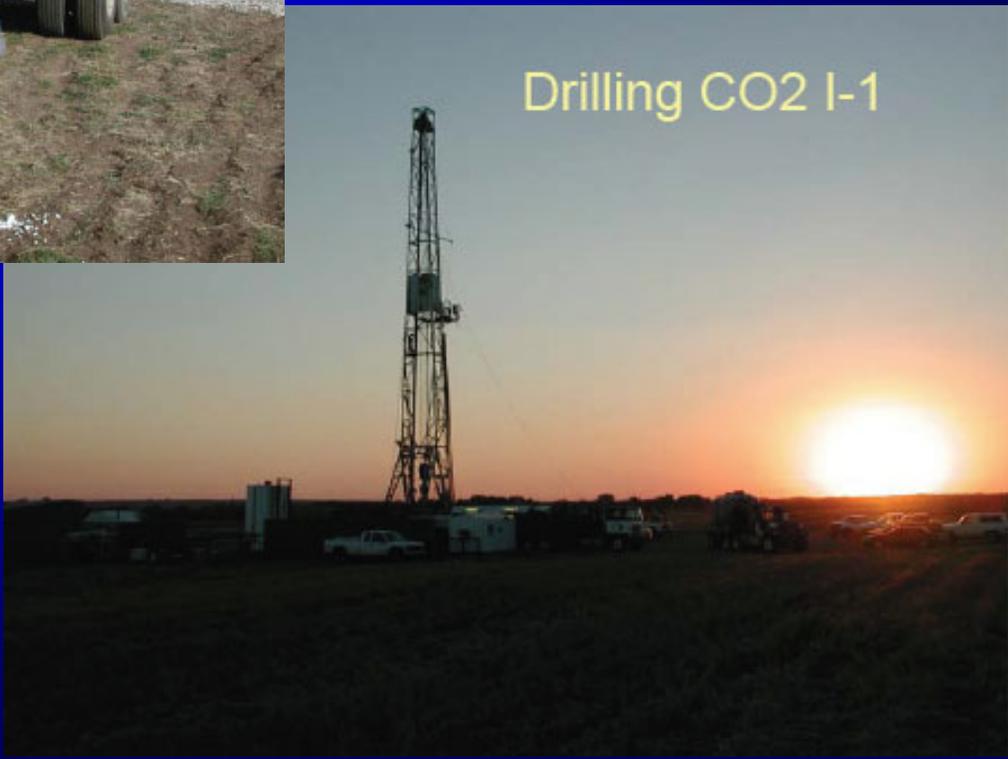
- 10+ acre, three-spot
- 1 CO<sub>2</sub> injector
- 2 Producers
- 1 Monitoring
- 2 Containment Water Injectors
- 0.29 BCF CO<sub>2</sub> injected-WAG
- 6 year operating life
- 18,000 BO estimated recovery



- CO<sub>2</sub> Injection 12/2/2003
  - 7,360 metric tons (104 MMcf)
- Converted to Water 6/21/2005
- Produced < 700 Mcf CO<sub>2</sub>
  - 95% Remains in Reservoir

