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Mountaineer Project – Lessons Learned and Implications for Regional and Local Storage Potential and Path Forward in the Appalachian Basin

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NETTL AEP bp MAKING OHIO COAL THE CLEAN CHOICE

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Schlumberger

The Ohio River Valley CO_2 Project - A Unique Public Private Collaboration

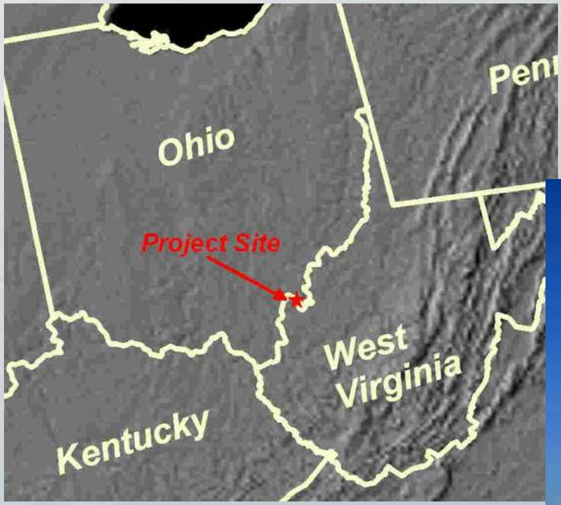
- **Battelle –** ***Jim Dooley, Judith Bradbury, Diana Bacon, Prasad Saripalli, Mark Kelley, Mark White, Frank Spane, Ken Humphreys, et al.***
- **DOE/NETL –** ***Charlie Byrer and others***
- **AEP –** ***Mike Mudd, Dale Heydlauff, Gary Spitznogle, Charlie Powell, Chris Long, John Massey-Norton, Jeri Matheney, Tim Mallan, et al.***
- **Ohio Coal Development Office –** ***Jackie Bird, Howard Johnson***
- **BP –** ***Charles Christopher, Gary Kizior, Steve Lamb***
- **Schlumberger –** ***T.S. Ramakrishnan, Nadja Mueller, and John Tombari et al.***
- **Ohio Geological Survey:** ***Larry Wickstrom***
- **Regional Geologists:** ***Tom Wynn, Bill Rike, John Forman, Amy Lang***
- **Stanford's GCEP Program –** ***Mark Zoback, Amie Lucier***
- ***CO_2 Capture and handling Companies***
- ***Regional Oil and Gas Companies***
- ***CRIEPI (Japan)***
- ***Midwestern Regional Carbon Sequestration Partnership (MRCSP) led by Battelle***

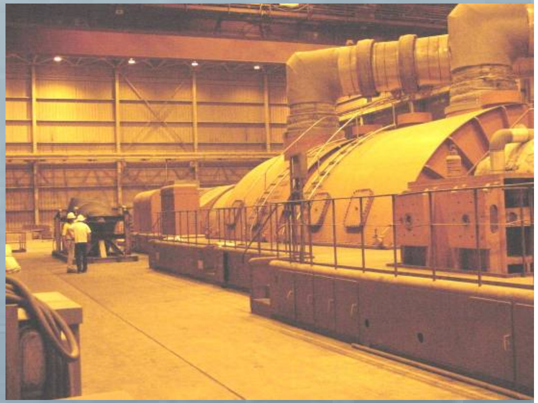
Ohio River Valley CO_2 Storage Project – Key Motivations

- A large number of CO_2 sources lie in the Ohio River Valley region and it is important to determine the CO_2 storage opportunities in this region
- Potential geologic storage reservoirs in deep basins are poorly characterized
- Systematic field tests and regional geologic data are essential for understanding storage potential and building stakeholder confidence
- The objective of this project is to characterize the CO_2 storage potential and demonstrate safe and cost effective storage at a coal-fired power plant
- We are now working on site design and permitting feasibility aspects:
  - Development of a capture and local transport system design
  - Design for injection and monitoring systems
  - NEPA and Underground Injection Permitting documents
  - Enhancing regional geologic framework development
  - Building on the foundation of stakeholder outreach
- Decision about moving to the injection and monitoring phase will be made by the sponsors during the next year

Site Location

- 1300 MW pulverized coal plant





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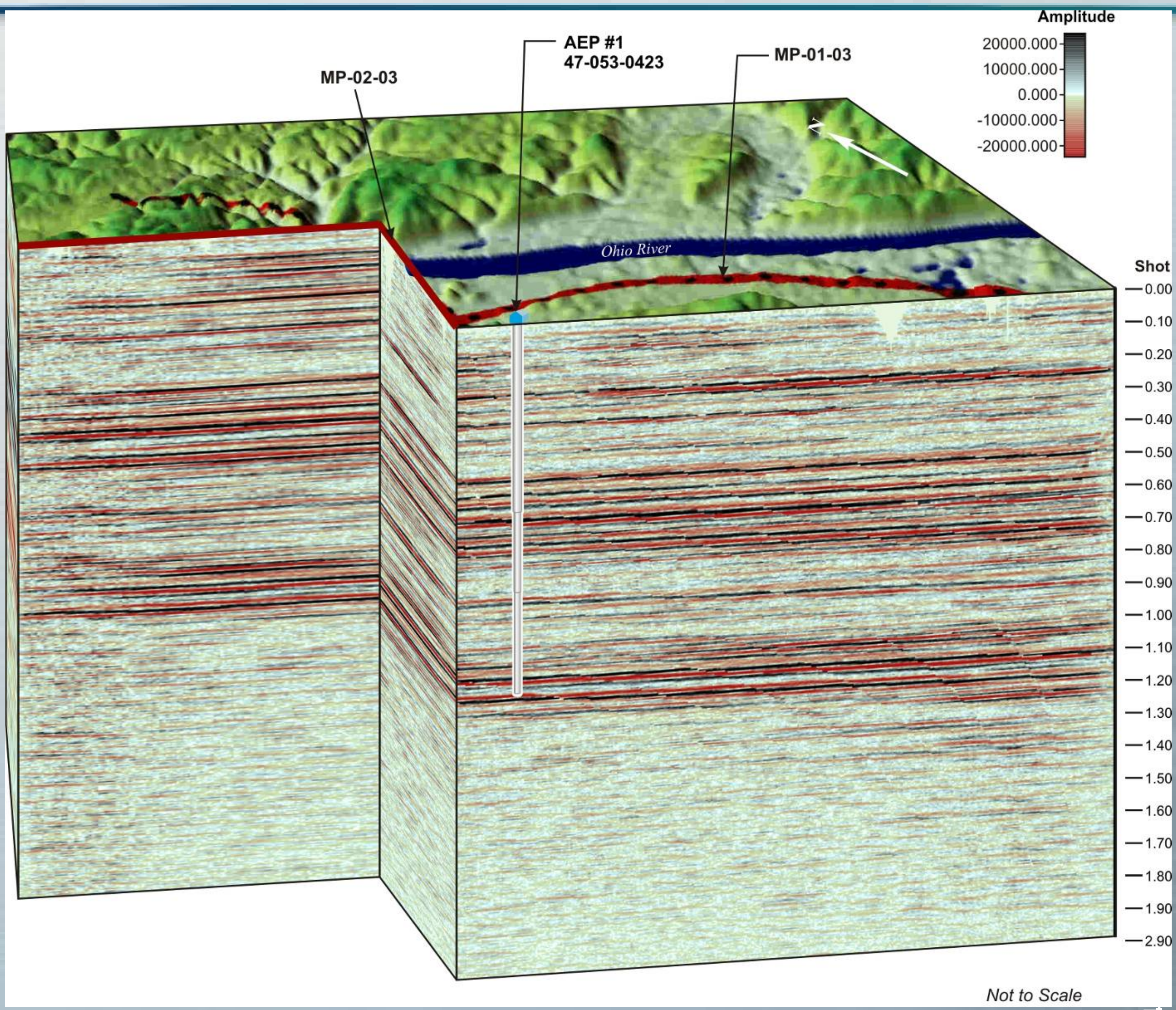
Seismic Survey Demonstrated Impact of Plant Noise and Lack of Faulting



