Pilot Scale CO_2 EOR in Mississippian Carbonate Reservoir at Wellington Field in South-Central Kansas

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KU KANSAS GEOLOGICAL SURVEY
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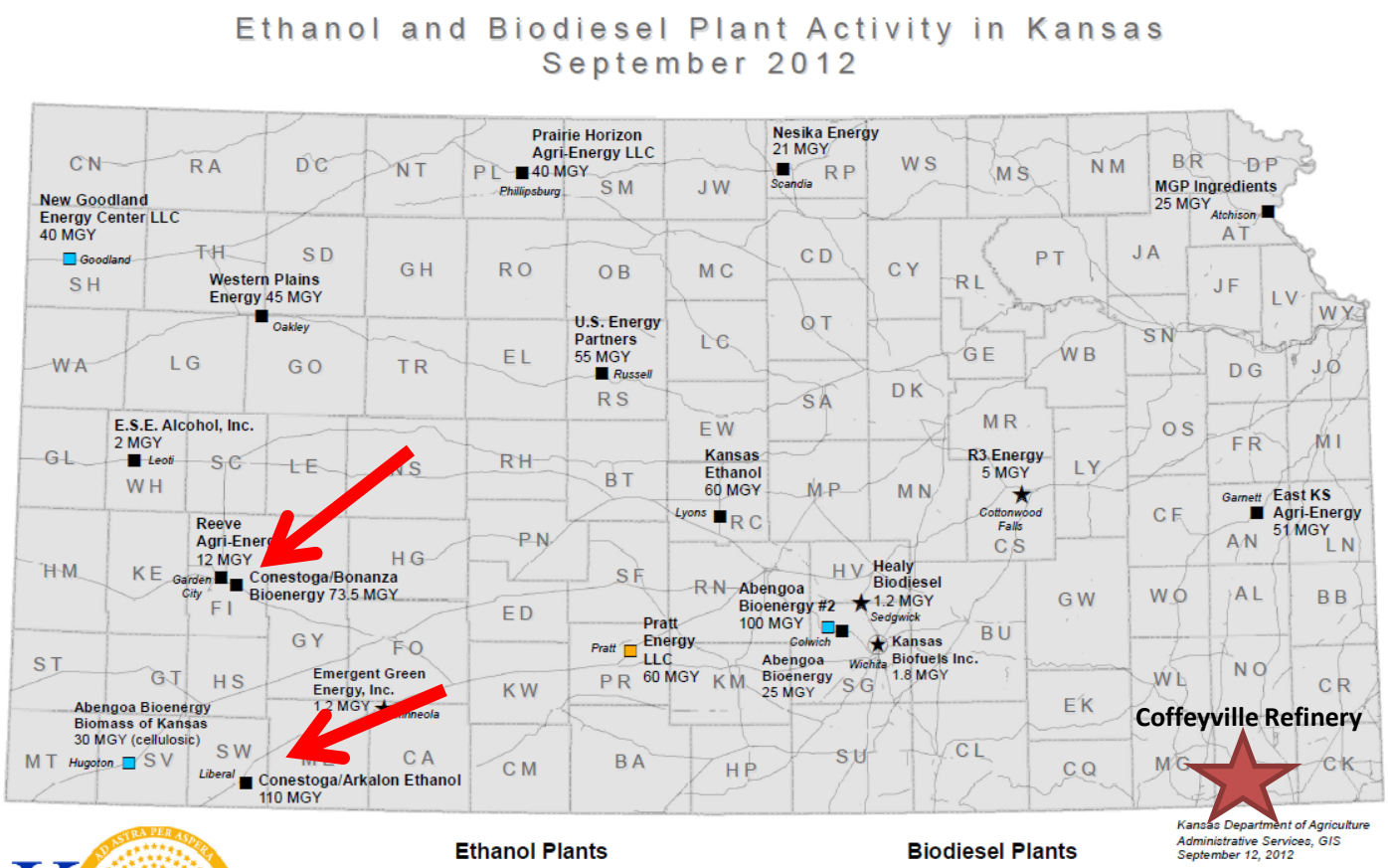
Participants

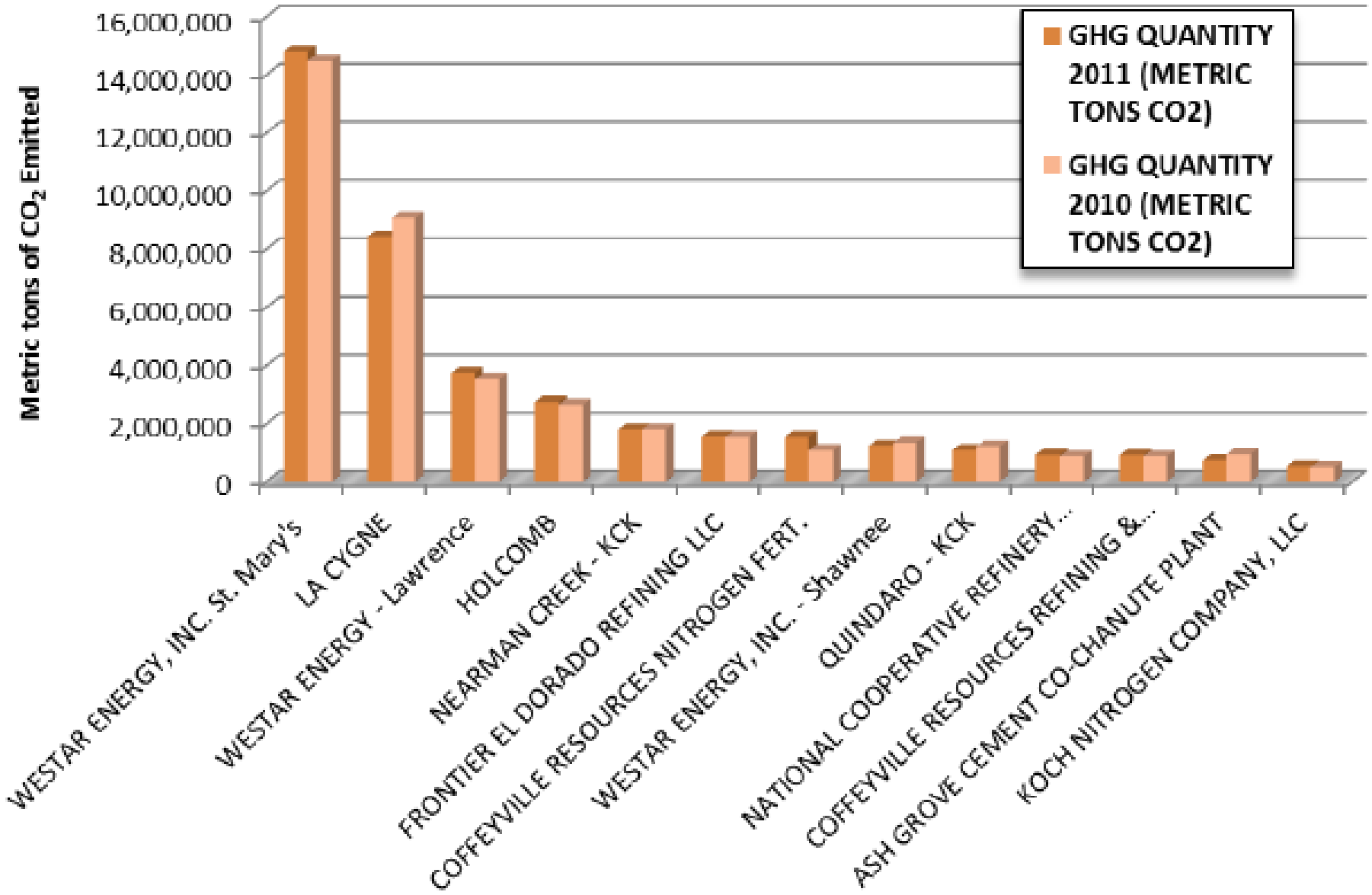
CO_2 Sources Suitable for EOR



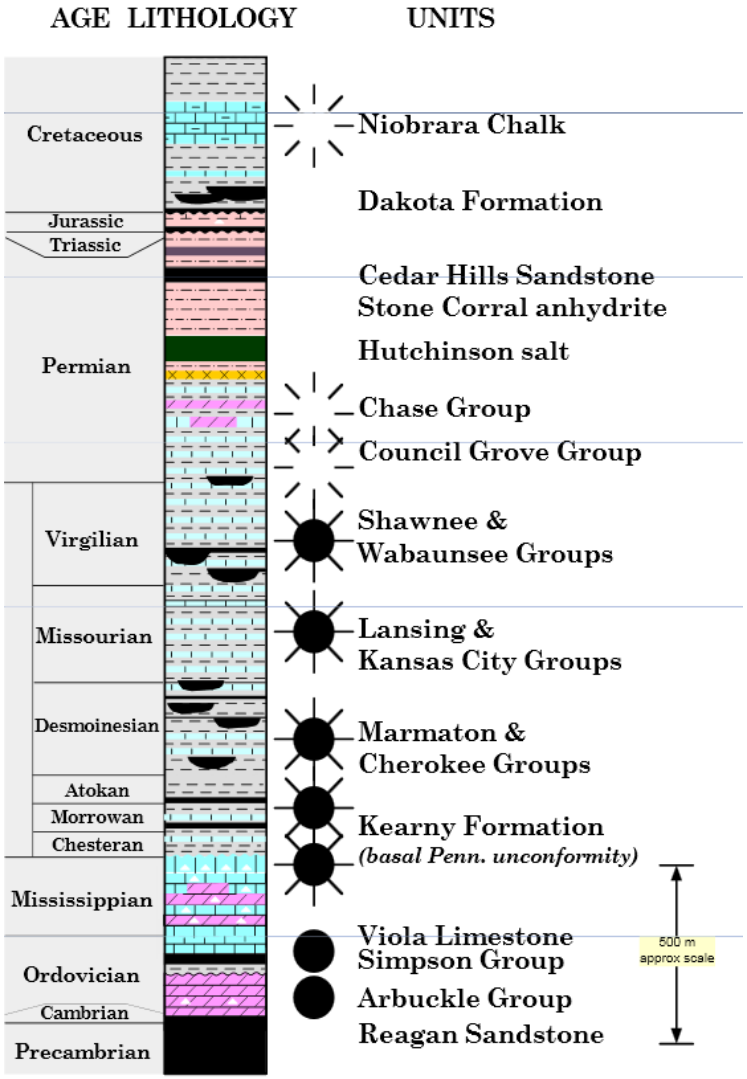
- Kansas holds more than **750 million barrels** of technical CO_2-EOR potential and **~240-370M** metric tons of CO2 is required for recovery
- Economic results based on Hall Gurney field suggest an after-tax project IRR of about 20%
- Access to the significant volumes of ethanol-based CO_2 in Nebraska