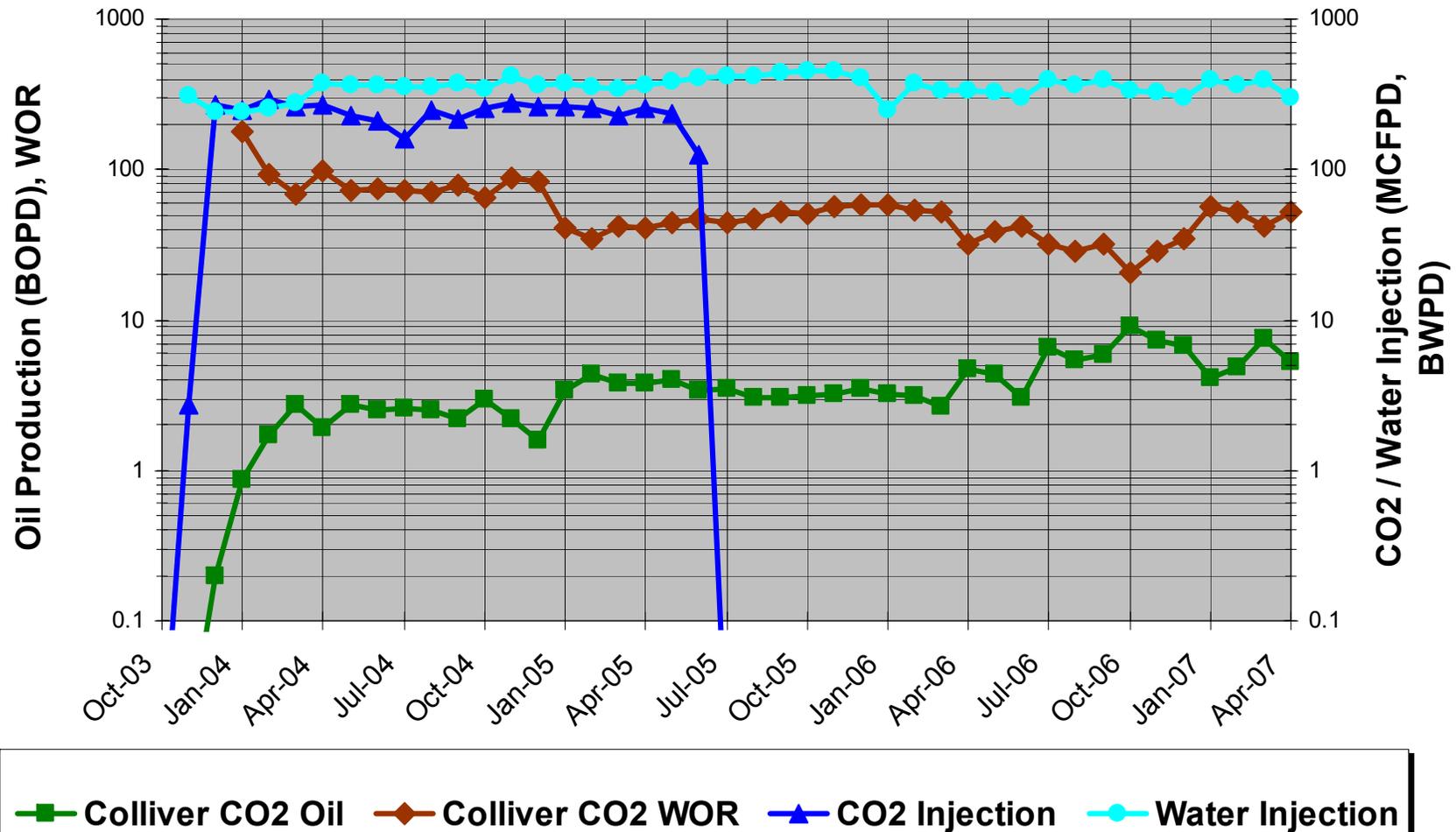


CO2 I-1 Wellhead

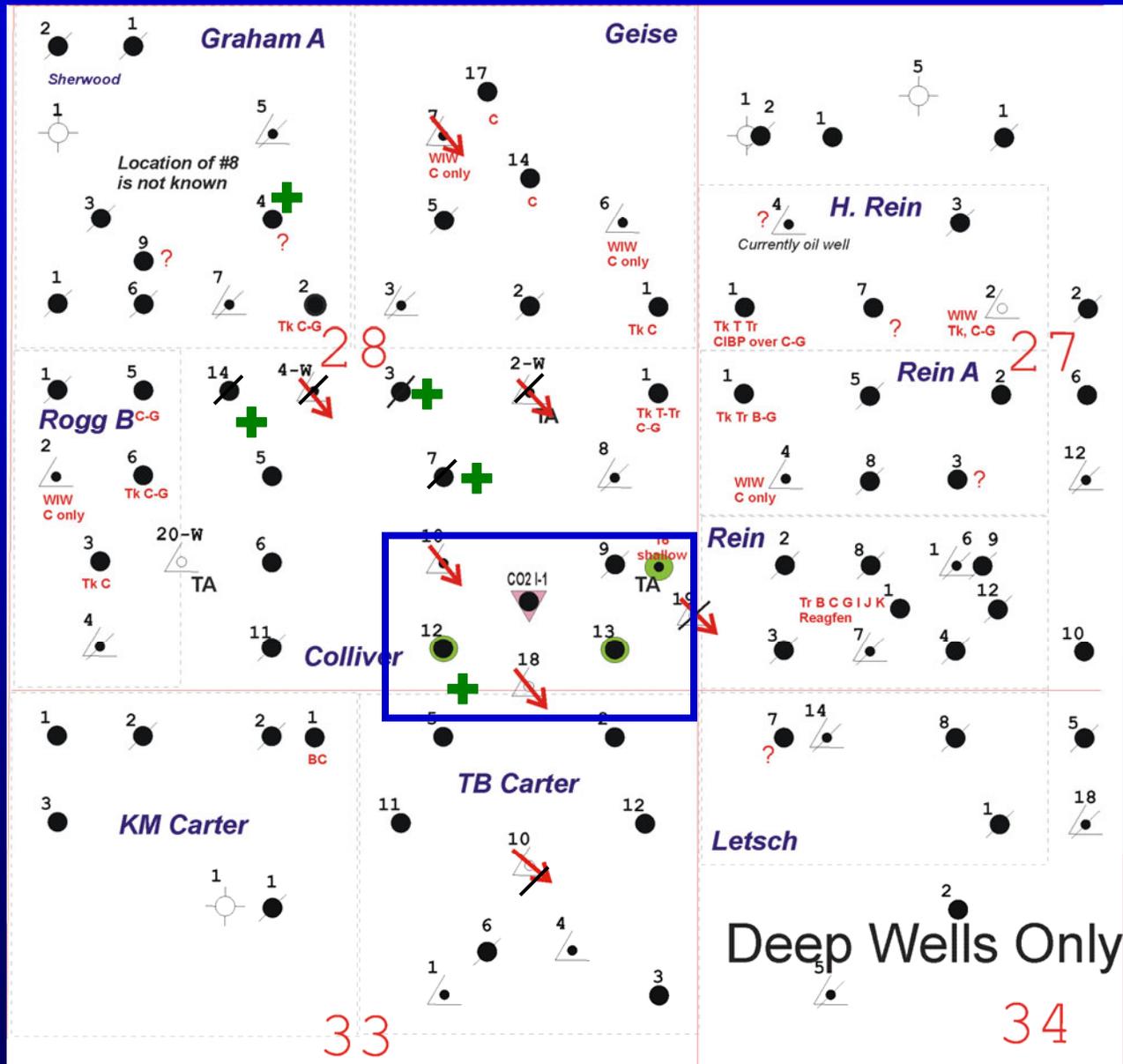


Drilling CO2 I-1

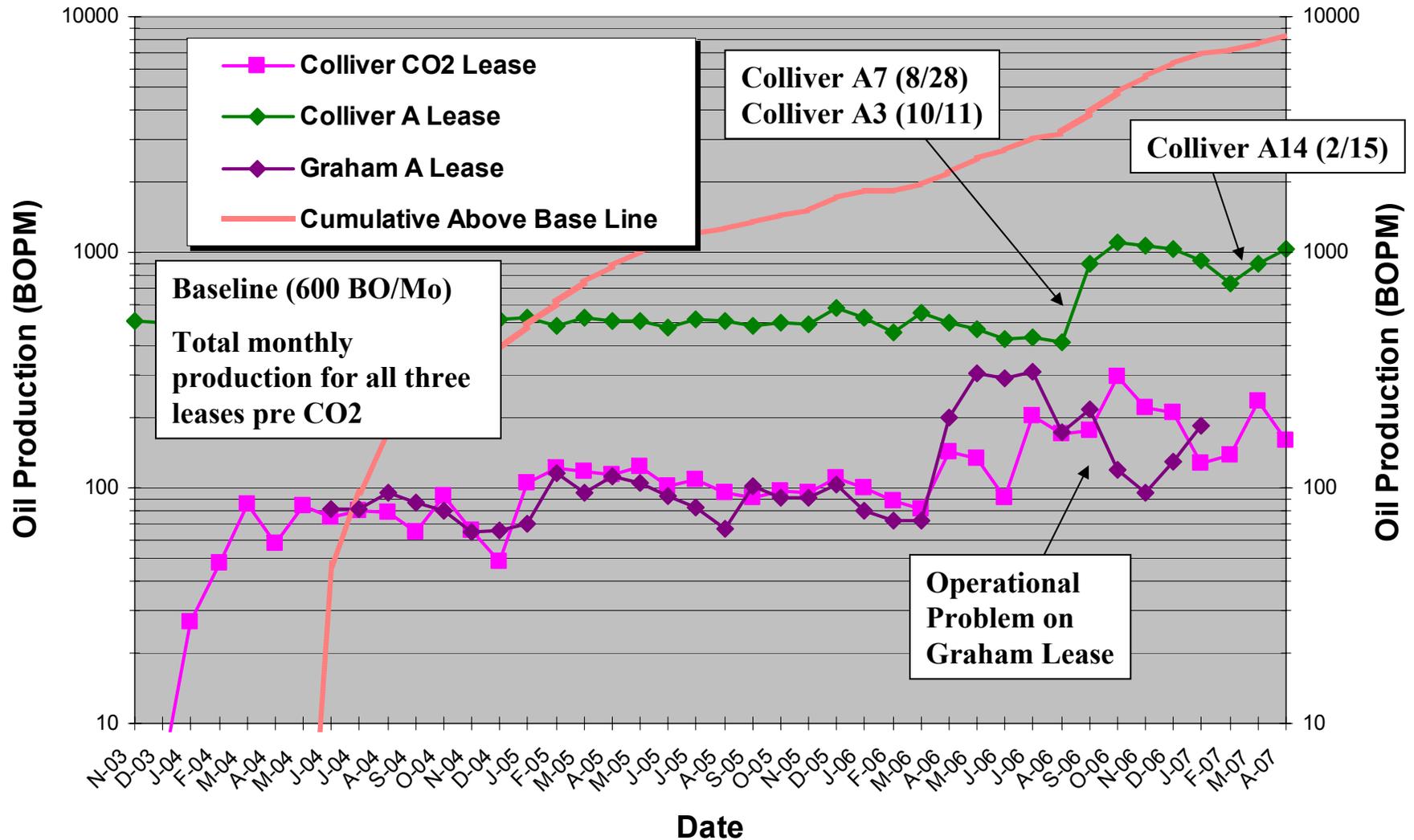
# Daily Injection & Production



# Colliver CO<sub>2</sub> Flood Area

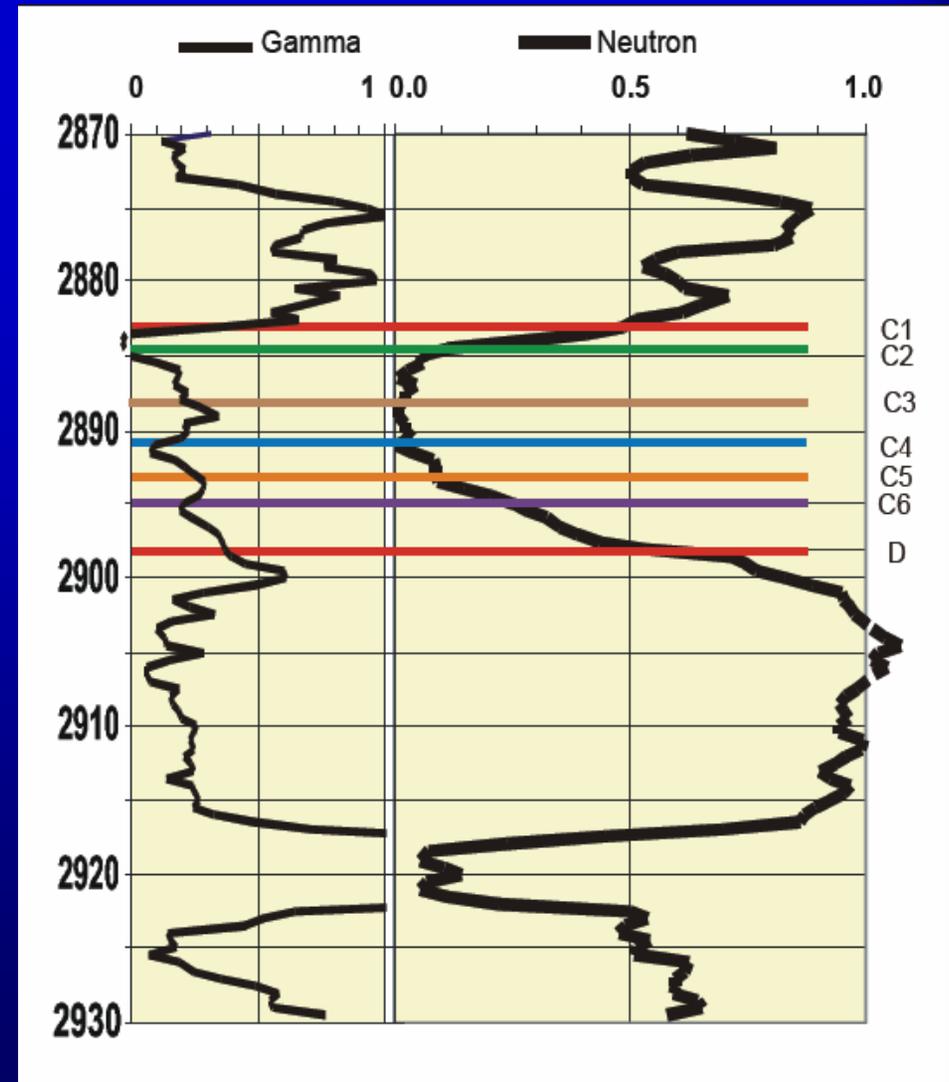


# Monthly Oil Production



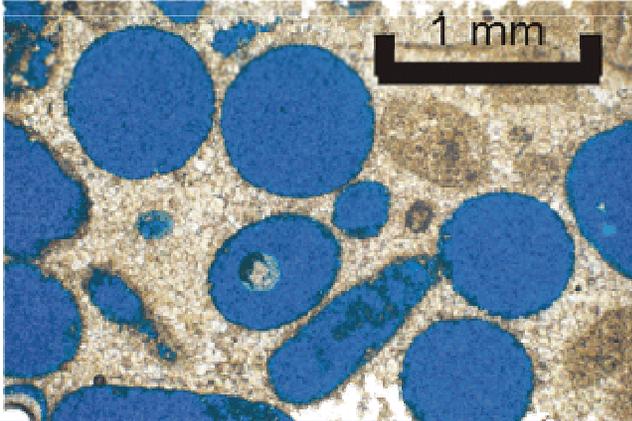
# Geologic Overview

- Type Log CO2#18
  - L-KC “C” divided into 6 Layers-three flooding cycles