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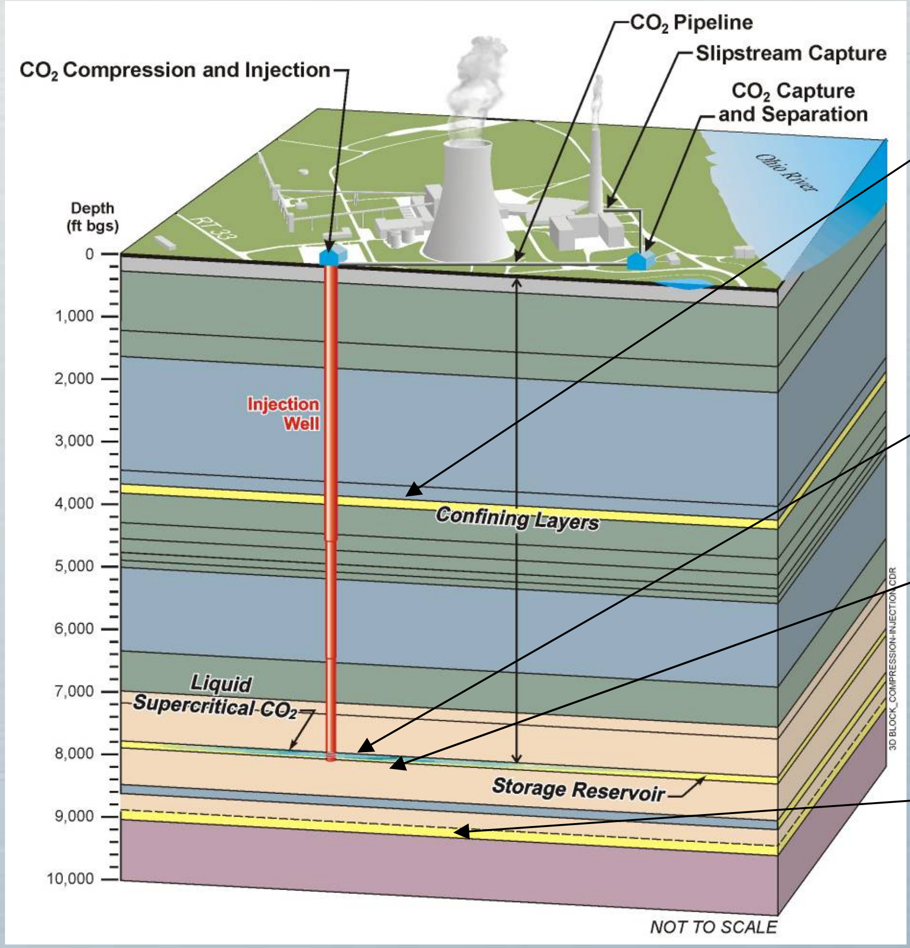
CO_2 Injectivity in the Mountaineer Area

- A number of geologic formations have been evaluated for CO_2 storage potential in the Ohio River Valley region, as shown for Mountaineer site below



CO_2 injection should also be possible in shallower sandstone and carbonate layers in the region

Rose Run Sandstone (~7800 feet) is a regional candidate zone in Appalachian Basin

A high permeability zone called the "B zone" within Copper Ridge Dolomite has been identified as a new injection zone in the region

Mount Simon Sandstone/Basal Sand - the most prominent reservoir in most of the Midwest

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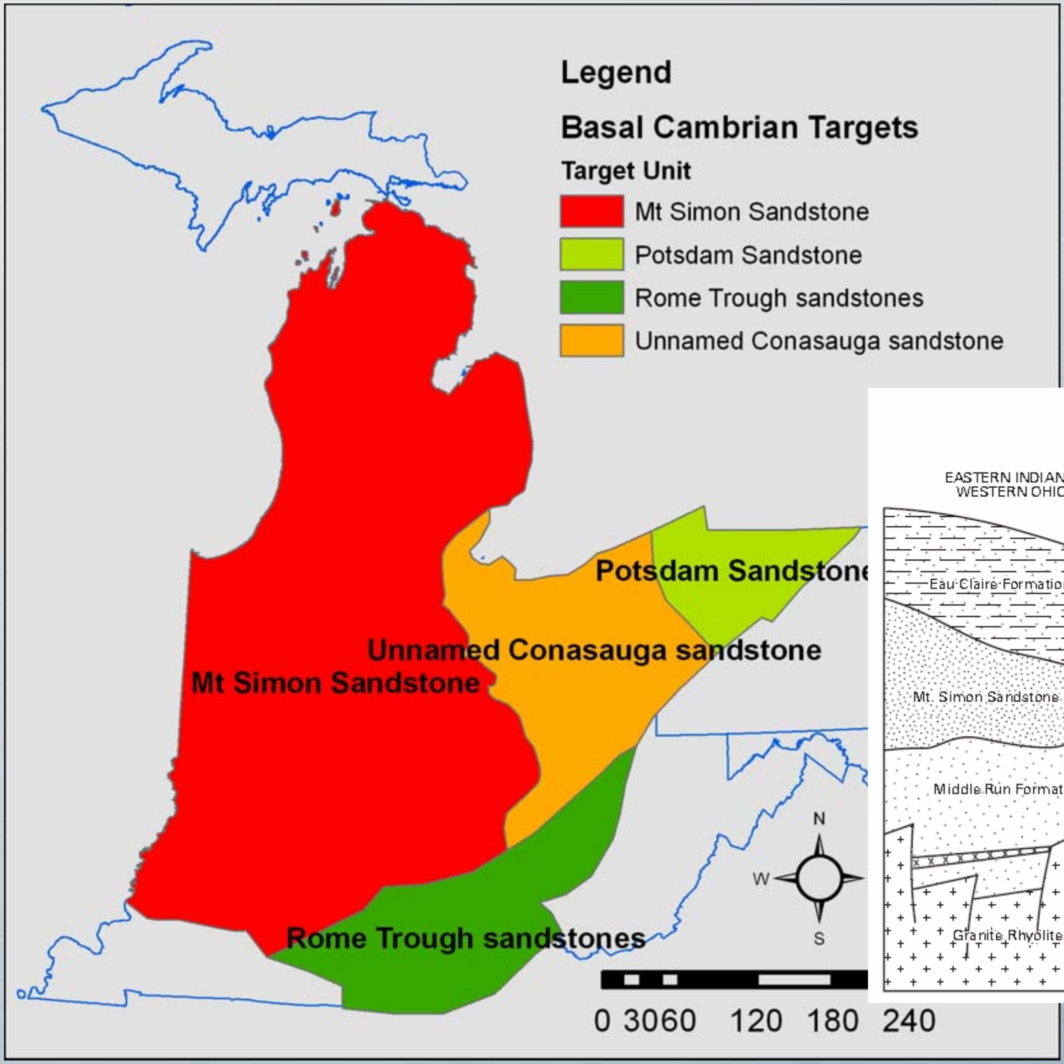
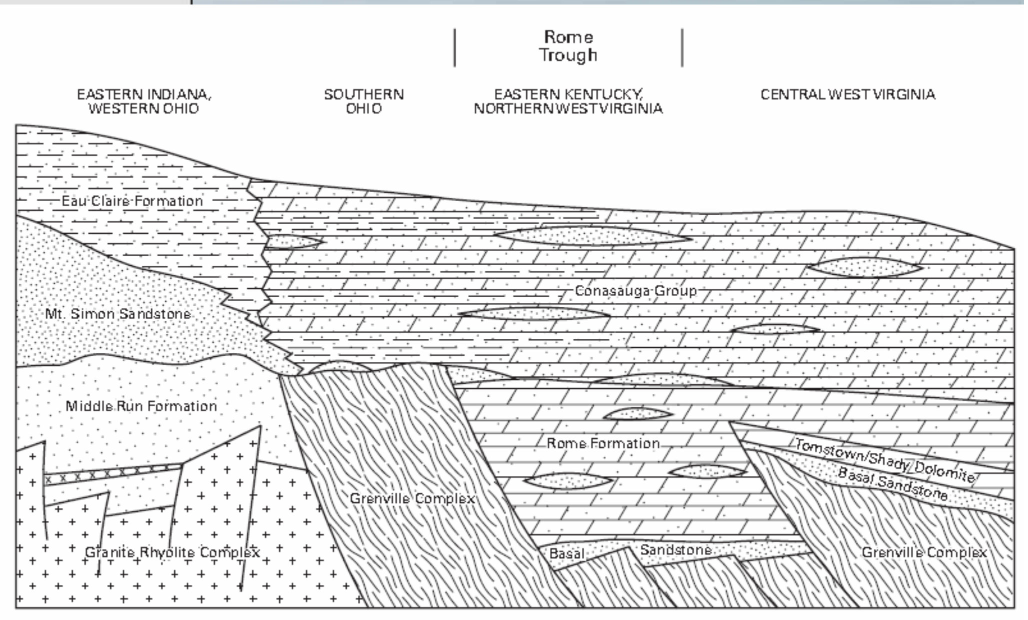
Nature of Mt. Simon/Basal Sandstone in Midwestern USA