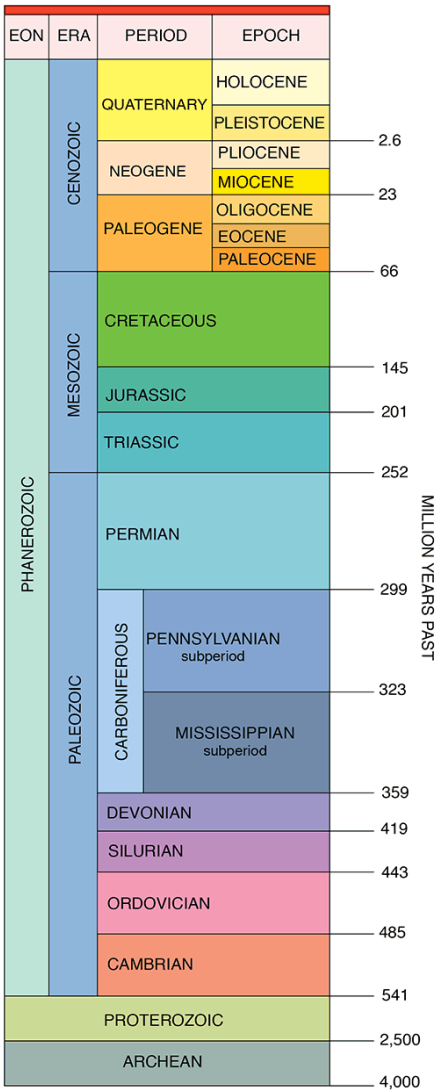
Kansas CO_2 Emissions

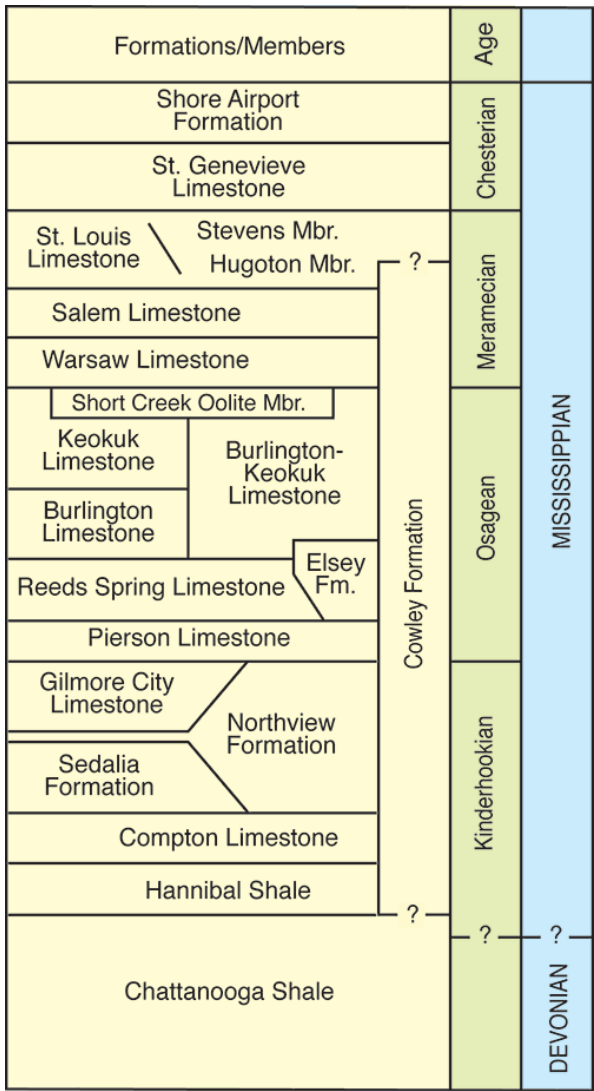
(From sources greater than 500,000 metric tons annually)



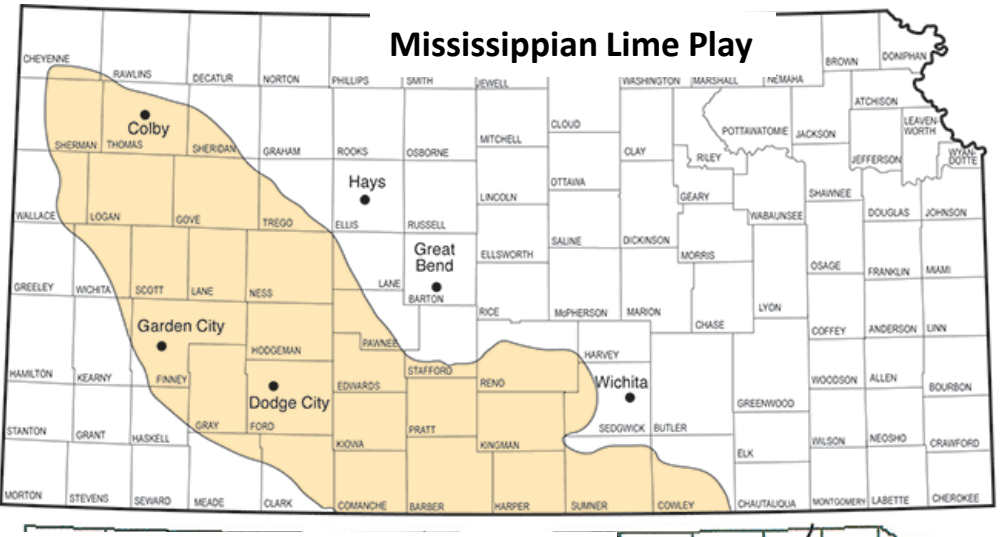
Potential Recoverable Resources: Formations of Interest