- General Properties
  - C1: 8 md, 18.8%
  - C2: 150 md, 25.8%
  - C3: 40 md, 22.0%
  - C4: 6 md, 19.4%
  - C5: 2 md, 14.7%
  - C6: 0.3 md, 12.0%

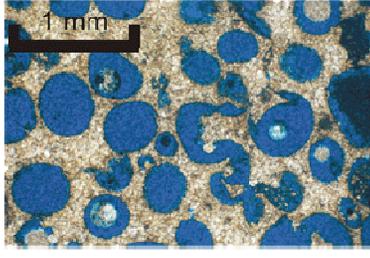


# Depositional Framework

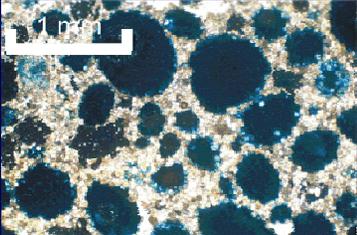
Layer 2  
Plug      Phi % 34.1      K md 113.9      2894.2



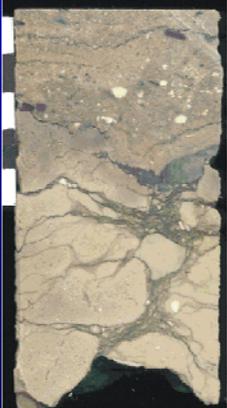
Layer 3  
Whl Cr      Phi % 27.7      K md 32.4      2897