Courtesy - MRCSP

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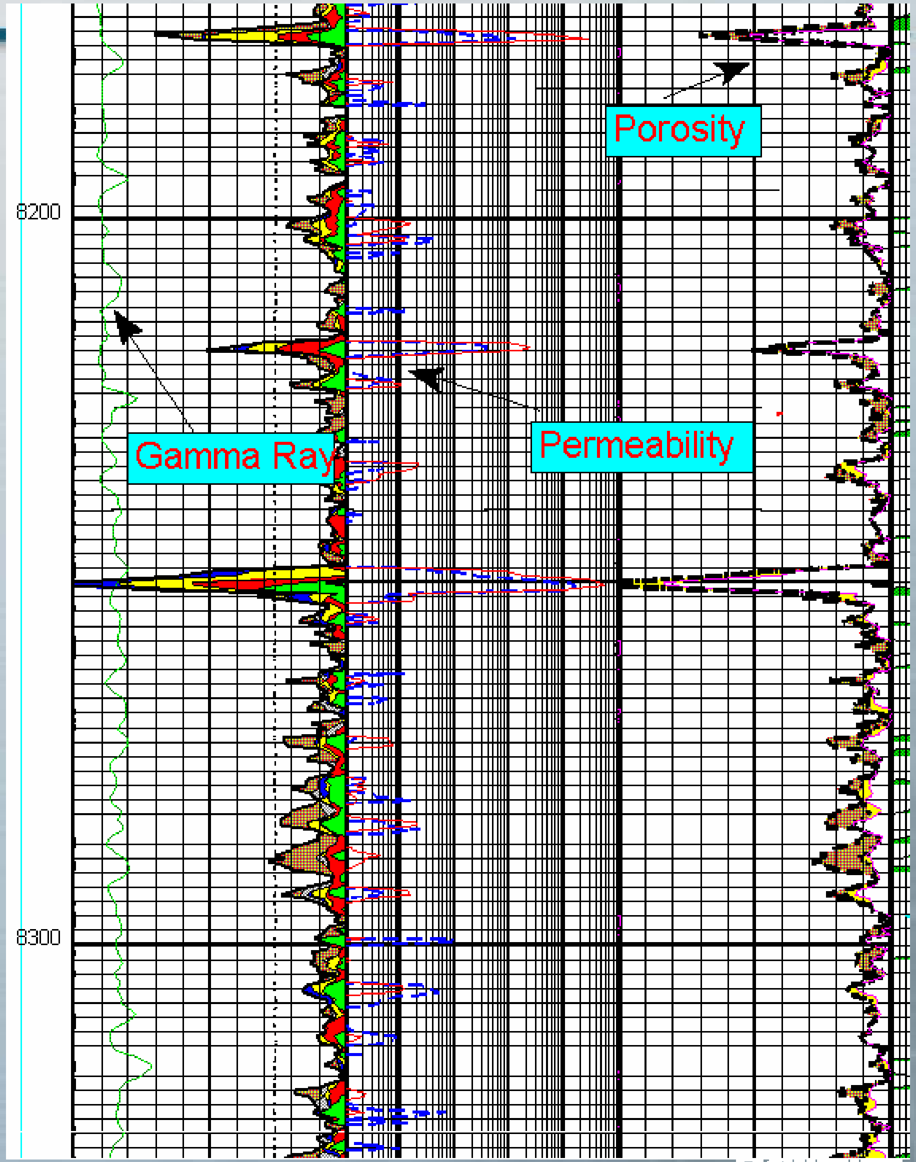
Lower Copper Ridge Dolomite –
A New Storage Candidate Identified

- Rocks under Rose Run dominated by dense dolomite (carbonate) layers
- However, storage potential was observed in part of Copper Ridge Dolomite (B-Zone at 8100-8300 ft depth) based on NMR testing
- This has also been validated through detailed stress tests in AEP well, which show that this zone may even have higher injectivity than the Rose Run
- Similar high permeability zone observed in several wells, including one near Gavin plant. This is promising for regional storage potential



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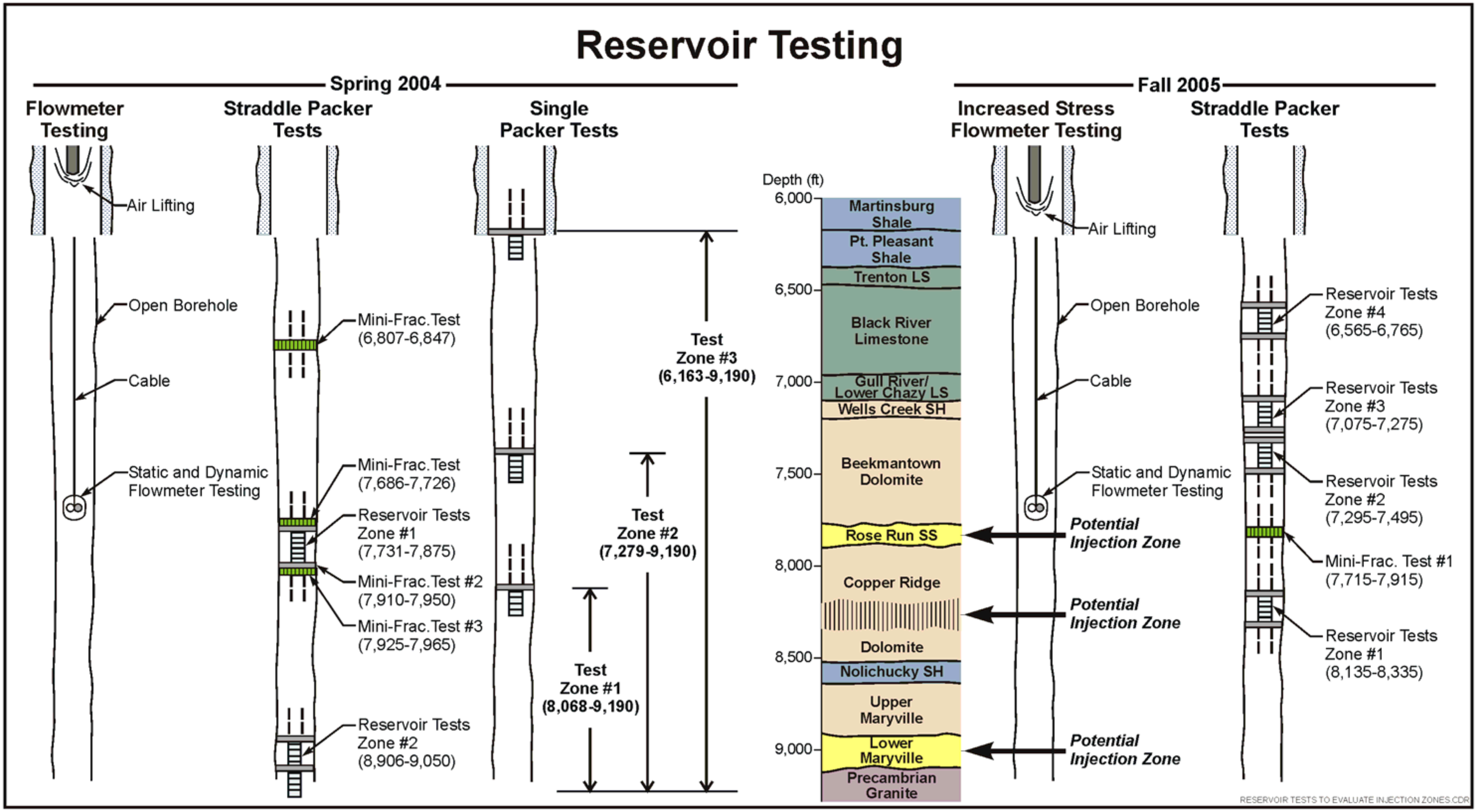
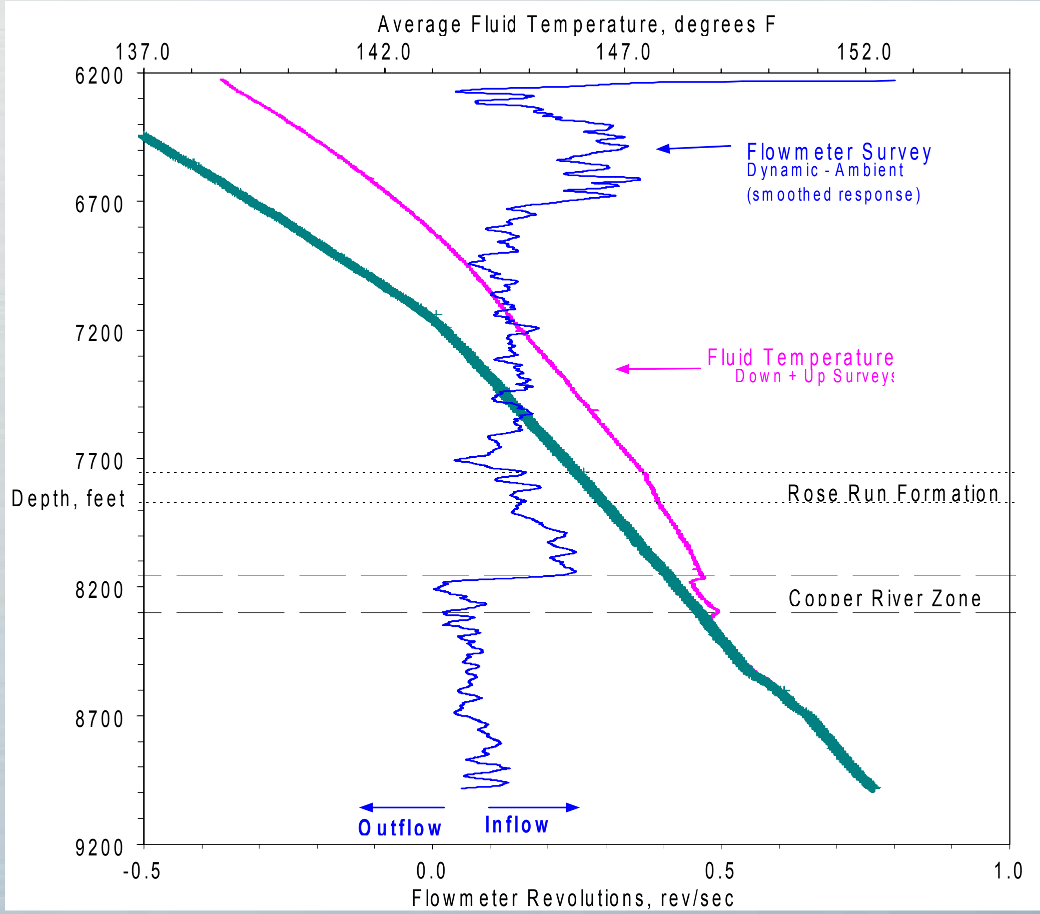
Detailed Reservoir Tests of entire open borehole to Validate Injectivity in Rose Run and Copper Ridge have been Conducted