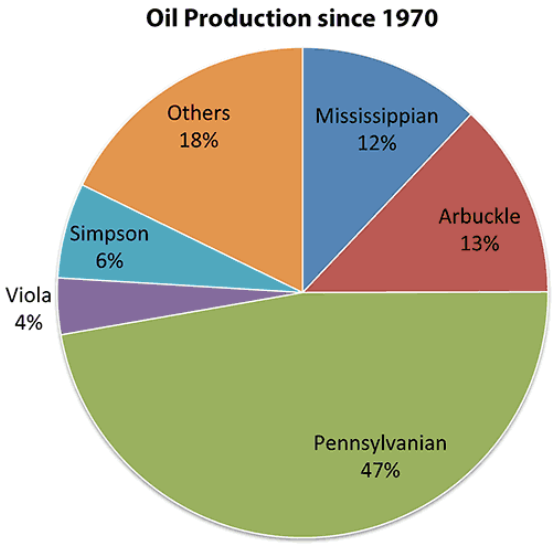


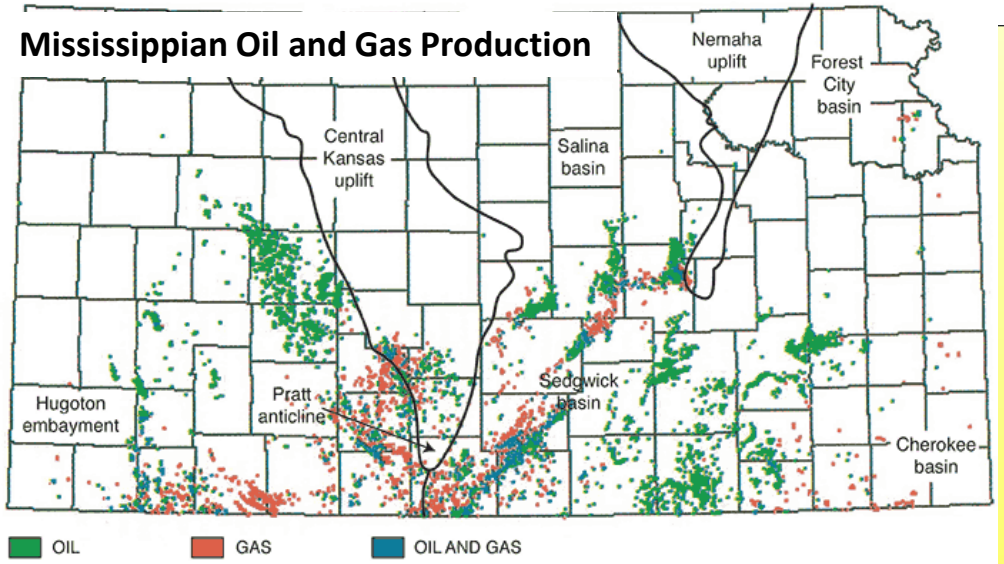


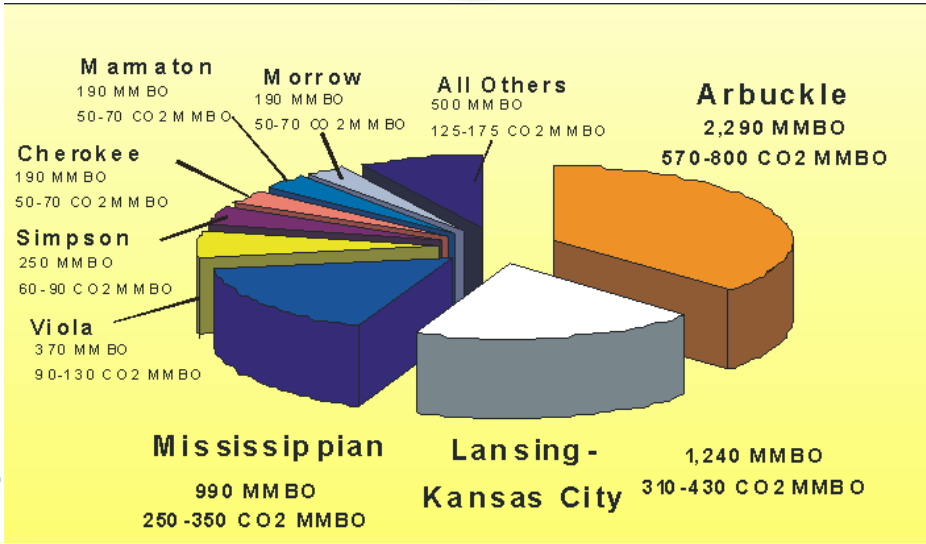


Potential Recoverable Resources: Mississippian Group

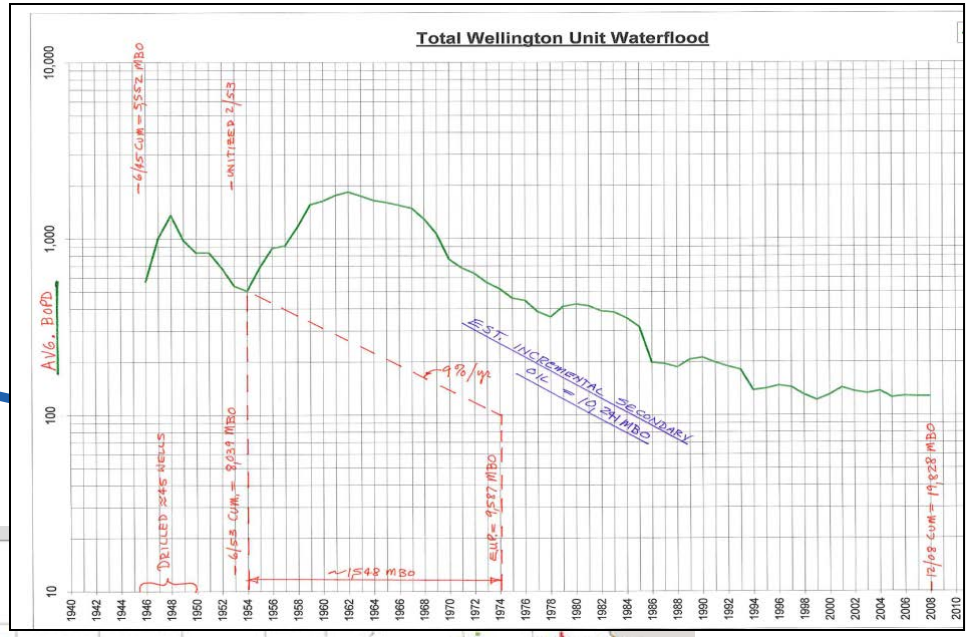


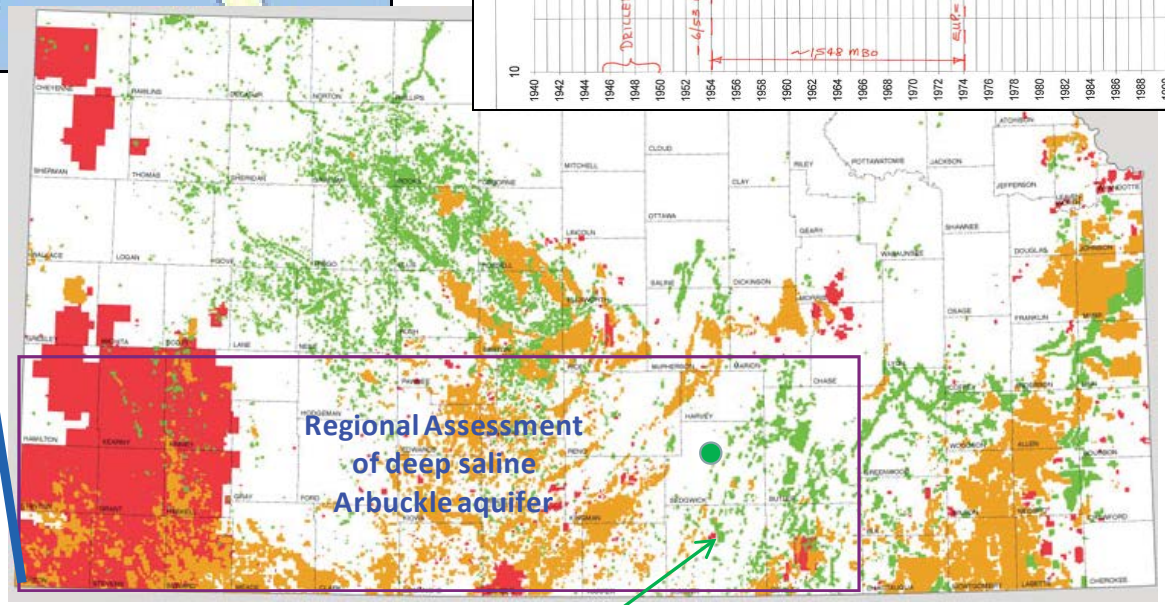






Wellington Field, South KS



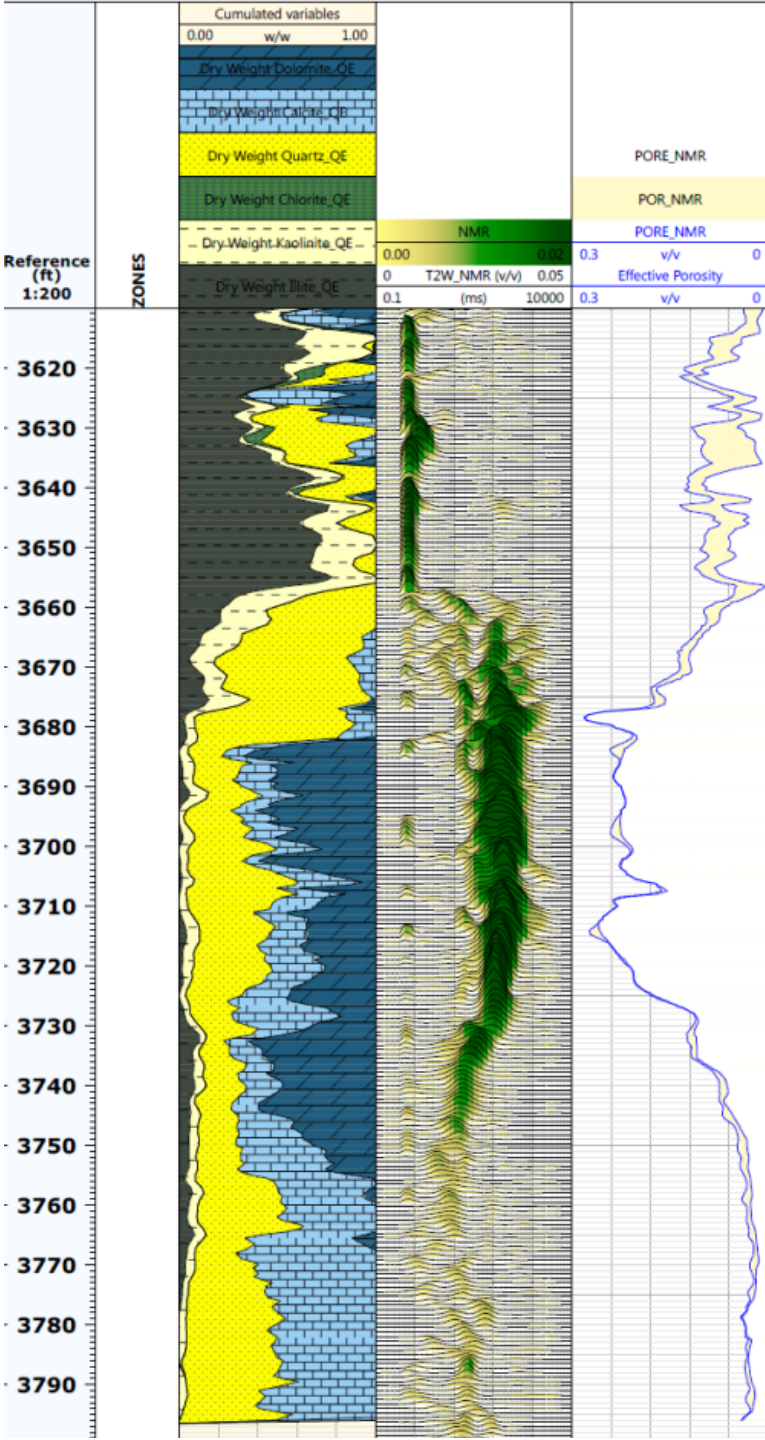


Plan for CO_2 EOR Pilot

- Find, characterize, and prepare oil field
- Find CO_2 source
  - Initially, ethanol plant → multiple sources
- Develop strategy for resource recovery through reservoir modeling
  - Several revisions
- Obtain a permit and drill a new injection well
- Organize surface infrastructure and deliver CO_2
  - Truck delivery
- Inject ~~~26,000~~ ~20,000 tones of CO_2 at 100-150 tones/day
- Monitor and manage CO_2 plume
- Vent produced CO_2

Reservoir Characterization

- Very old Neutron logs with or without resistivity logs for all wells
- 16 wells with complete suites of resistivity and porosity logs
- New wells drilled by KGS have a full set of modern logs
- Core is available from KGS #1-32
  - Porosity/permeability
  - Geochemistry
  - Geomechanical data
- 3D Seismic
- Formation fluids analysis