Layer 5  
Whl Cr      Phi % 20.7      K md 1.4      2902

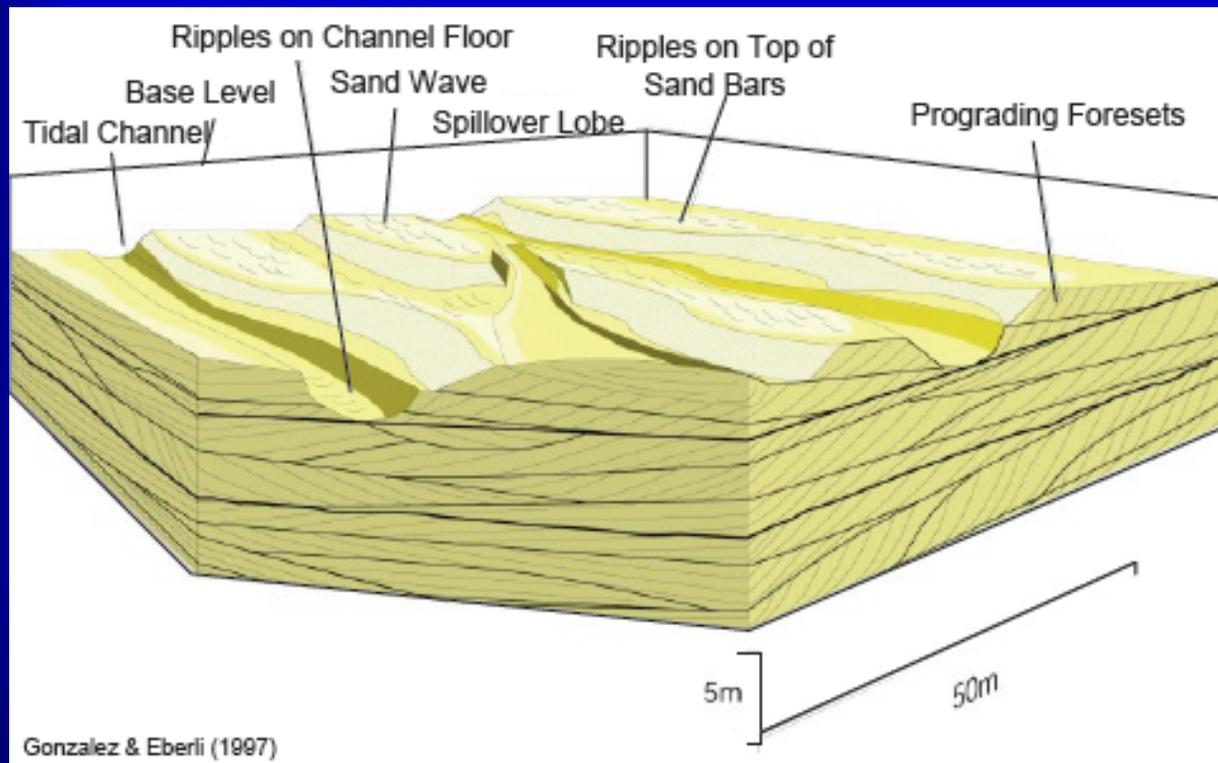


Layer 6  
2903





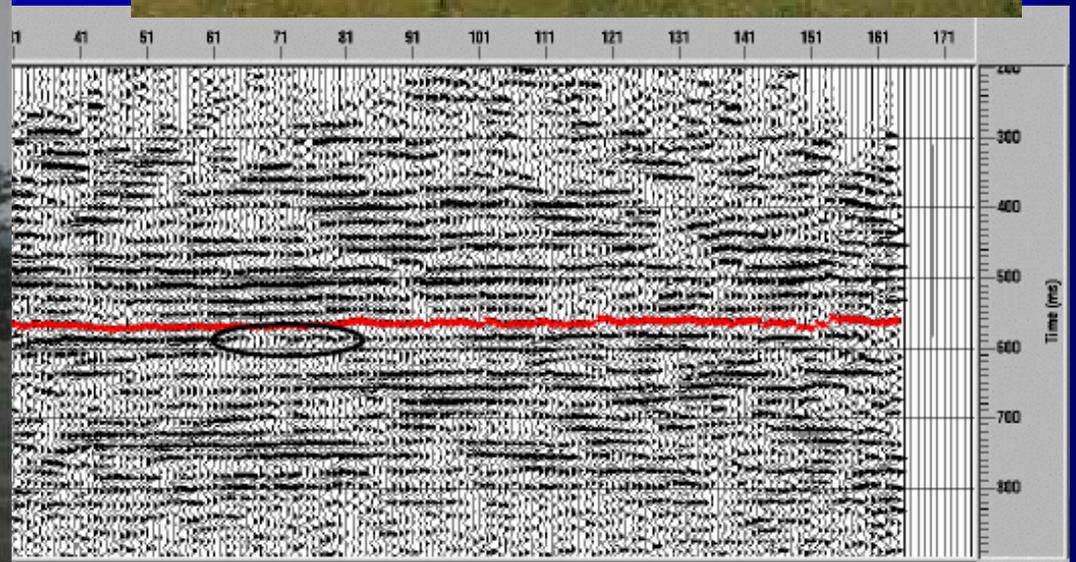
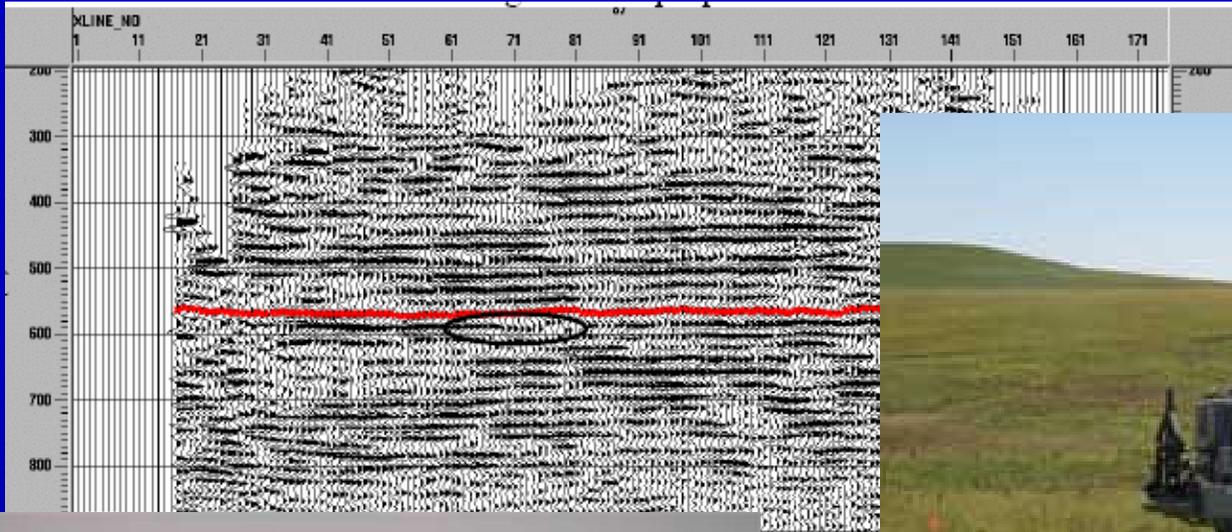
# Colliver CO<sub>2</sub> Flood



Shoal orientation assumed to strike to the NW, and cross-bedding dipping to the SW.

$k_{\text{SW-NE}}$  assumed to be 10% of  $k_{\text{NW-SE}}$  resulting in highly elliptical patterns.