Reservoir Tests on the B Zone



- *Flowmeter results helped to determine packer interval and setting*
- *Testing during fall 2005 confirms that transmissivity of Copper Ridge B zone is several times greater than the Rose Run*

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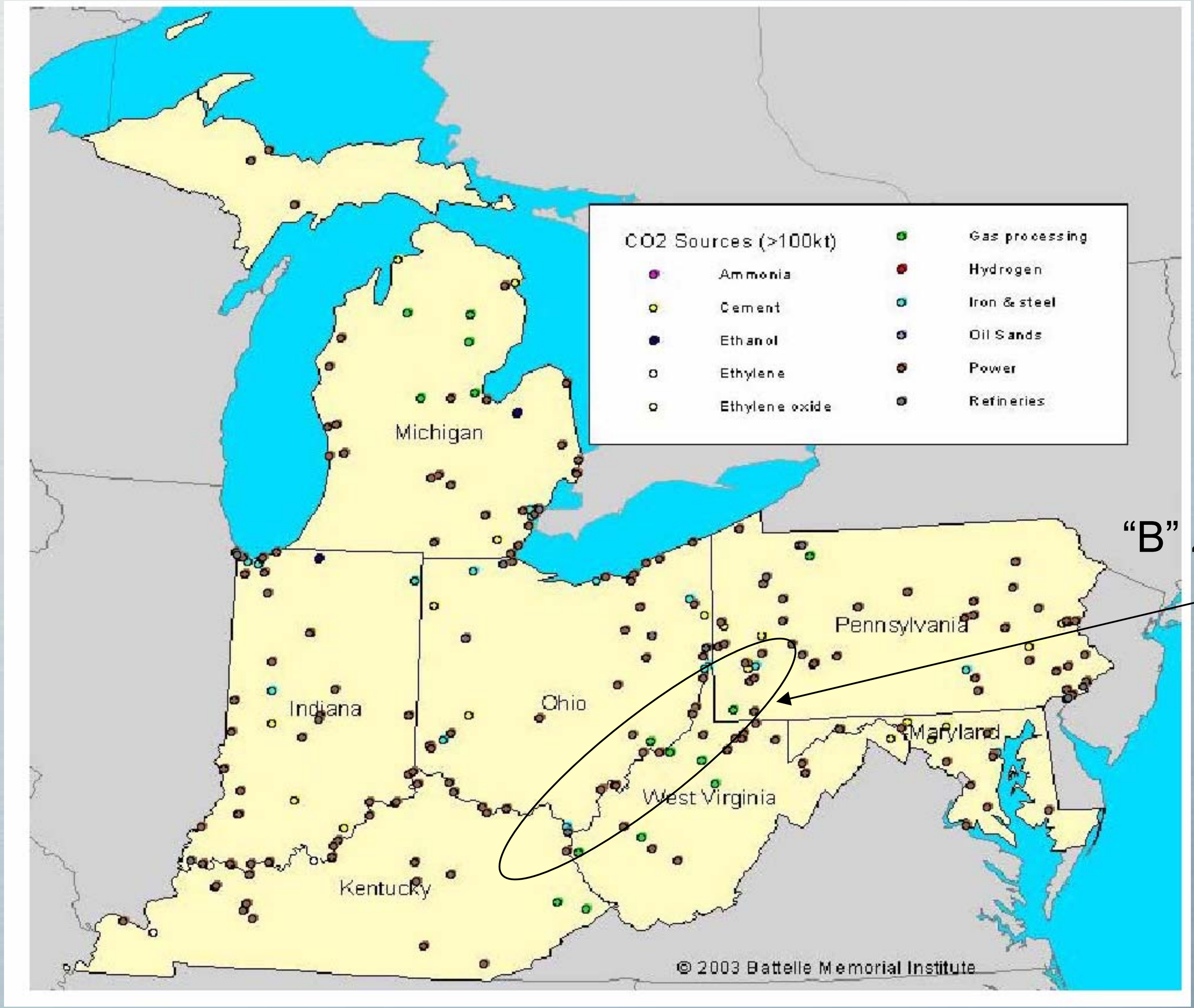
Is the “B” Zone Significant Regionally?