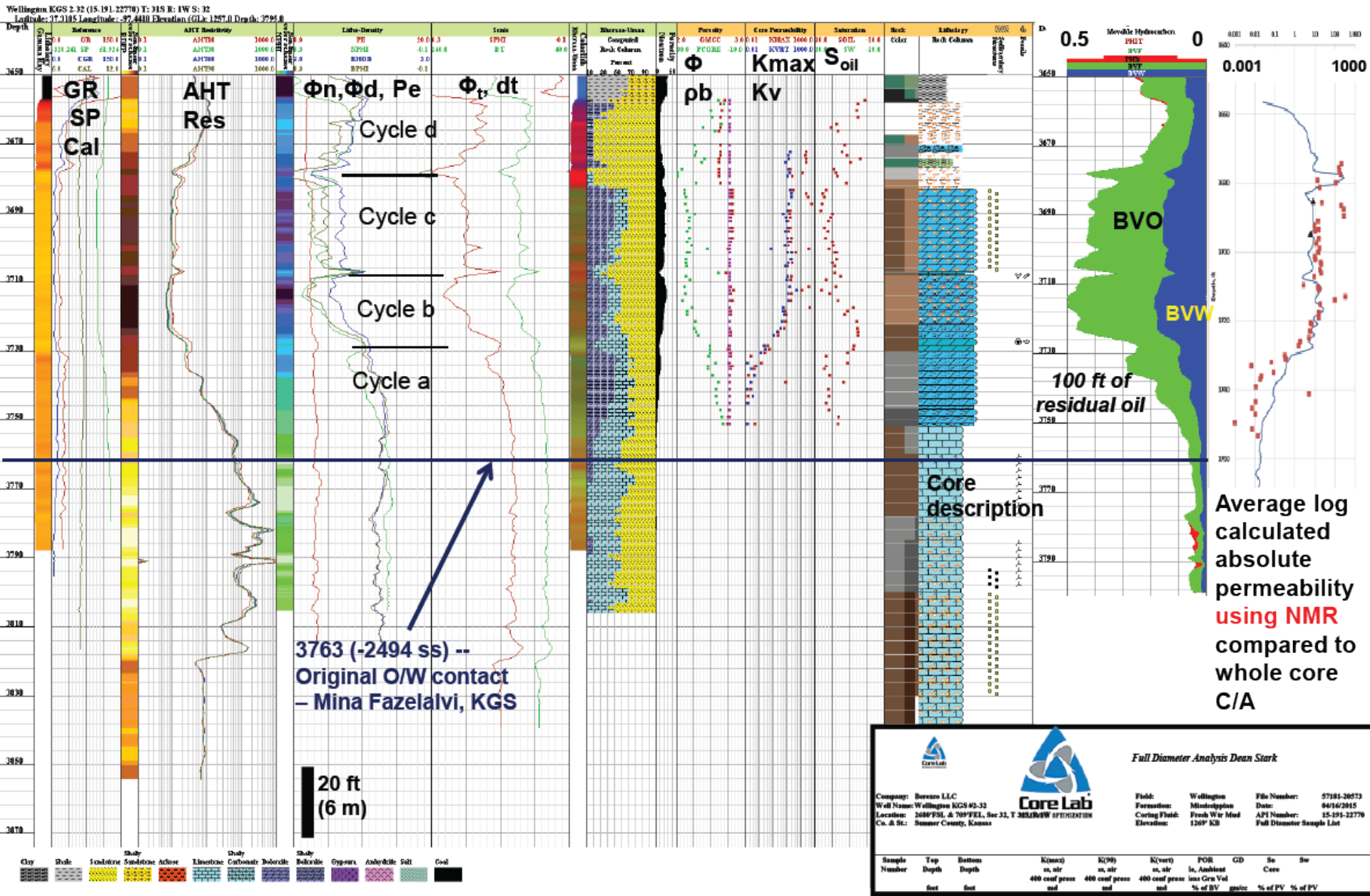


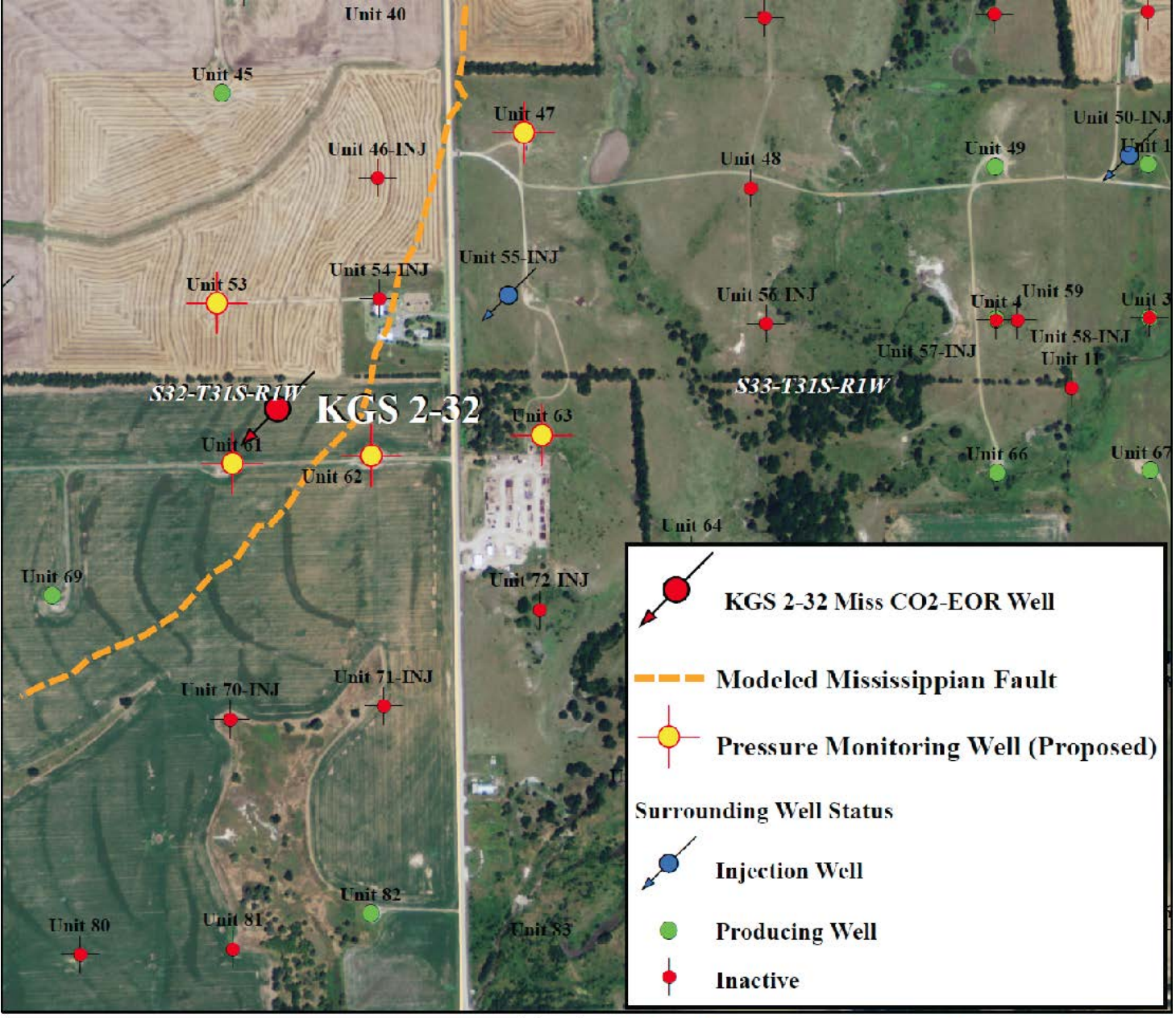
Injection Well Drilling and Coring

- Class II Well Permit
  - 30 days process

- ~100 ft of new new core
- 70 ft of ~23% S_{or}
- 20% Phi
- 15-18 mD

Injection Well Logging

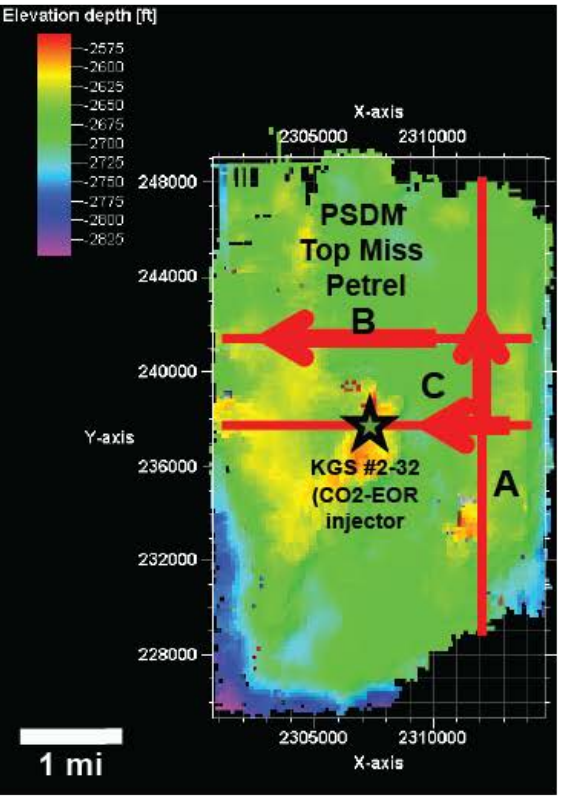


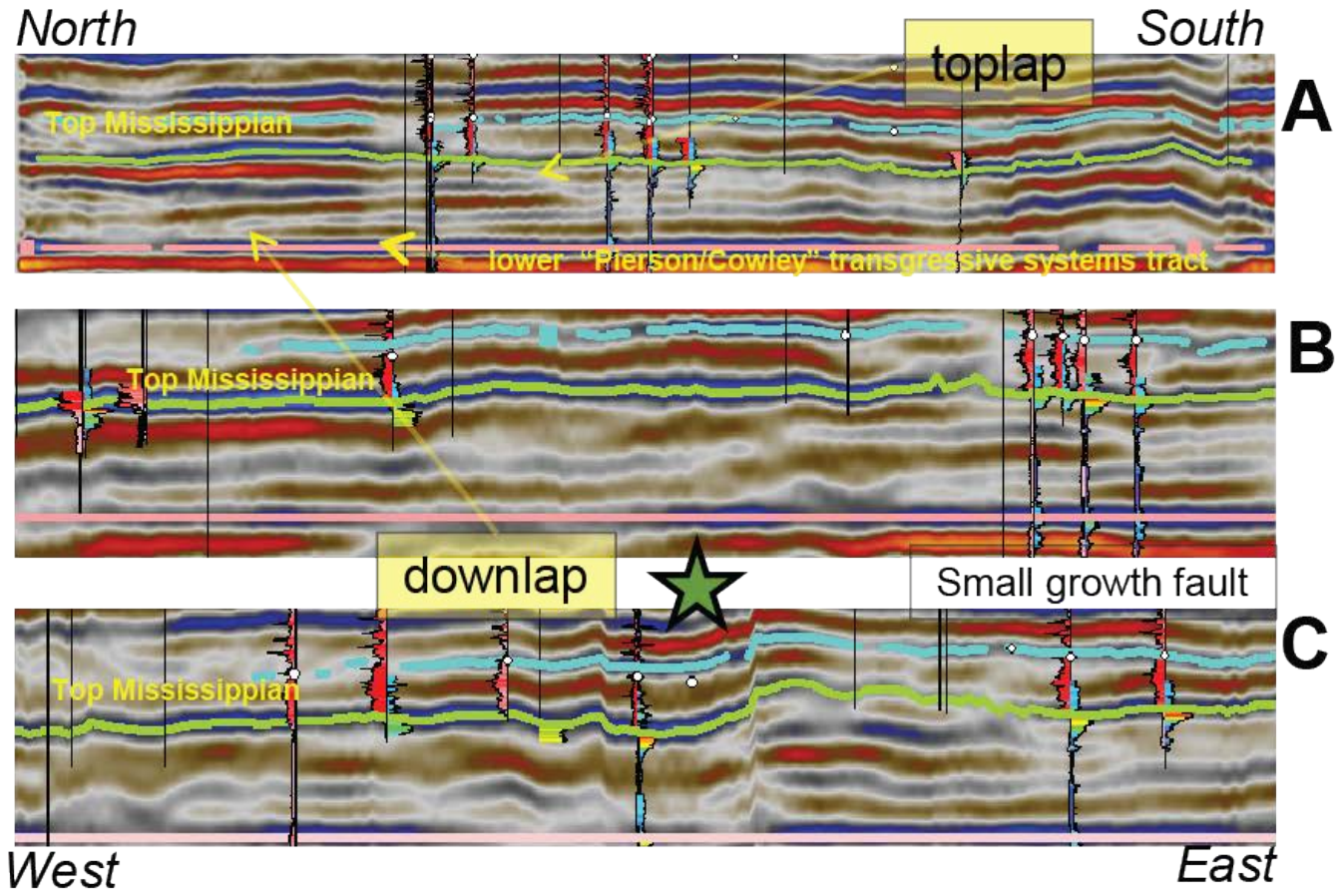