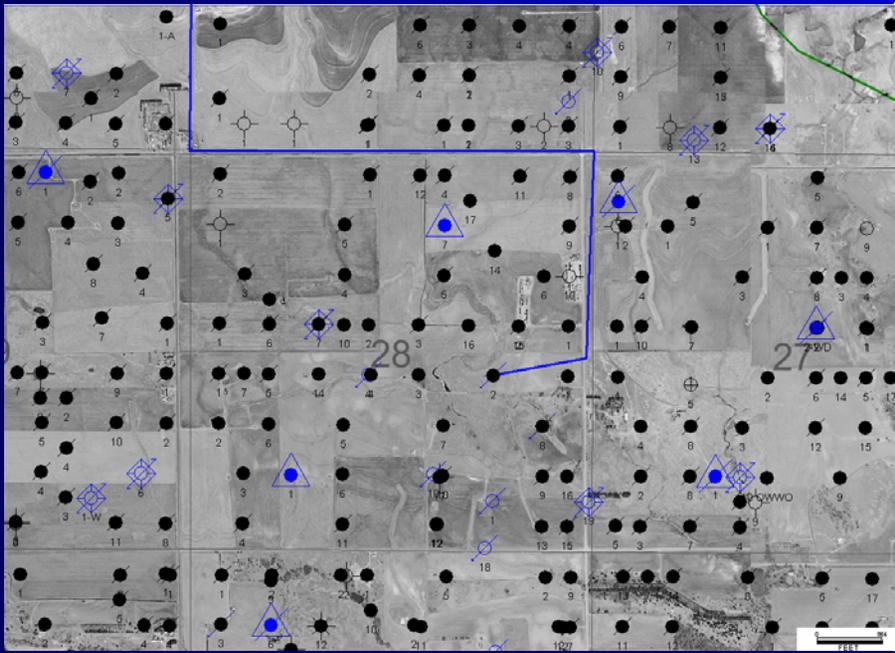
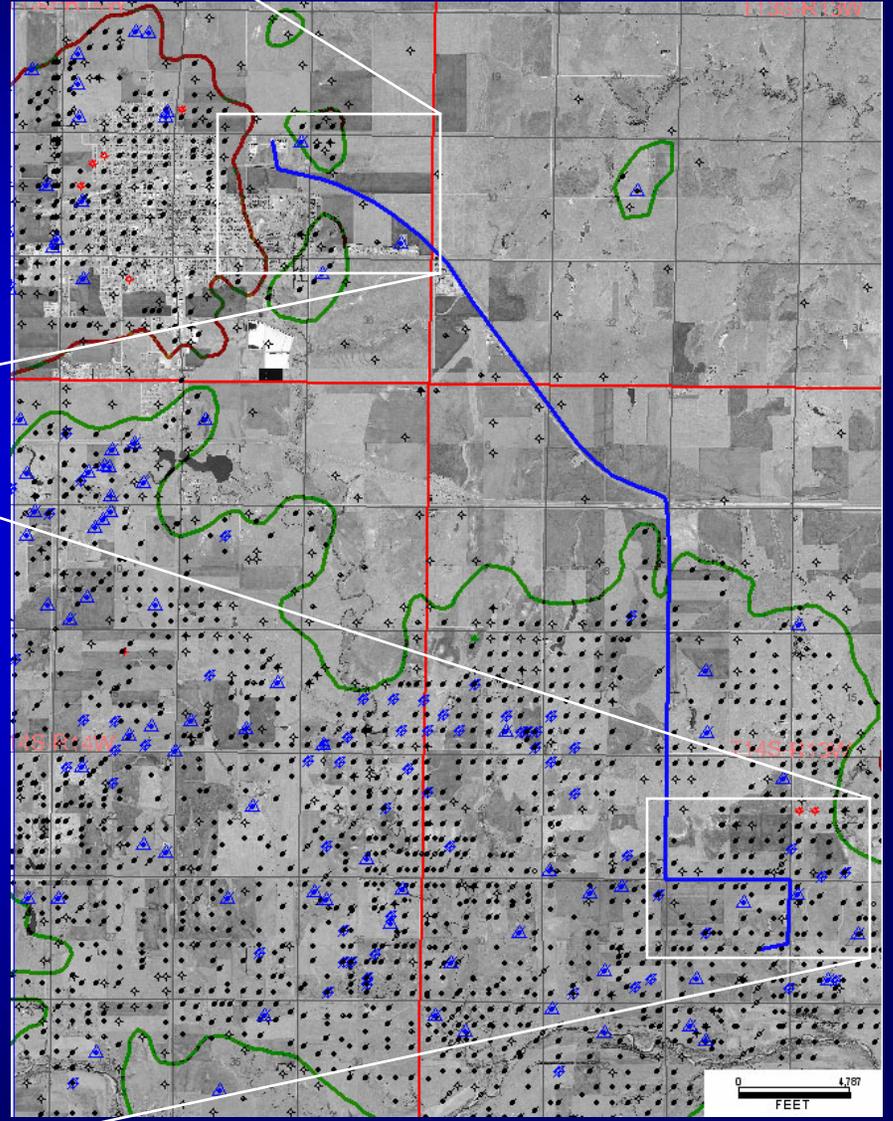
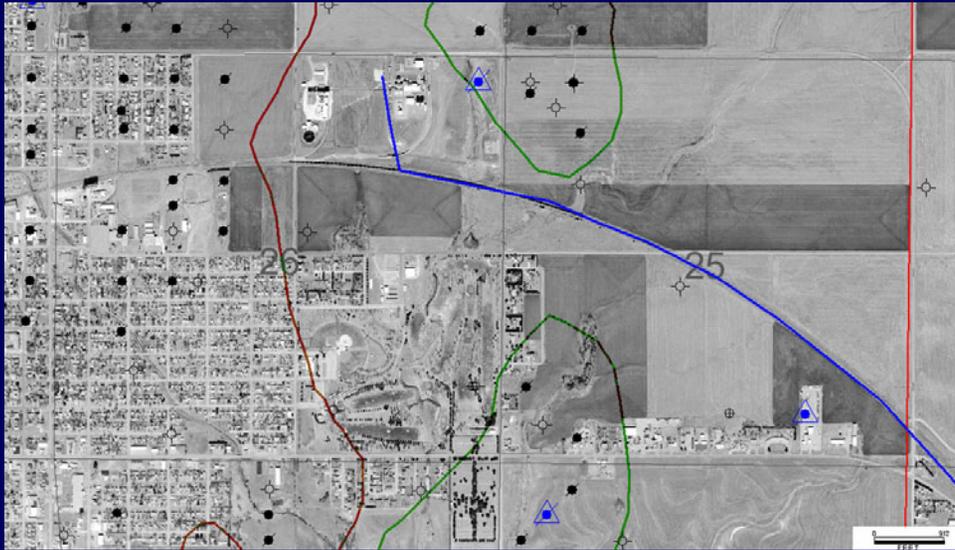
# 4-D Seismic Monitoring



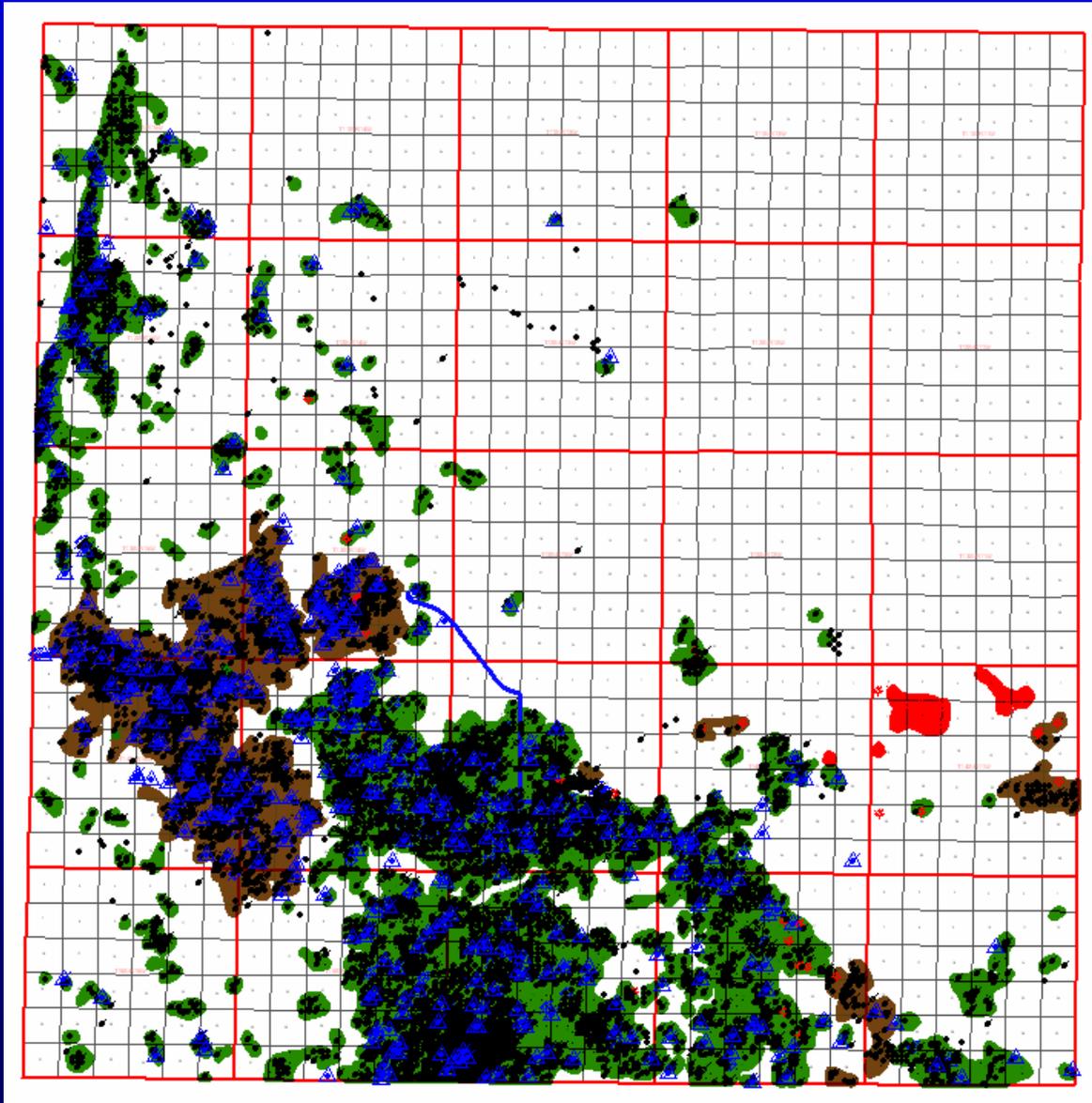
<http://www.kgs.ku.edu/Geophysics/4Dseismic/index.html>