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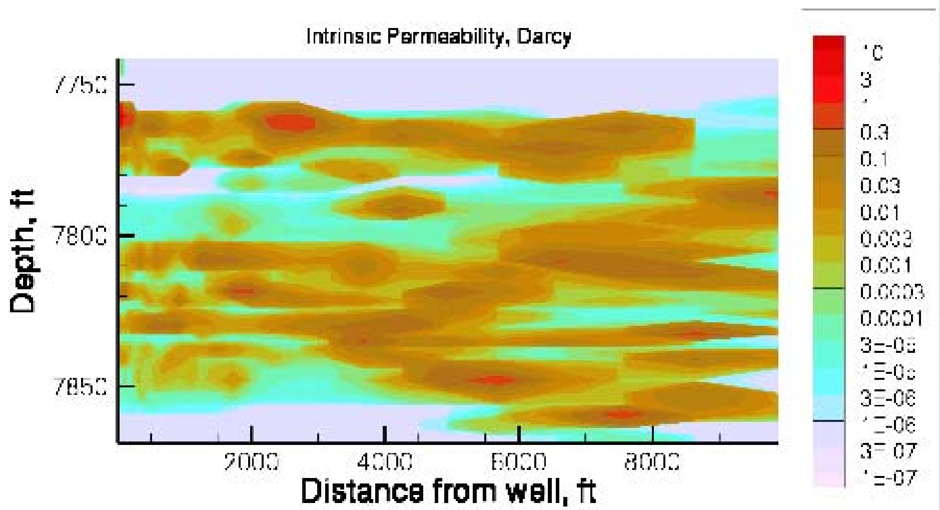
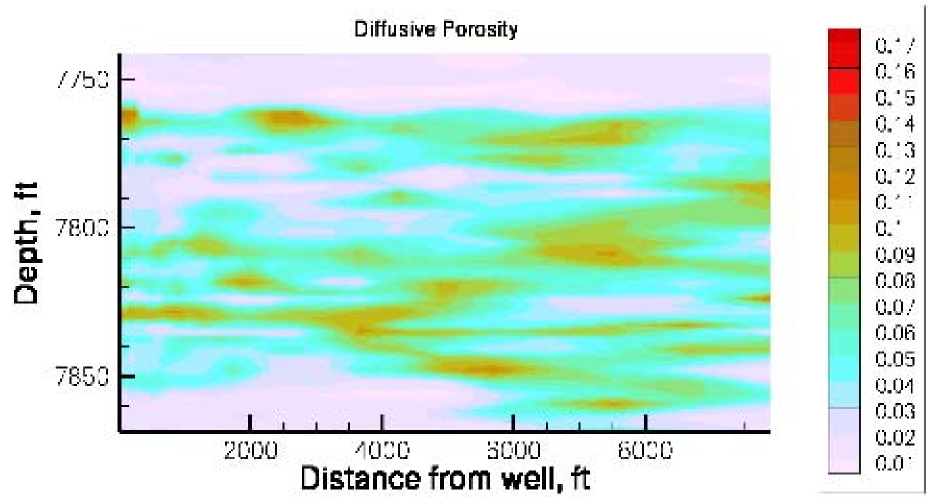
Rose Run Simulation – Integrating Core, Wireline, and Reservoir Test Data





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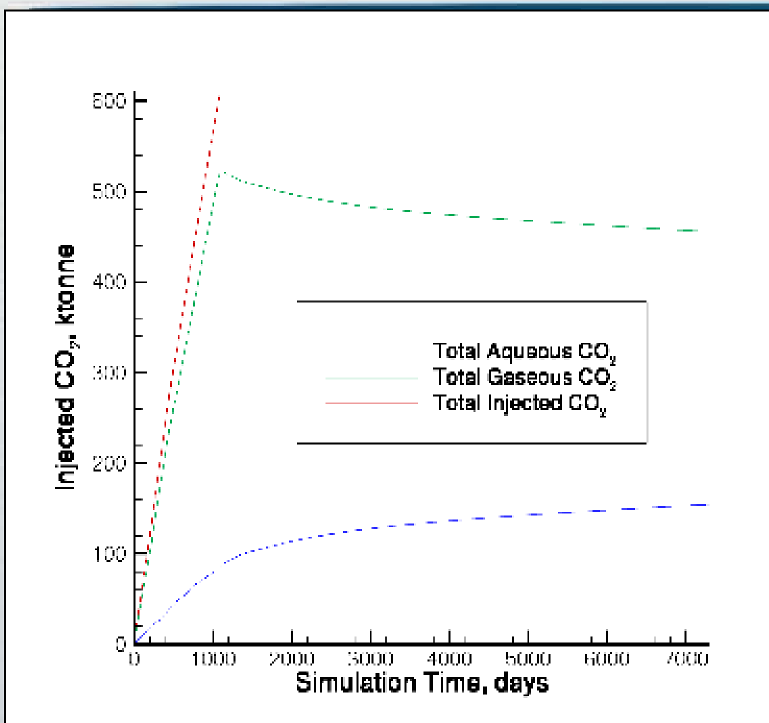
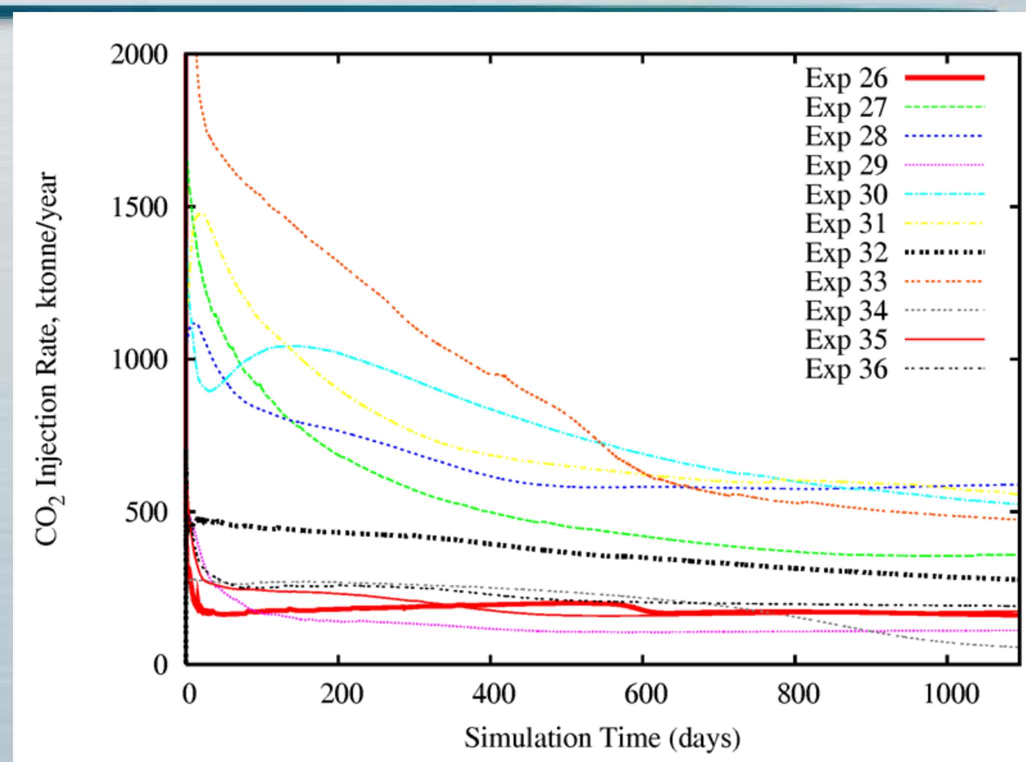
Rose Run Simulation – Injection Rate Change and Dissolution for Vertical Well





- Comparison of 11 geostatistical realizations for Rose Run shows a mean injection rate of ~300,000 per year for a single vertical well
- Calibrated with reservoir testing data
- Despite high salinity, there appears to be substantial CO_2 dissolution