Well Tests

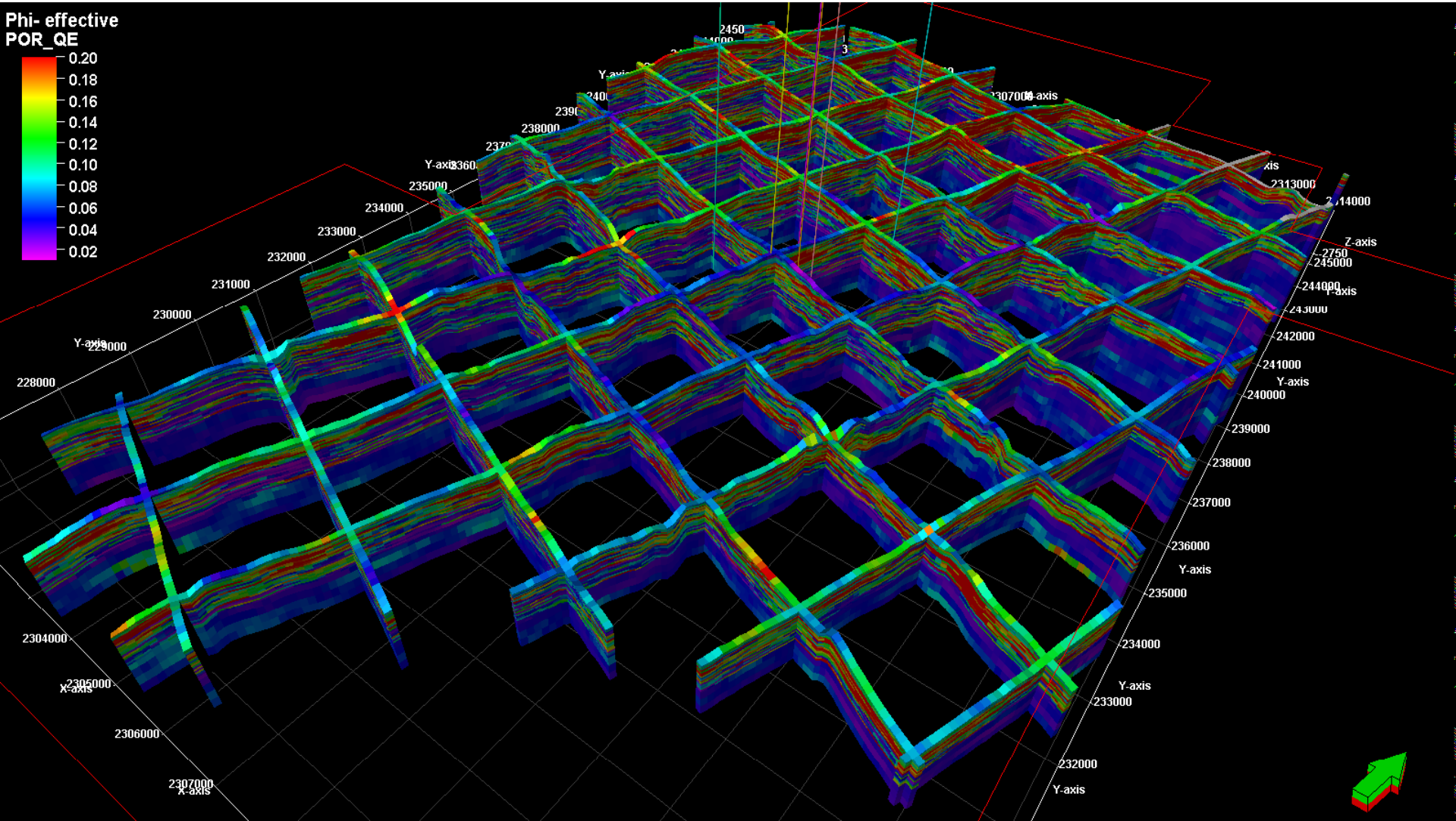
- Drill stem test
- Step rate test
- Interference test

Seismic Stratigraphy Using PSDM

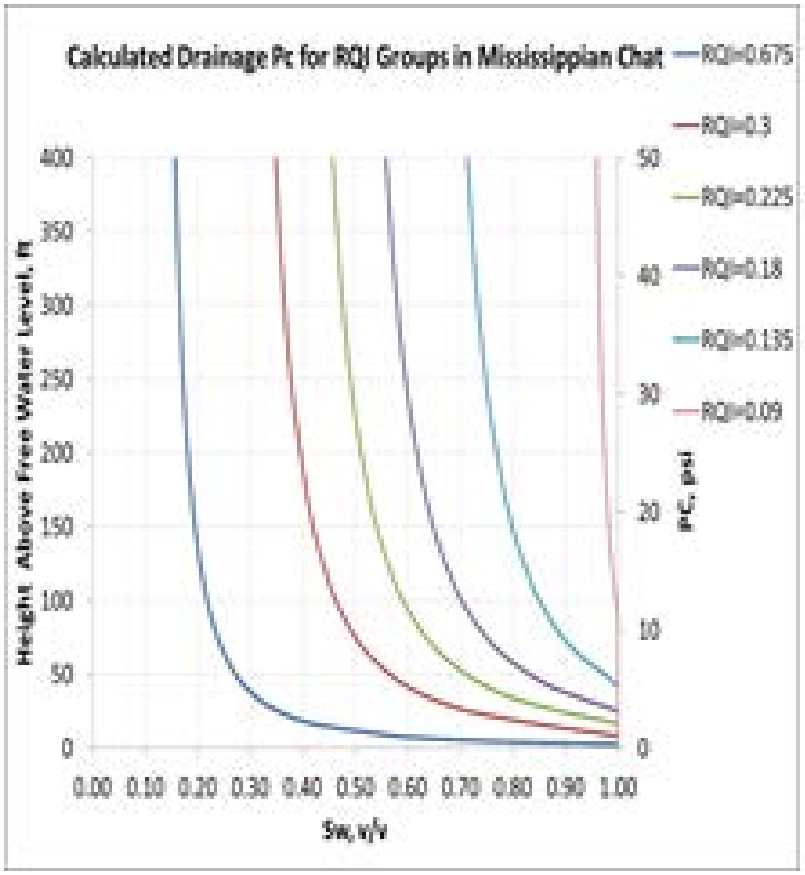


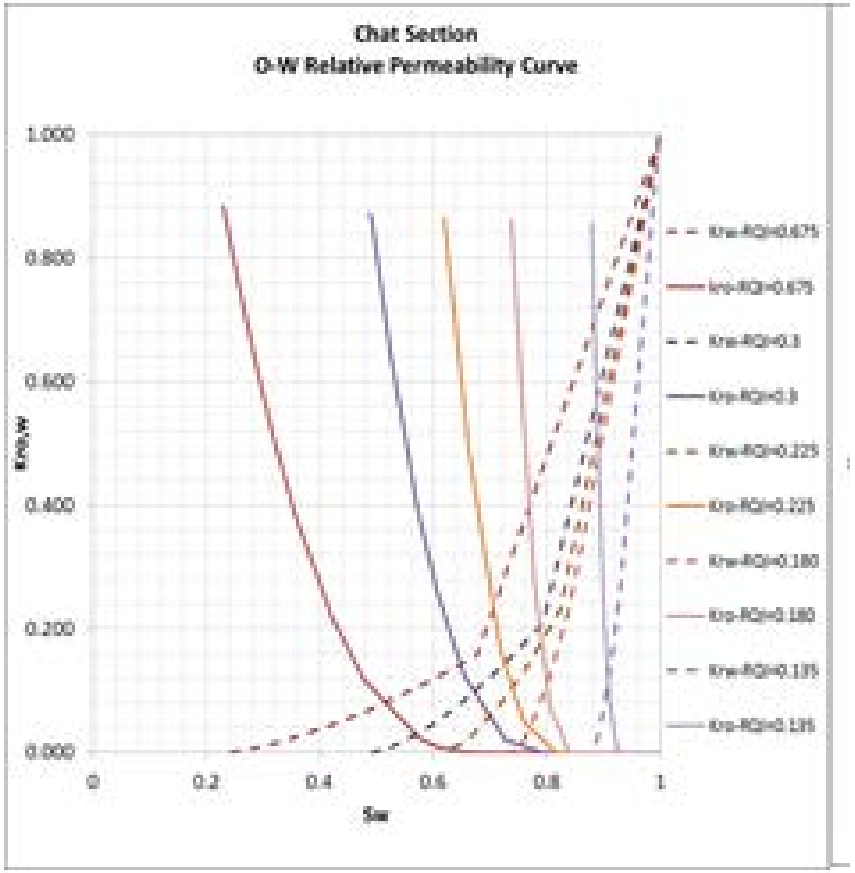


Improved Geologic Model



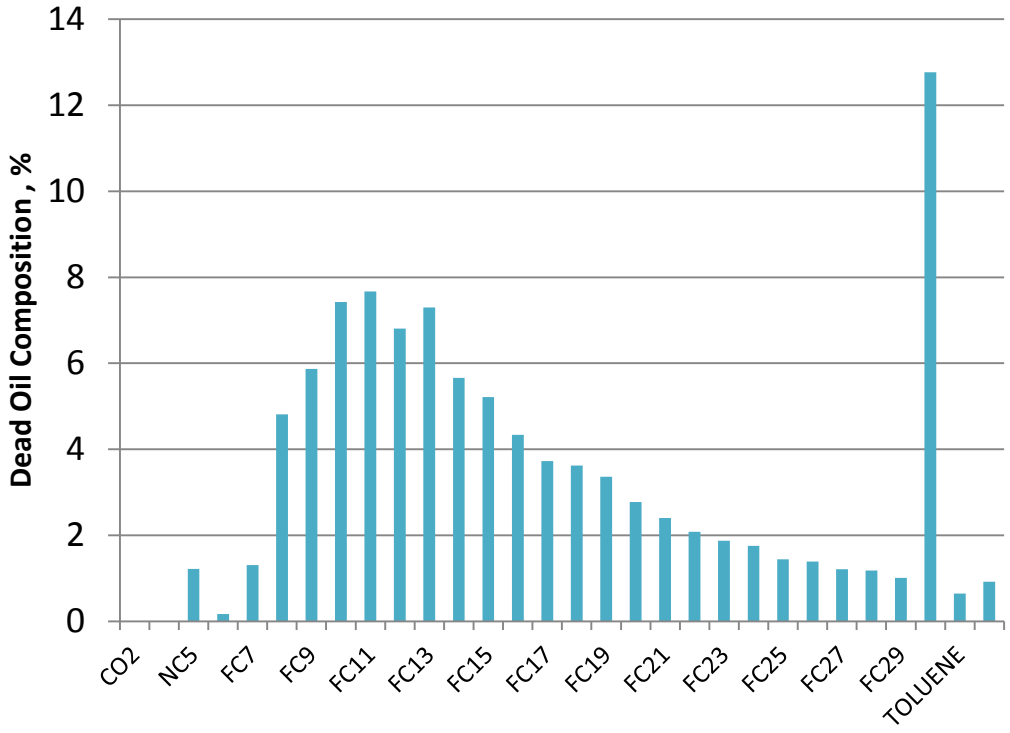
Capillary Pressure and Relative Permeability