# Russell - Colliver CO<sub>2</sub> Pilot

- Injected ~7,400 Metric Tons CO<sub>2</sub>
  - >95% Remains in Reservoir
- Injected 80,000 bbls of Water
  - Maintained Pressure >MMP
- No Leakage Detected on 4D Seismic
- Estimate Production Attributable to CO<sub>2</sub> at ~15,000 bbl (12/31/07)
  - CO<sub>2</sub> Utilization ~10Mcf/bbl

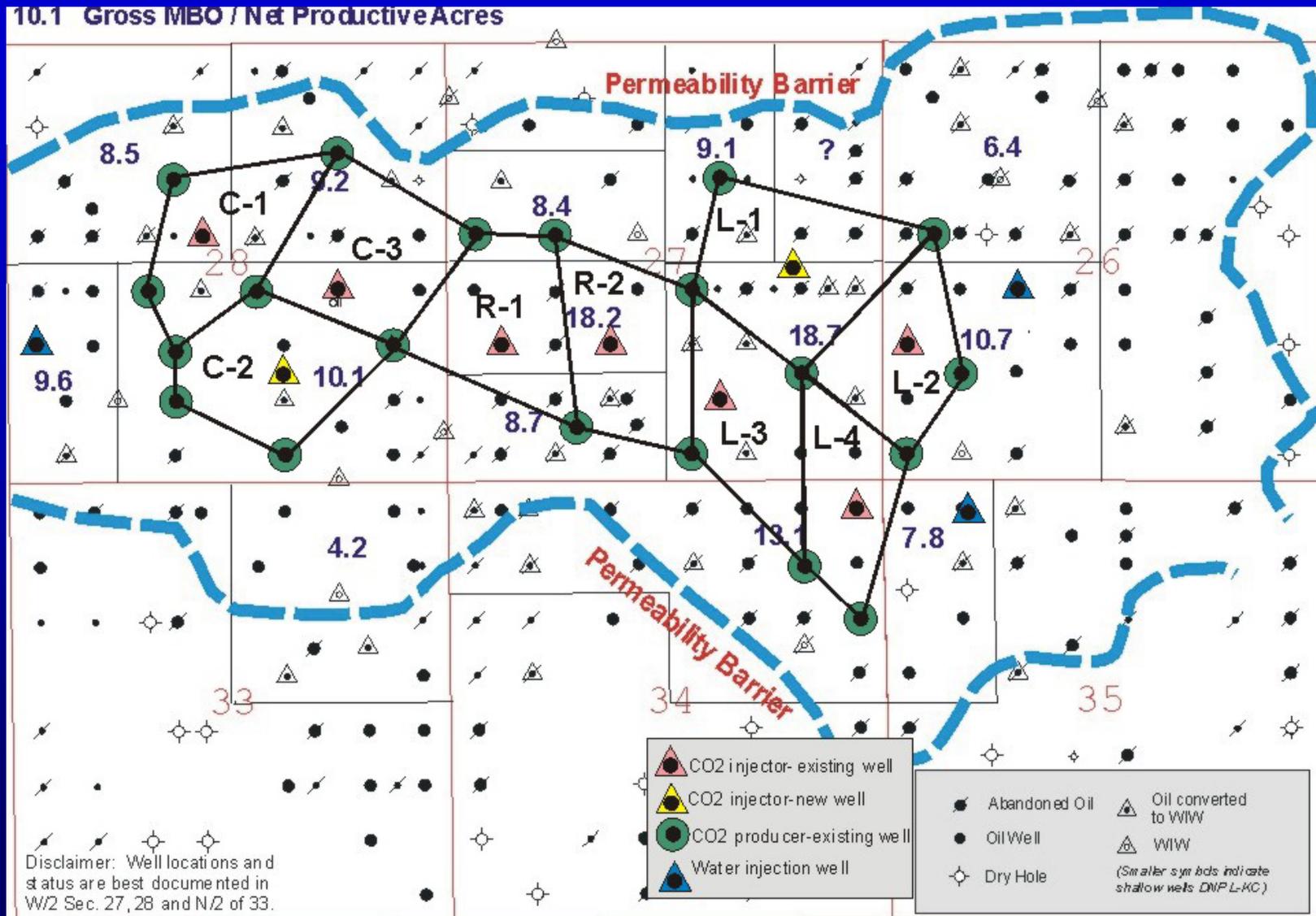


# Russell County, Kansas



7,759 Well that  
Have producing  
oil

# Hall-Gurney 620 Acre Area



M K Dubois, 11-07-01

# Economics - Oil Operations

Price/BBL	\$30	\$35	\$40	\$45	\$50
<b>Economic Measures</b>					
ROR (Mid Yr Discount)	18.57%	27.59%	35.67%	43.13%	50.13%
NPV (Mid Yr Discount)	\$2,069,904	\$4,586,480	\$7,103,057	\$9,619,633	\$12,136,210
ROR (End Yr Discount)	17.07%	25.14%	32.23%	38.65%	44.58%
NPV (End Yr Discount)	\$1,801,798	\$4,201,259	\$6,600,721	\$9,000,182	\$11,399,643
Profit (BFIT)	\$6,013,905	\$9,760,407	\$13,506,910	\$17,253,413	\$20,999,915
Profit/Capital	170%	275%	381%	487%	593%
Net Ultimate Rec (BO)	<b>749,301</b>	<b>749,301</b>	<b>749,301</b>	<b>749,301</b>	<b>749,301</b>
<b>Cost/Net BBL</b>					
Capital	\$4.26	\$4.26	\$4.26	\$4.26	\$4.26
LOE	\$7.91	\$7.91	\$7.91	\$7.91	\$7.91
Purchased CO2	\$5.62	\$5.62	\$5.62	\$5.62	\$5.62
Recycle CO2	\$3.07	\$3.07	\$3.07	\$3.07	\$3.07
Total Cost/Net BBL	<b>\$20.86</b>	<b>\$20.86</b>	<b>\$20.86</b>	<b>\$20.86</b>	<b>\$20.86</b>
Gross CO2 Utilization	<b>10.4</b>	<b>10.4</b>	<b>10.4</b>	<b>10.4</b>	<b>10.4</b>
Net CO2 Utilization	<b>4.4</b>	<b>4.4</b>	<b>4.4</b>	<b>4.4</b>	<b>4.4</b>