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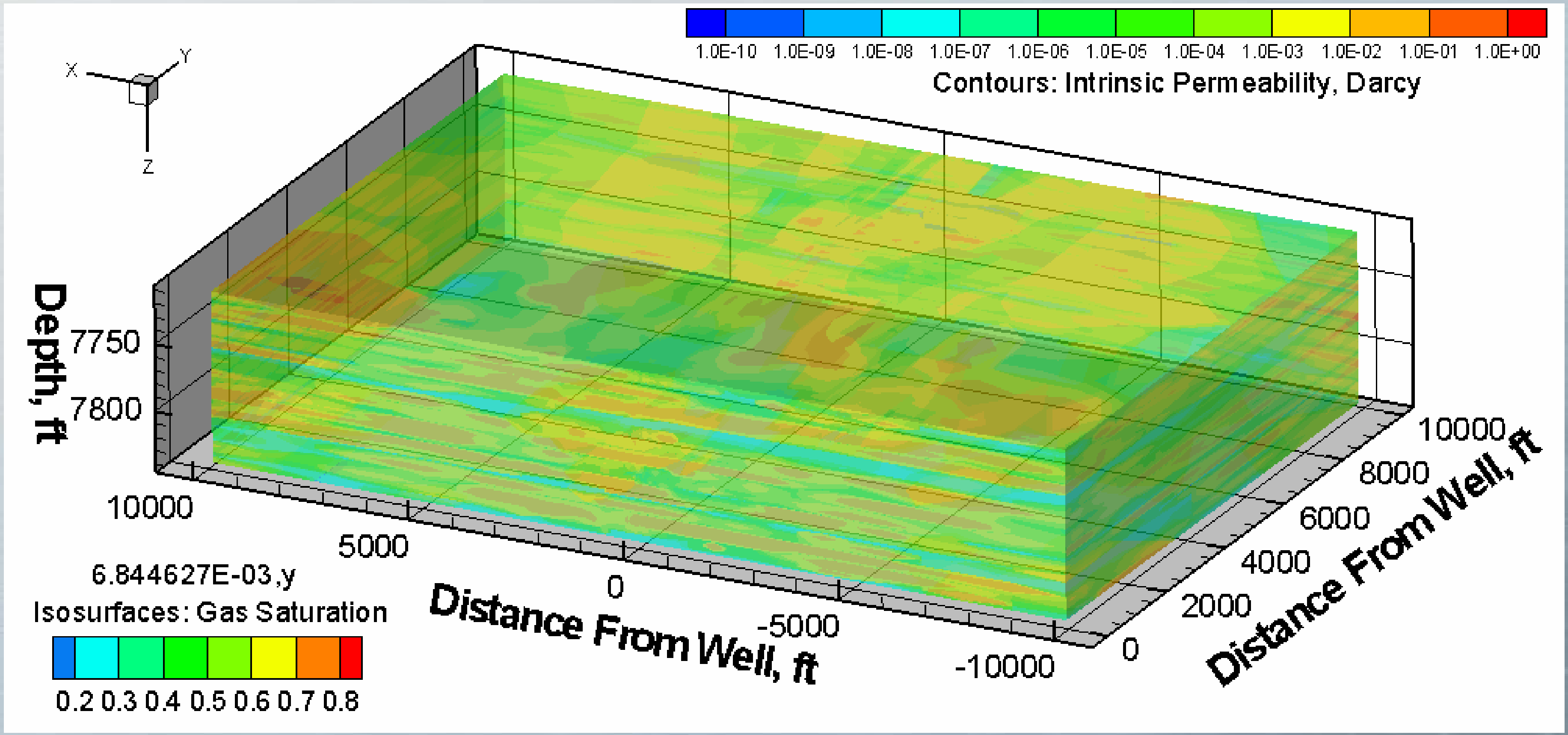
3-D Simulation of Injection in Rose Run in Vertical Well

- Initial modeling suggests several hundred kilo-tons/yr CO_2 injection possible in single well (plant emits 7-8 million tones per year).



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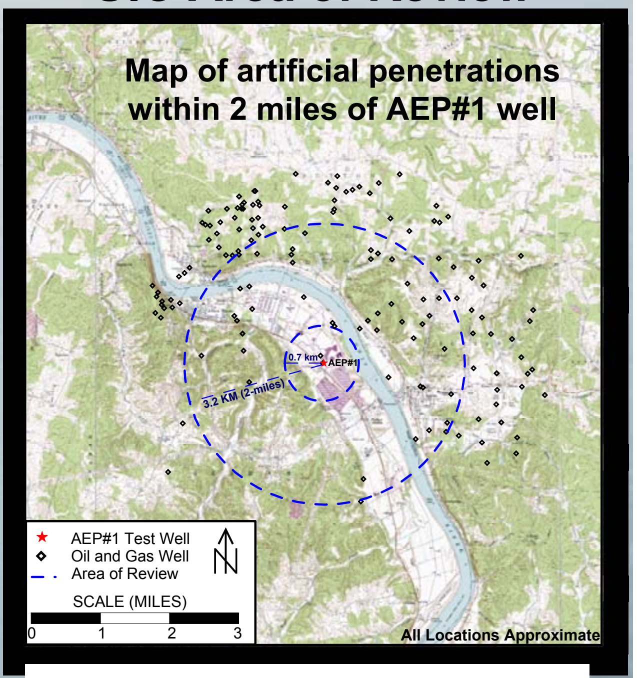
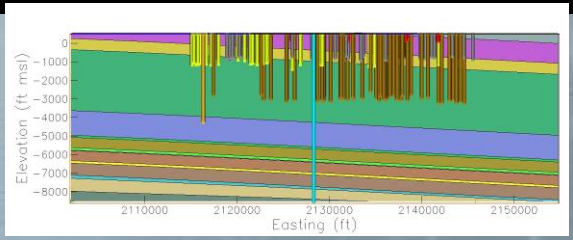
NEPA Environmental Assessment and Injection Permit are being Prepared

- USEPA Class V UIC Permit is under development, to be submitted to West Virginia Department of Environmental Protection, when decided by AEP and DOE.
- Discussions with local, regional, and national regulators have been positive, and no roadblocks are foreseen at this time.
- Site characterization testing was designed to support permitting process and should minimize additional permitting efforts.
- Permit will be finalized when final well design and injectate composition are determined.
- Remaining risk assessment and reservoir simulation tasks are being conducted to support permit.
- A draft EA has been prepared and is under review currently at Battelle

UIC Area of Review





Geologic cross section showing well depths near AEP#1 (in blue).

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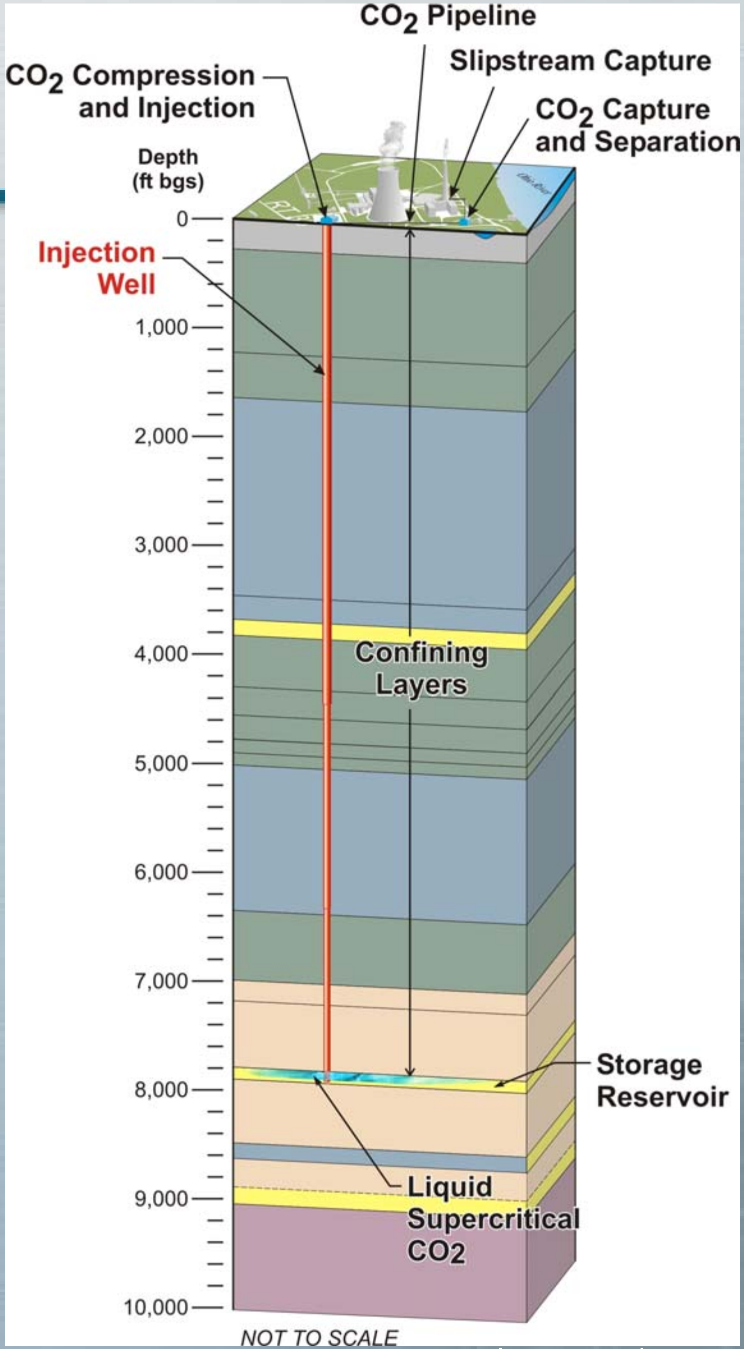
Mountaineer— Potential Future work