Fluid Properties

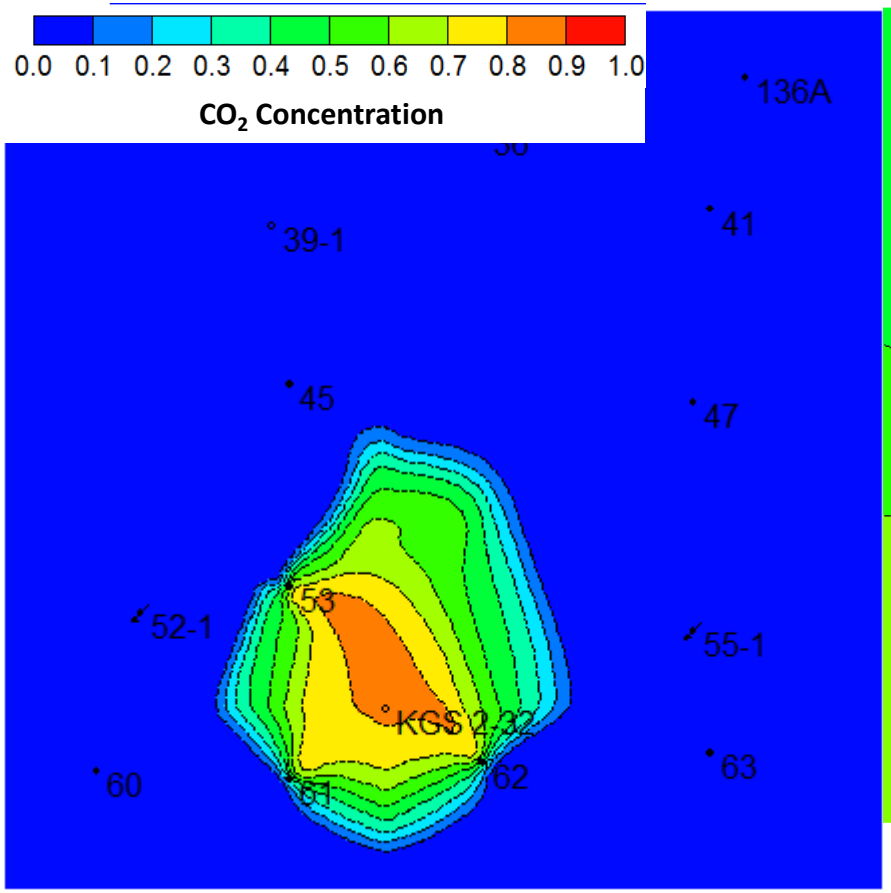
- CO_2 Miscibility pressure is ~1650 psi
- Oil API gravity is 30°
- Oil composition
- Water composition
- PVT



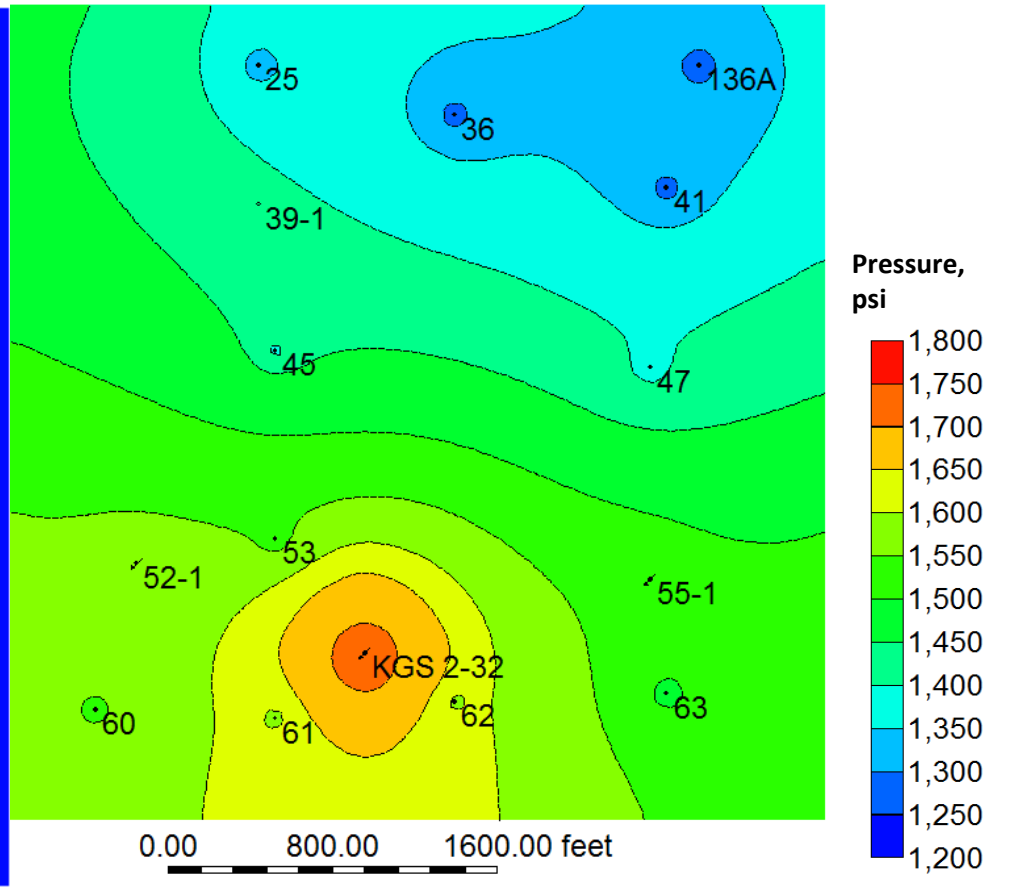
Reservoir Modeling

- Strategy for a flood
  - Monitoring optimization
  - Re-pressurization strategy for miscibility
  - CO_2 movement
- Economic forecast
  - Sweep efficiency
  - Oil production
  - CO_2 production

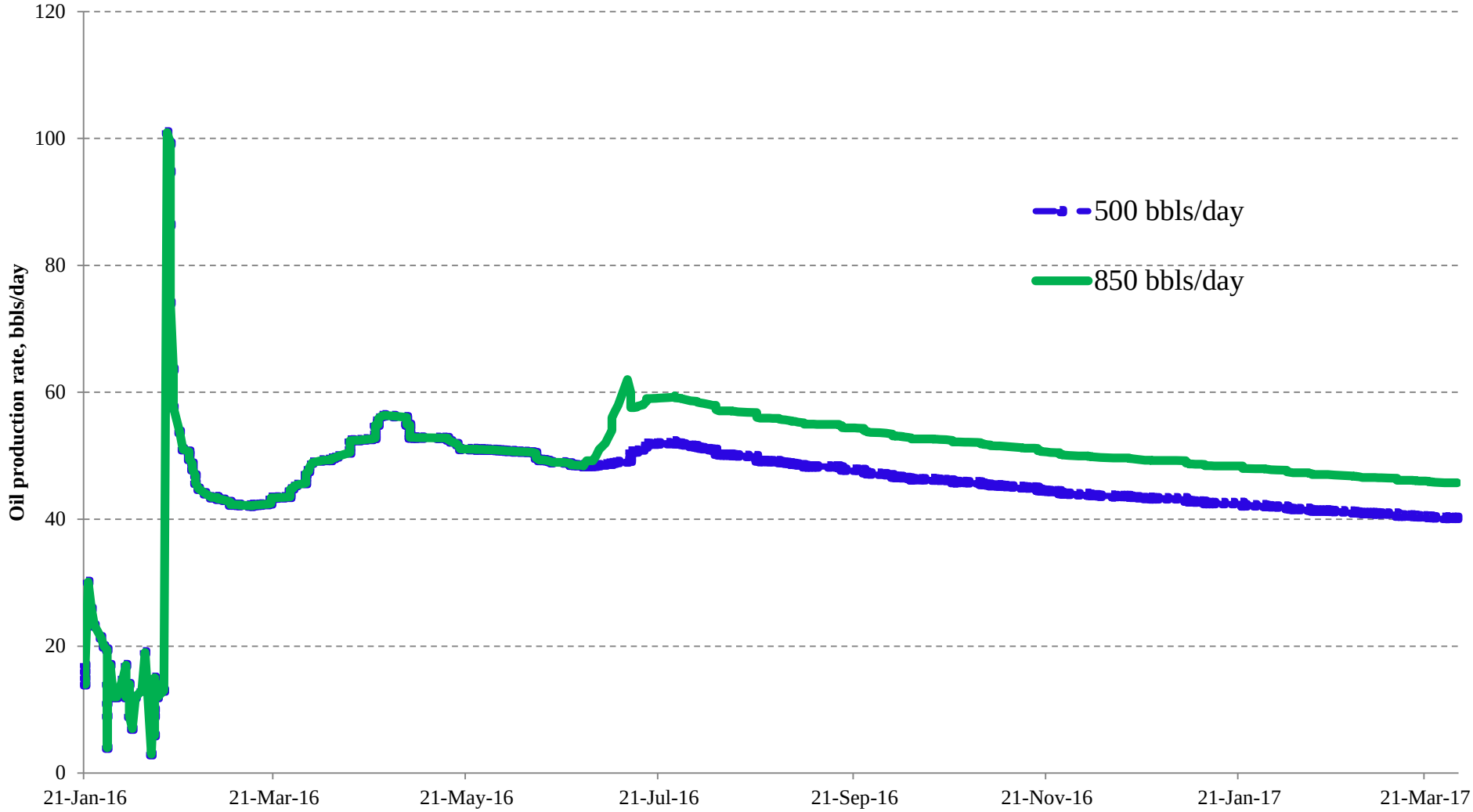
Forecasted CO_2 Movement in Reservoir



Forecasted Pore-Pressure Distribution at the Start of CO_2 Injection
Required miscibility pressure is ~1650

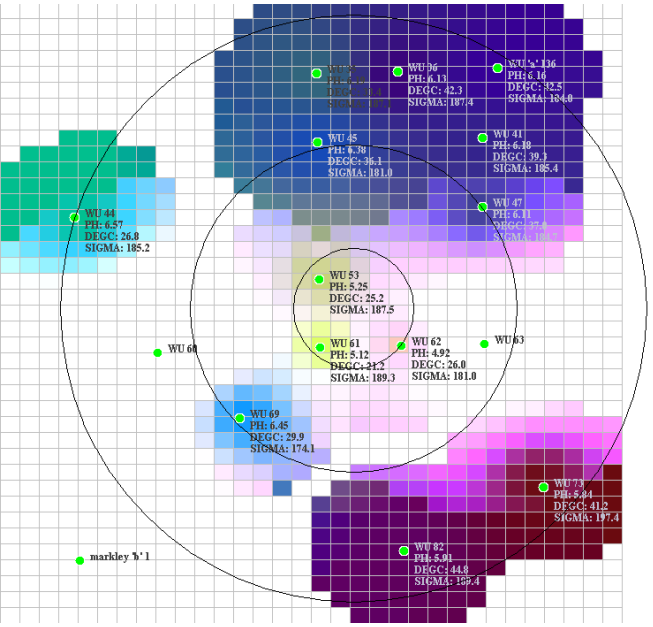


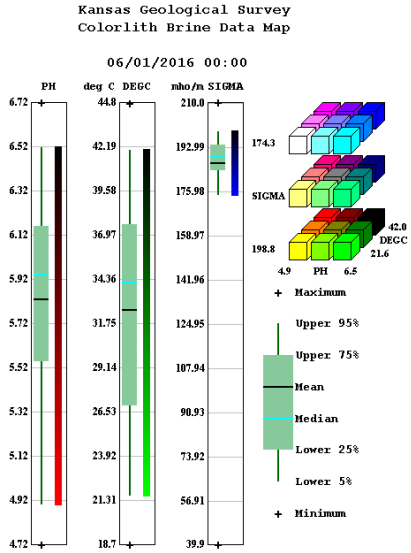
Waterflood Strategy after CO_2 Injection