# CO<sub>2</sub> Pipeline Economics

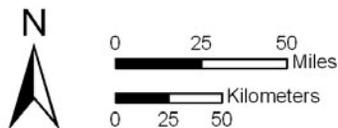
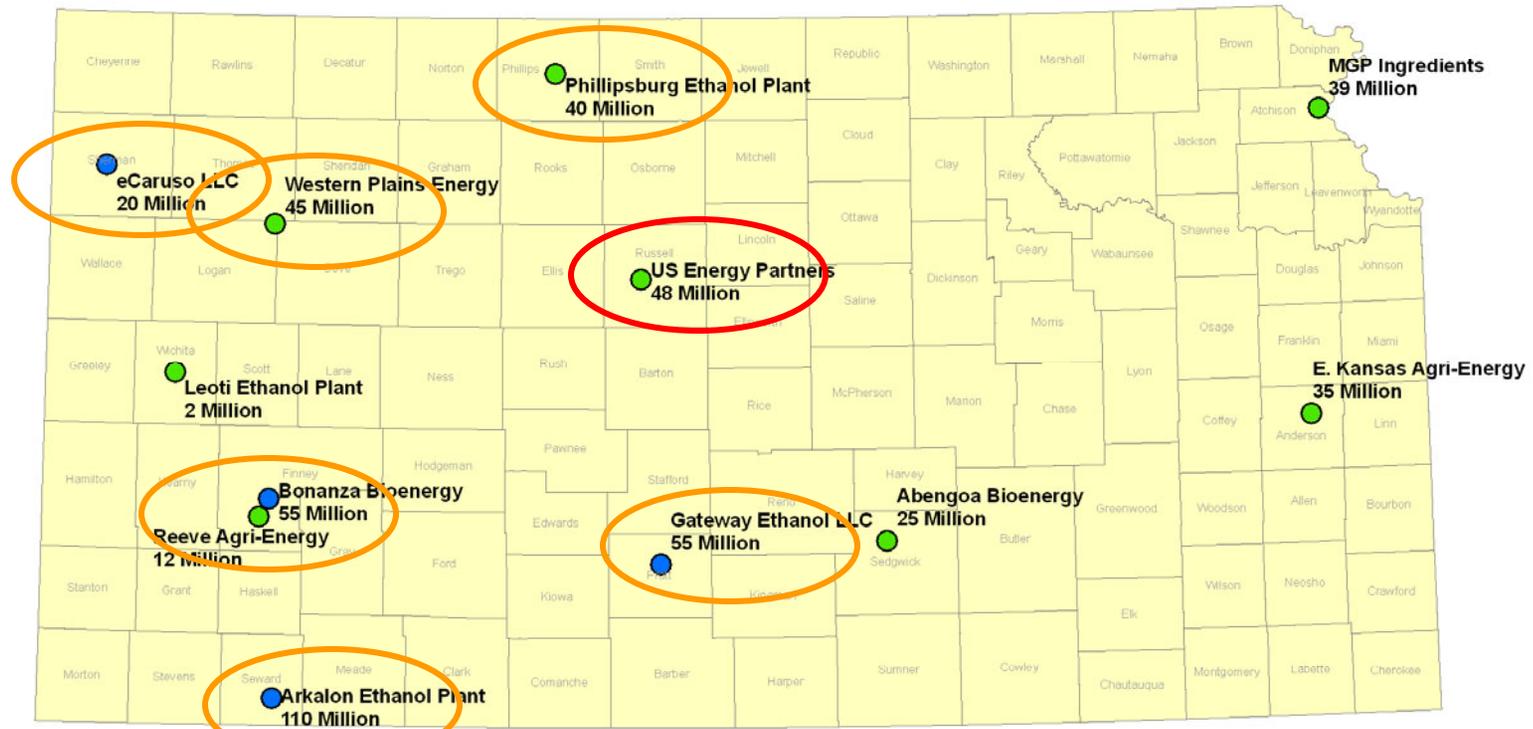
Operating Costs	Sales Mcf	Revenue	Revenue/Mcf	Operating Cost/Mcf	Cost of CO <sub>2</sub> /Mcf
\$1,971,000	2,700,000	\$3,375,000	\$1.25	\$0.31	\$0.42
\$2,004,480	2,700,000	\$3,375,000	\$1.25	\$0.32	\$0.42
\$2,039,299	2,700,000	\$3,375,000	\$1.25	\$0.34	\$0.42
\$2,075,511	2,700,000	\$3,375,000	\$1.25	\$0.35	\$0.42
\$2,113,172	2,700,000	\$3,375,000	\$1.25	\$0.36	\$0.42
\$2,152,338	2,700,000	\$3,375,000	\$1.25	\$0.38	\$0.42
\$2,193,072	2,700,000	\$3,375,000	\$1.25	\$0.39	\$0.42