- ***Subject to funding and permitting***
- Select injection well design
- Install injection well
- Install monitoring well
- Install surface capture/ injection system
- Perform injection test
- Pre- and post-injection monitoring

Injection System

- Conceptual design for 30-100 tonnes/day injection in Rose Run and/or Copper Ridge
- 3-5 years of continuous injection
- Entire system contained on the plant



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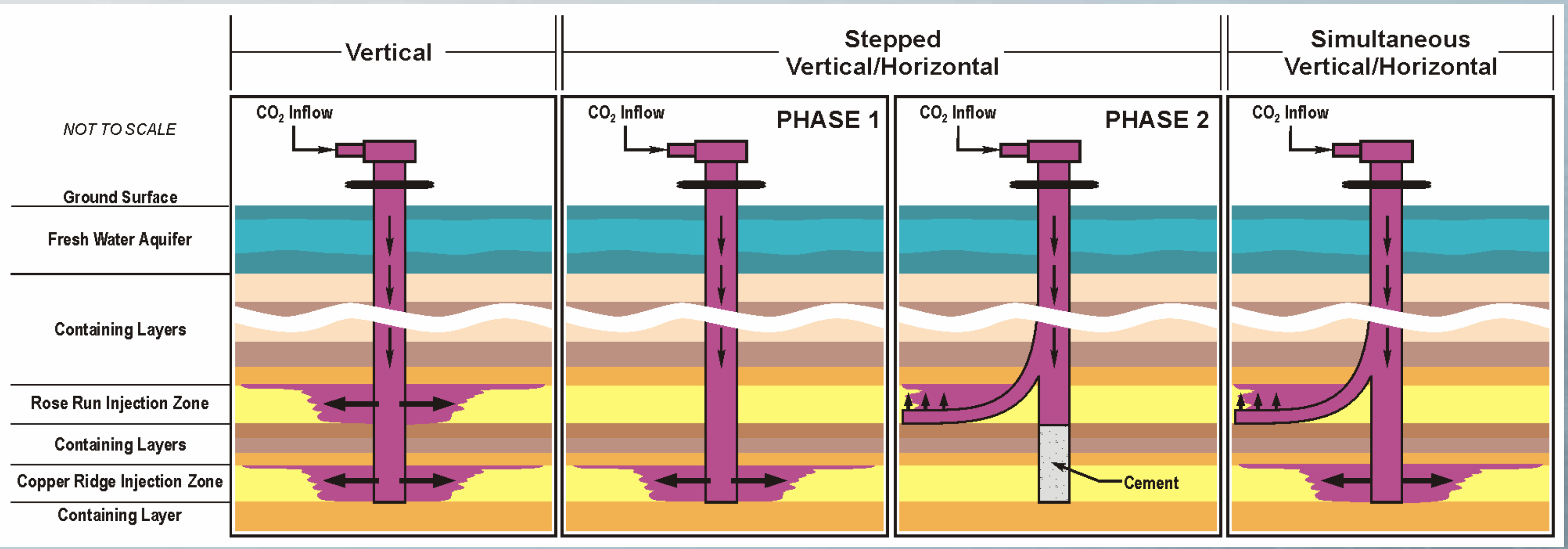
Select Injection Well Design, Install

- Options to utilize both zones
- Installation and operation phase subject to DOE and AEP approval



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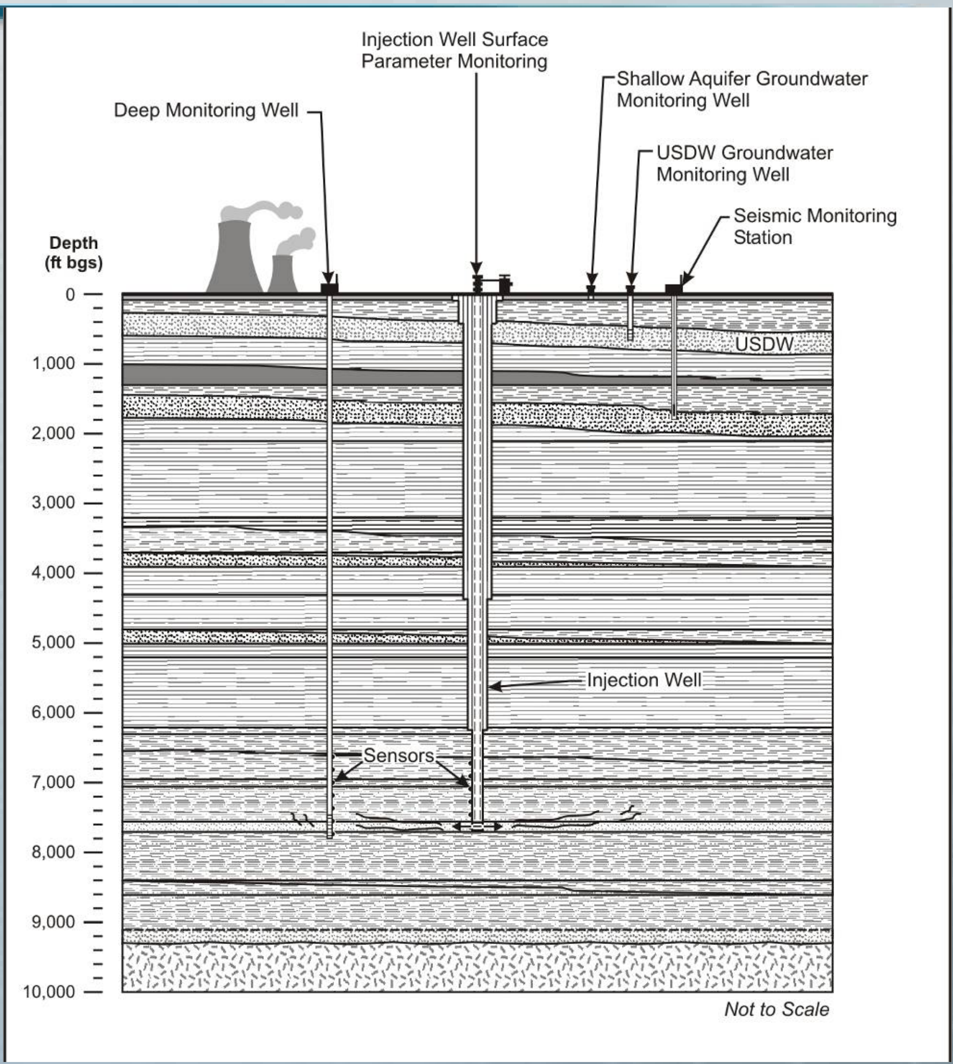
"Layered Monitoring Objectives"