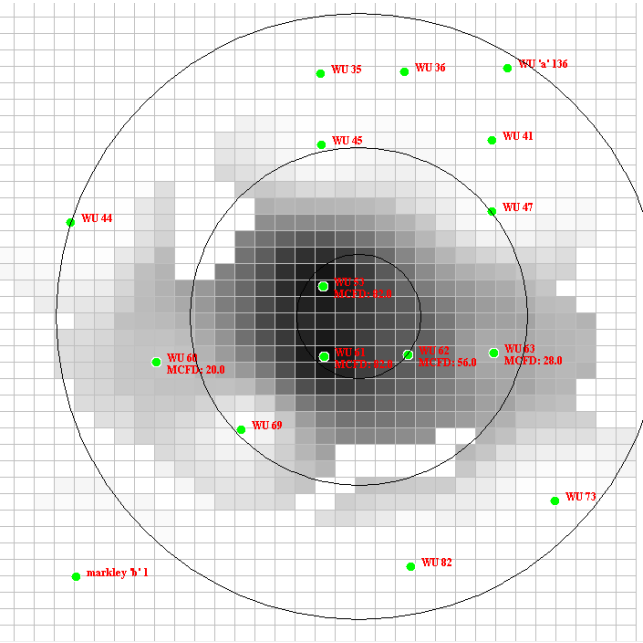


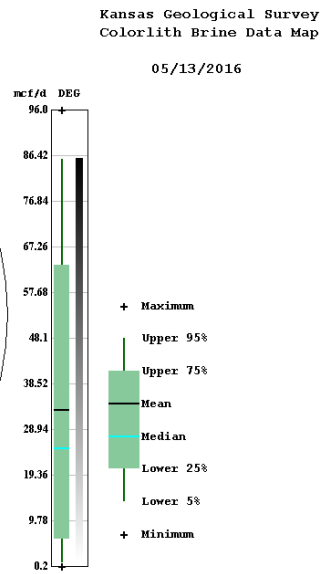
Operations: CO_2 Delivery and Surface Facilities

Fluid Monitoring



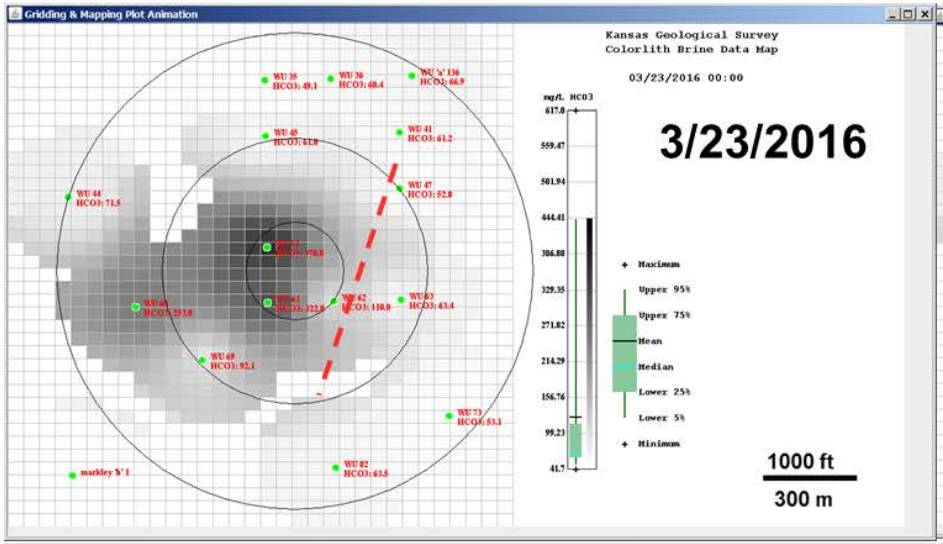


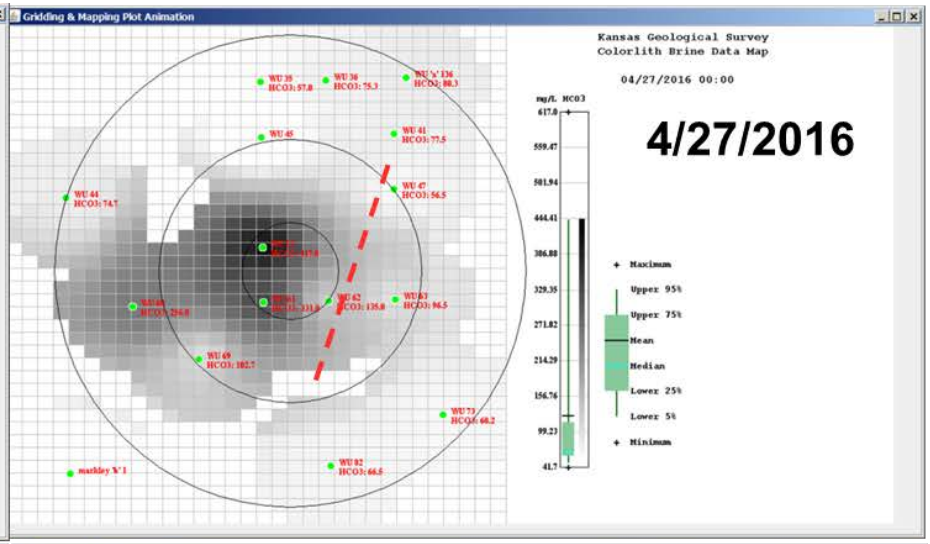


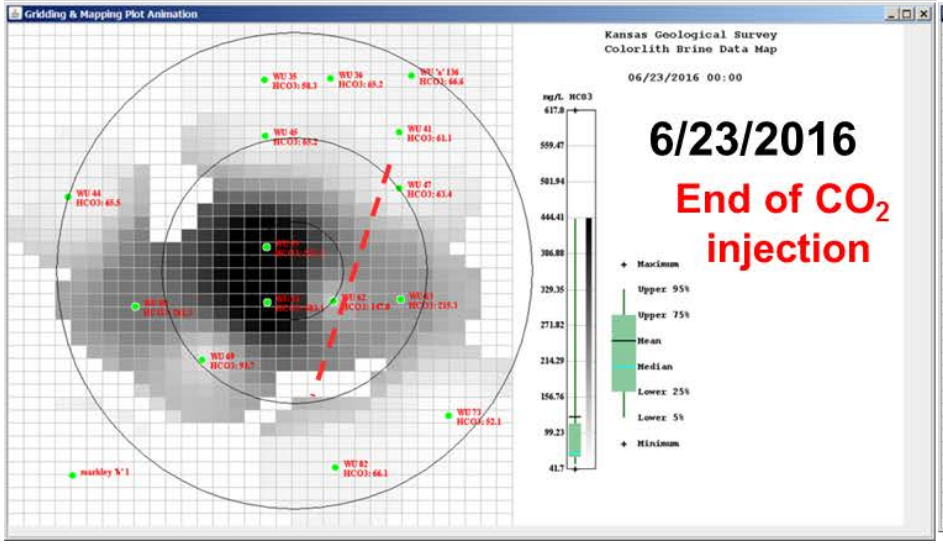


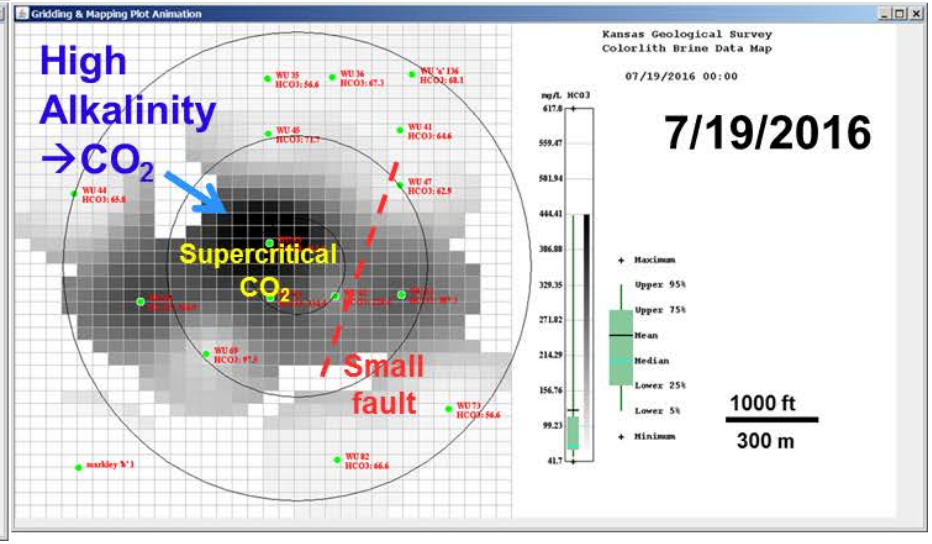
- Water chemistry
  - Alkalinity
  - pH
  - Cations/anions
  - Microbial
- Production history
  - Oil/water
  - CO_2 account