**NPV = \$1,348,327, IRR = 20.42%, ROC = 32.26%**

# KS Ethanol Production Capacity

## Kansas Ethanol Plants Operating and Under Construction

January 2007

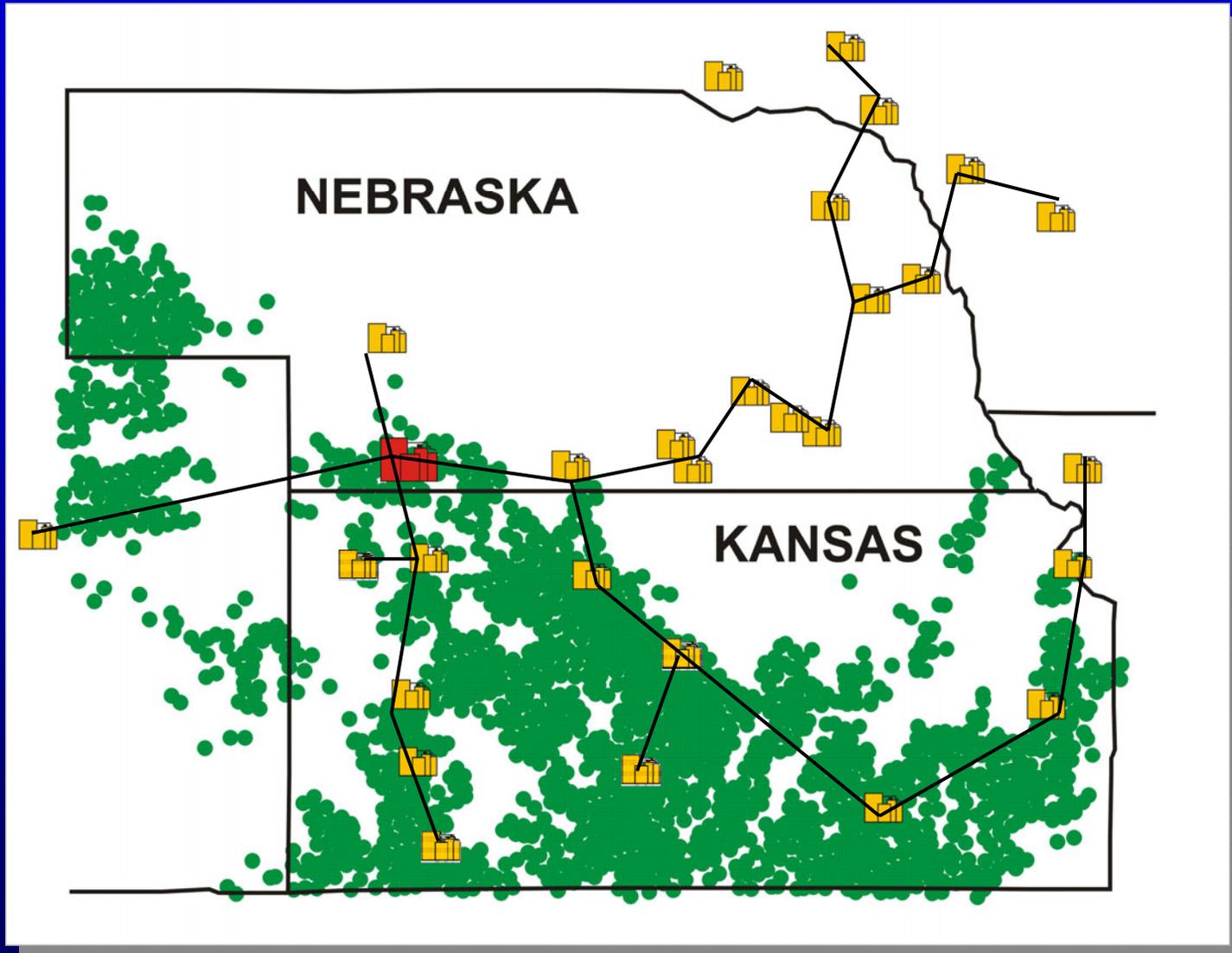


### Ethanol Plants

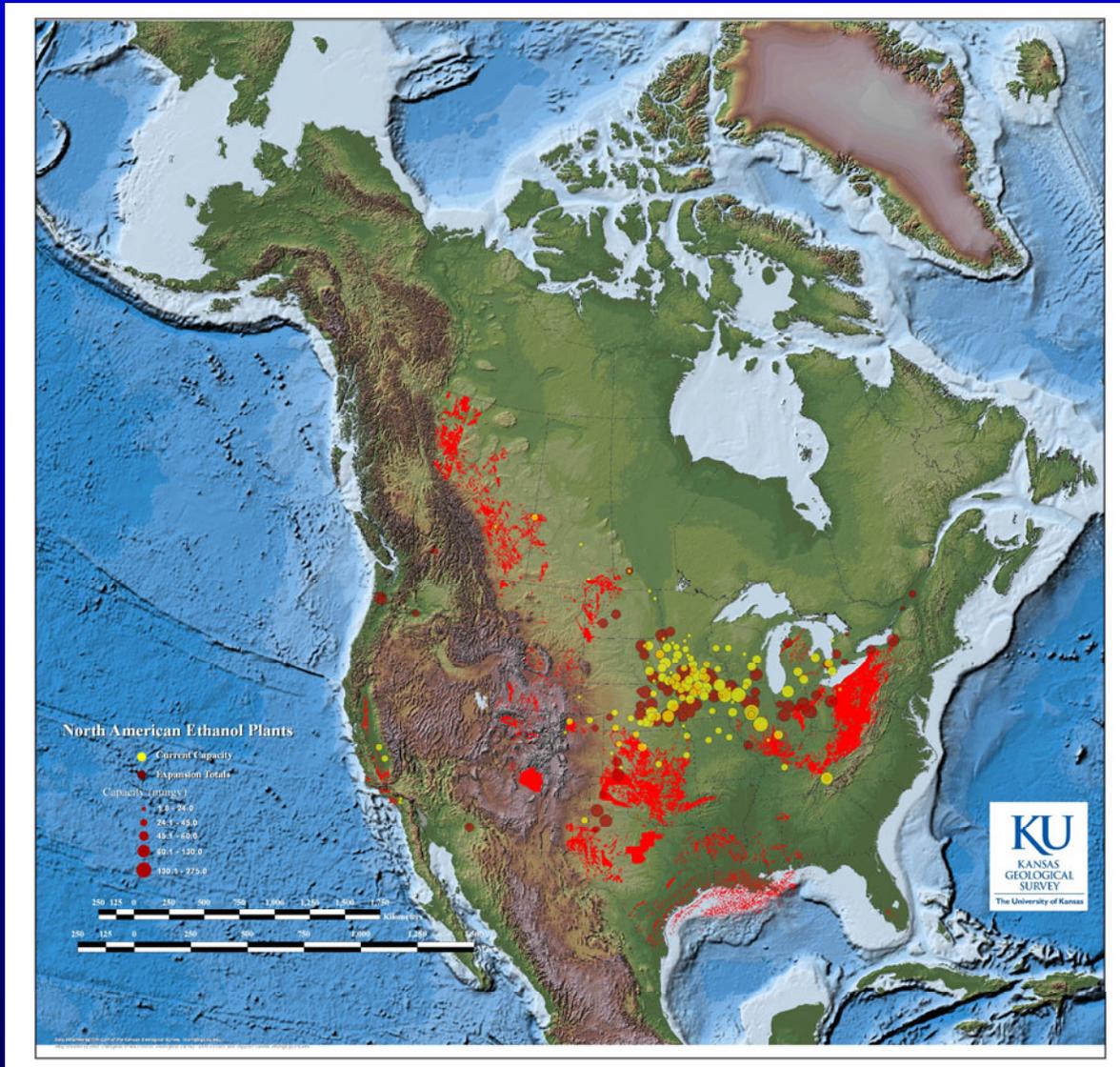
#### Status

- Under Construction
- Existing

# String of Pearls



# North American Ethanol Capacity and Oil & Gas Fields



# Ethanol CO<sub>2</sub> Emissions

- A ethanol plant releases 6.624 pounds of CO<sub>2</sub> from fermentation per gallon produced.

12,517 mmg/y x 6.624 pounds

37.7 million tons of CO<sub>2</sub> per year

- A ethanol plant releases 4.499 pounds of CO<sub>2</sub> from combustion per gallon produced.

12,517 mmg/y x 4.499 pounds

28.2 million tons of CO<sub>2</sub> per year

# Electric Generation CO<sub>2</sub> Emissions

- A high efficiency (33%) 500 MW coal-burning plant will emit 4.4 billion kWh x 2.1 lb/kWh =  
**4.2 million metric tons of CO<sub>2</sub> per year**
- A high efficiency (50%) 500 MW natural gas plant will emit (1.4 lb/kWh)  
**1.5 million metric tons of CO<sub>2</sub> per year**
- CO<sub>2</sub> from fermentation for ethanol targeted in Kansas  
**1.32 million metric tons of CO<sub>2</sub> per year**
- Nine 500 MW coal-burning plants could be offset with the CO<sub>2</sub> from ethanol emissions (fermentation only).
- Additional six 500 MW coal-burning plants could be offset with the CO<sub>2</sub> from combustion used in ethanol production