Geochemical Monitoring: Field Alkalinity Progression

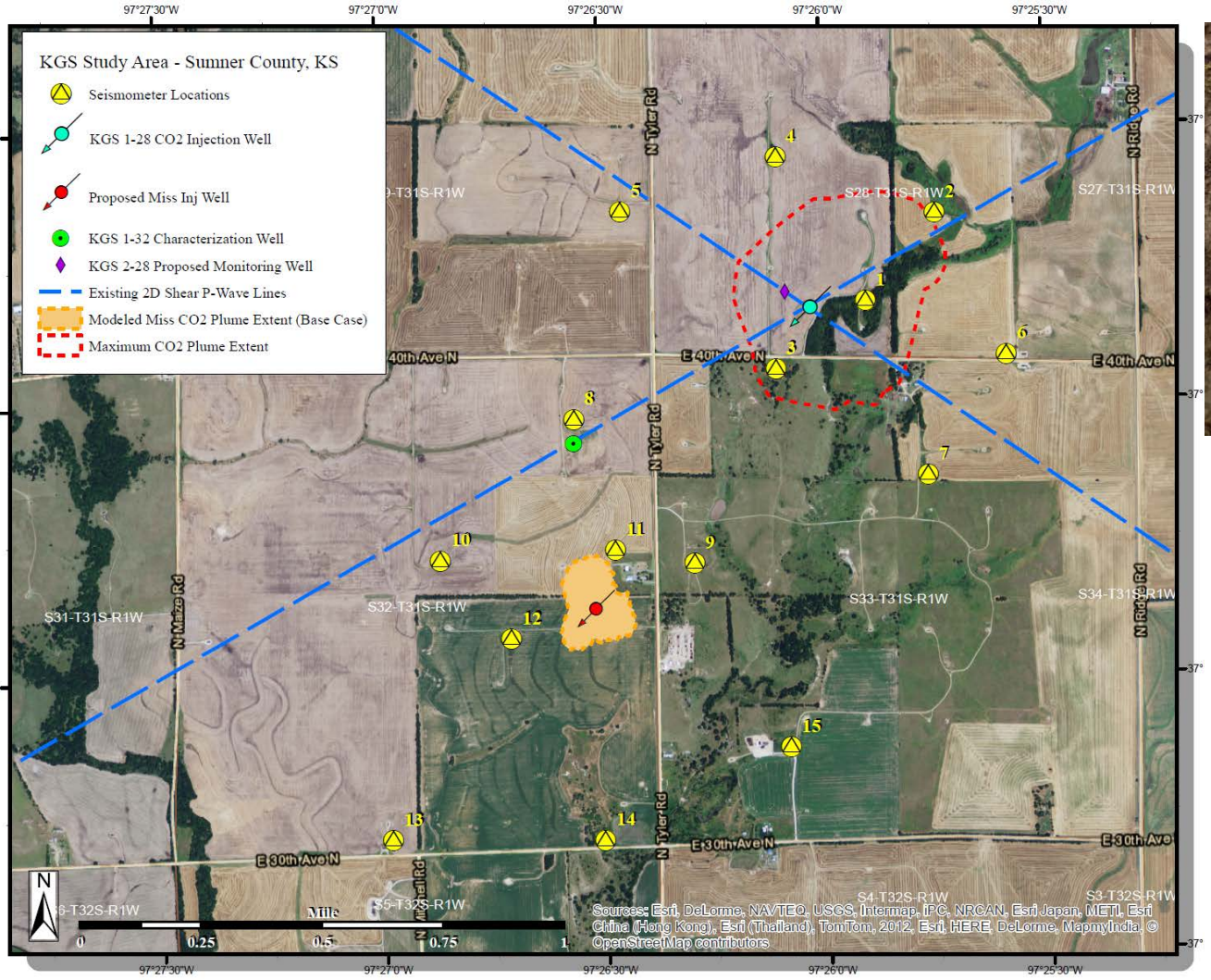






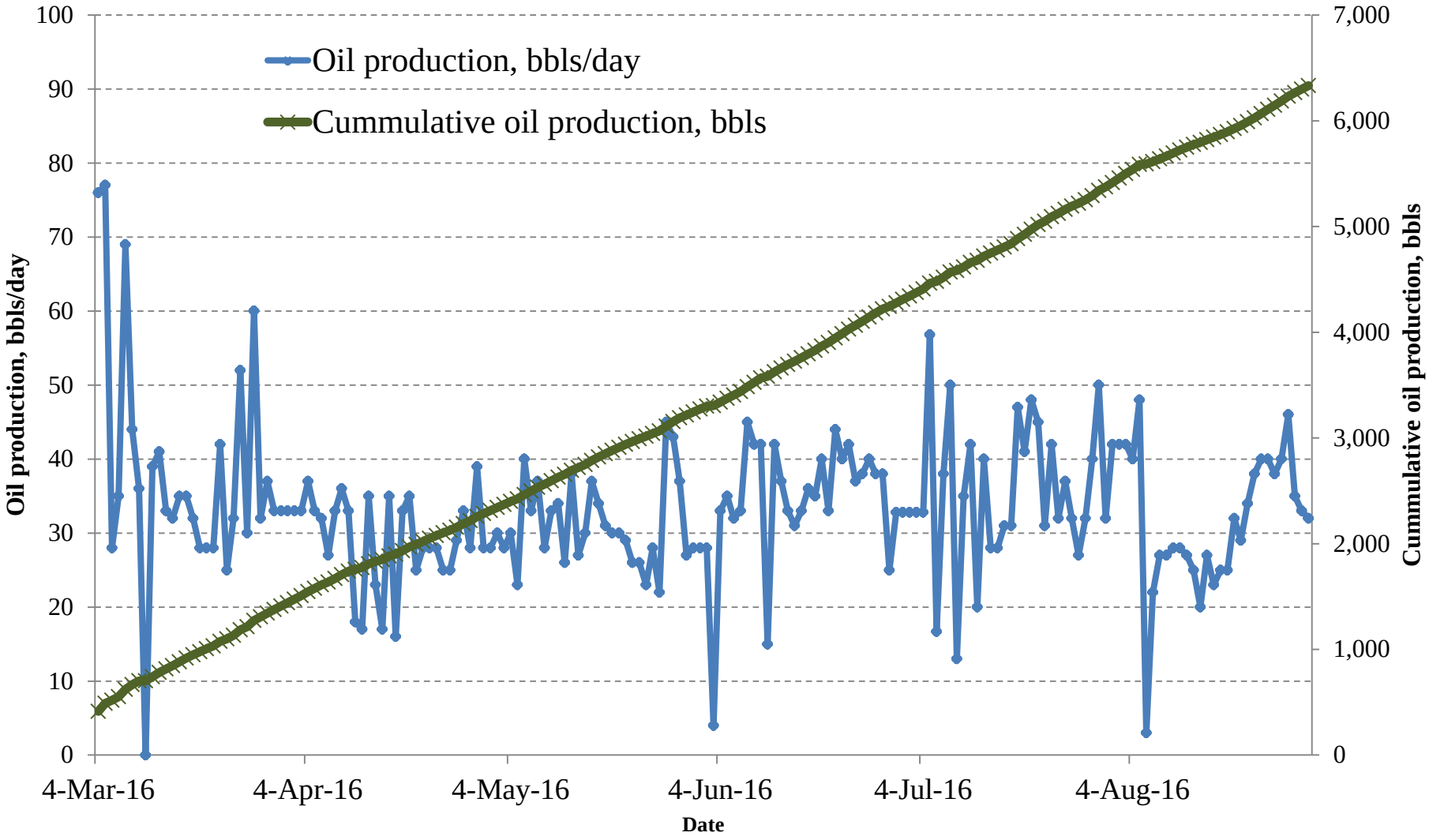


Seismic Monitoring

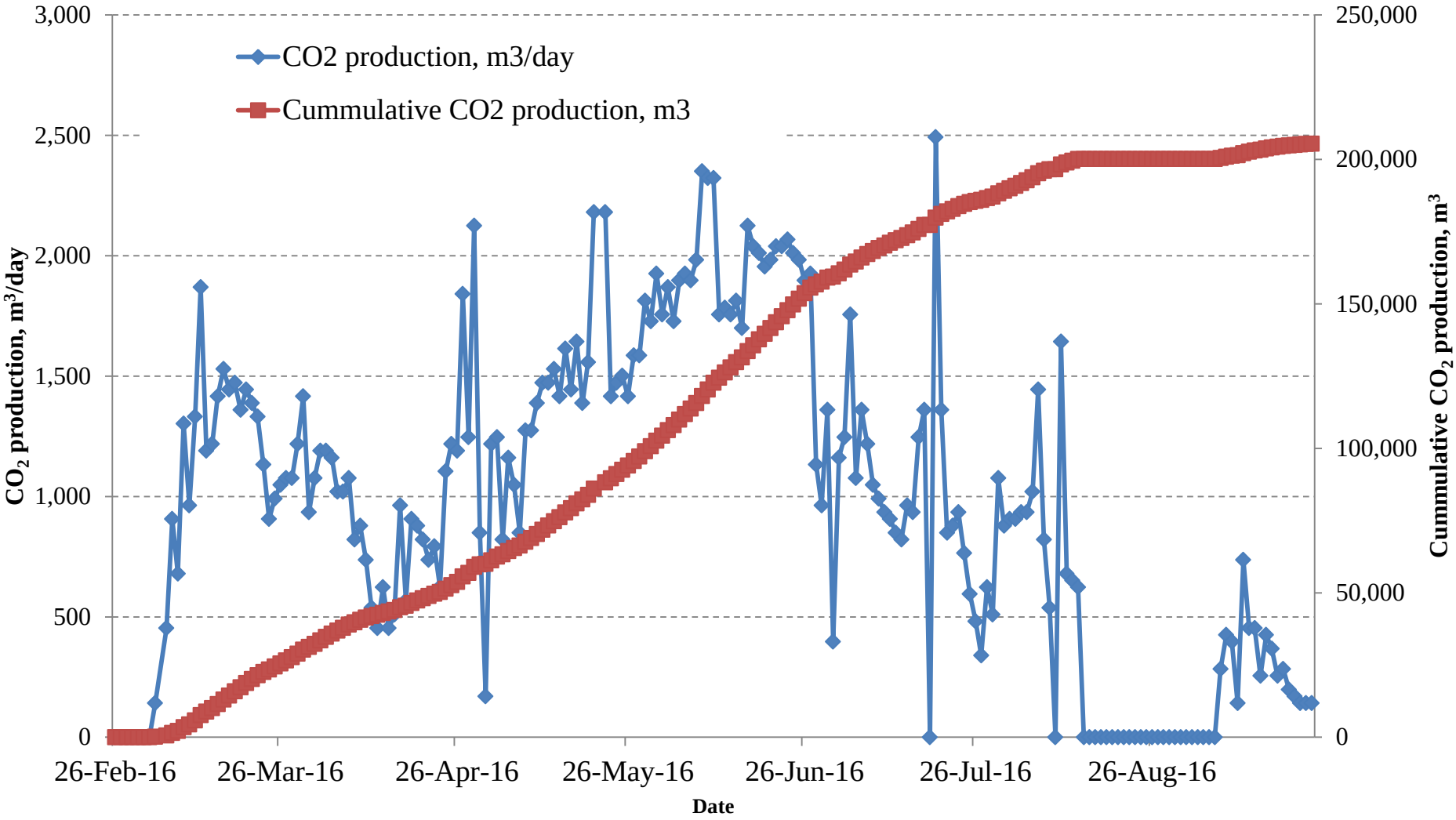


Housing setup for Sercel (Mark Products) L-22D-3D sensors, ~5 ft below surface to minimize surface noise; installed below frost line in bedrock

Incremental oil production (subtracted 9 bbls/day) recorded at a pilot area filed battery



CO_2 production from all installed separators at producing wells and pilot area field battery. At the end of September, 2016, 3 months since CO_2 injection cessation, only ~12% of injected CO_2 was produced



Summary

- Safe and efficient injection
  - No substantial deviations due to unforeseen circumstances (carbonate reservoir fracturing, temperature, pressure, etc.)
- Successful oil recovery
- Low CO_2 production/recovery
  - 13% of total injected CO_2 was lost to atmosphere since start of injection
- Manageable and conformable CO_2 plume

Acknowledgements & Disclaimer

Acknowledgements

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