- Injection/Capture System
- Operational Safety
- Leakage
- Injected CO_2



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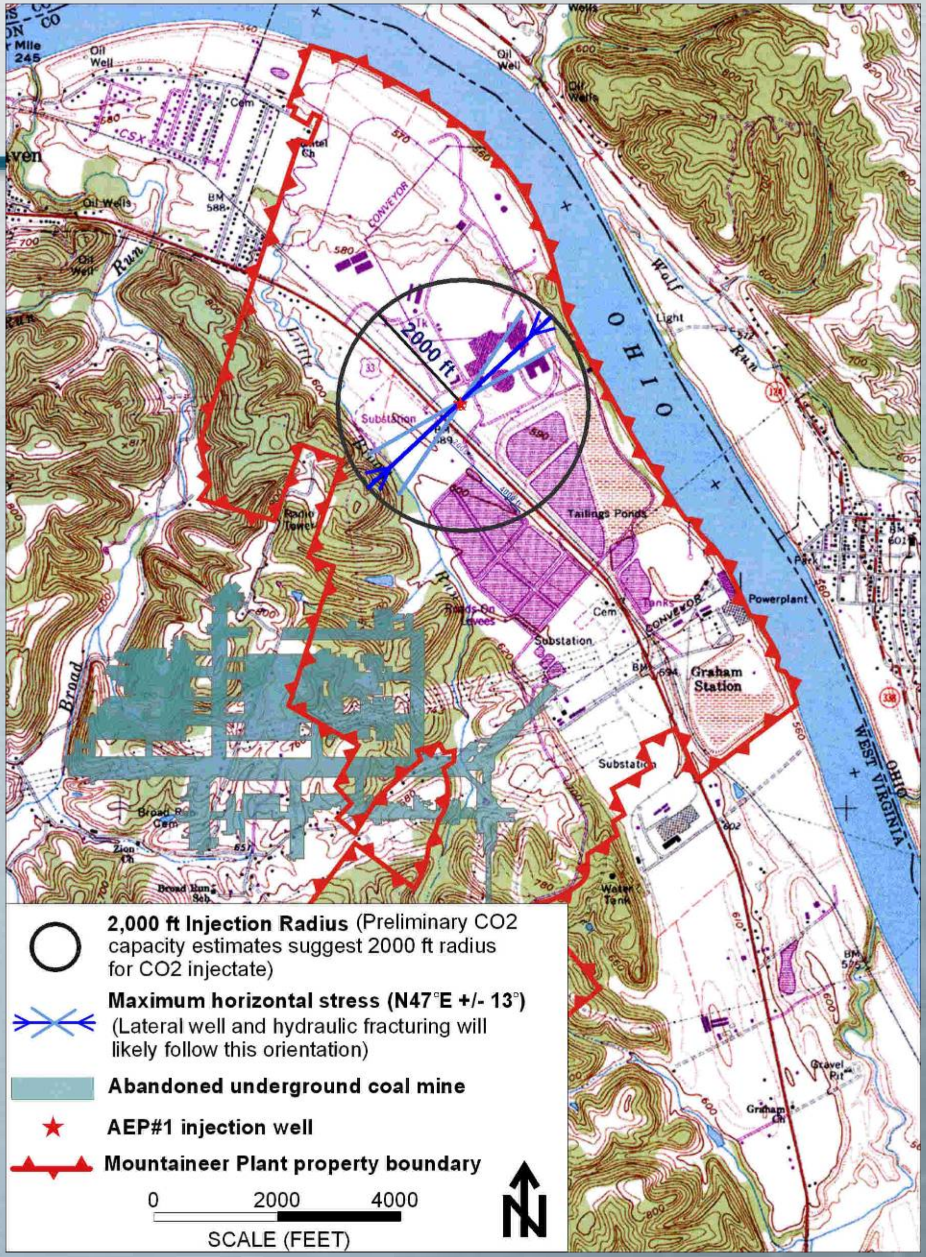
Ideal Monitoring Well Location

- **Predominant stress orientation N47E +/-13 and lateral well, if drilled is likely to follow this trend**
- **Options limited to the northeast due to plant building, so a well southwest of the injection well is ideal**
- **A monitoring well is essential for a detailed monitoring program**



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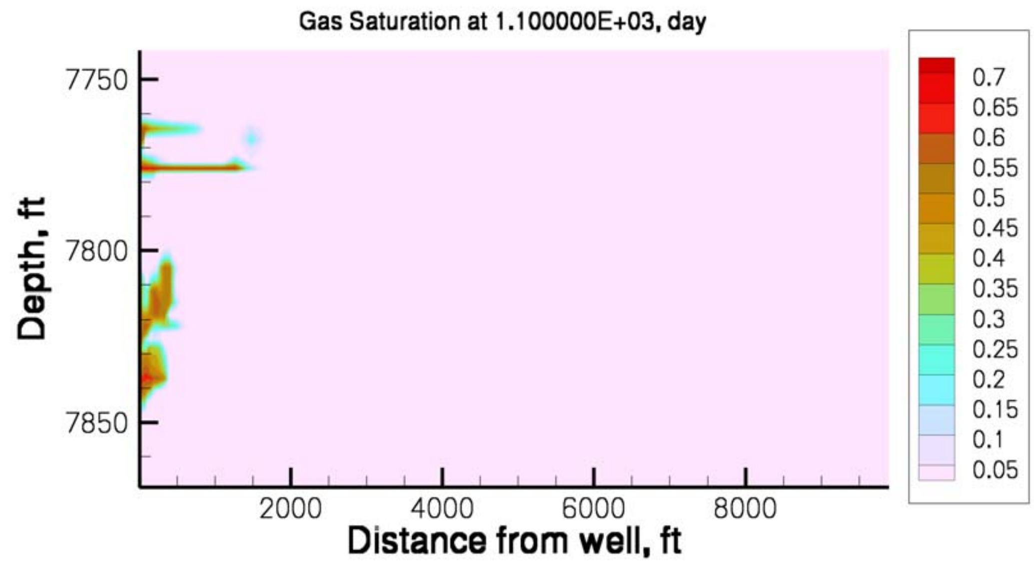
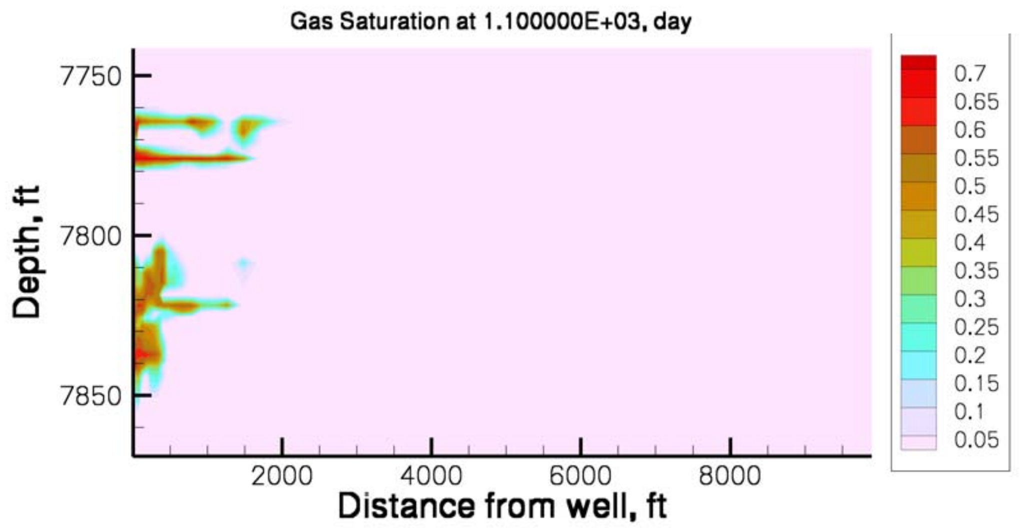
Rose Run Injection at 30 and 100 t/day

- Pilot scale simulations show a spreading radius of 1000-2000 ft, within the plant property



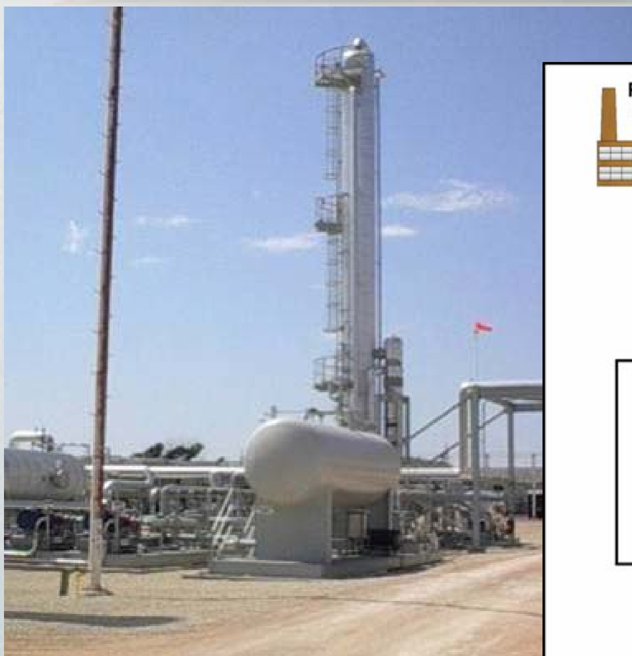


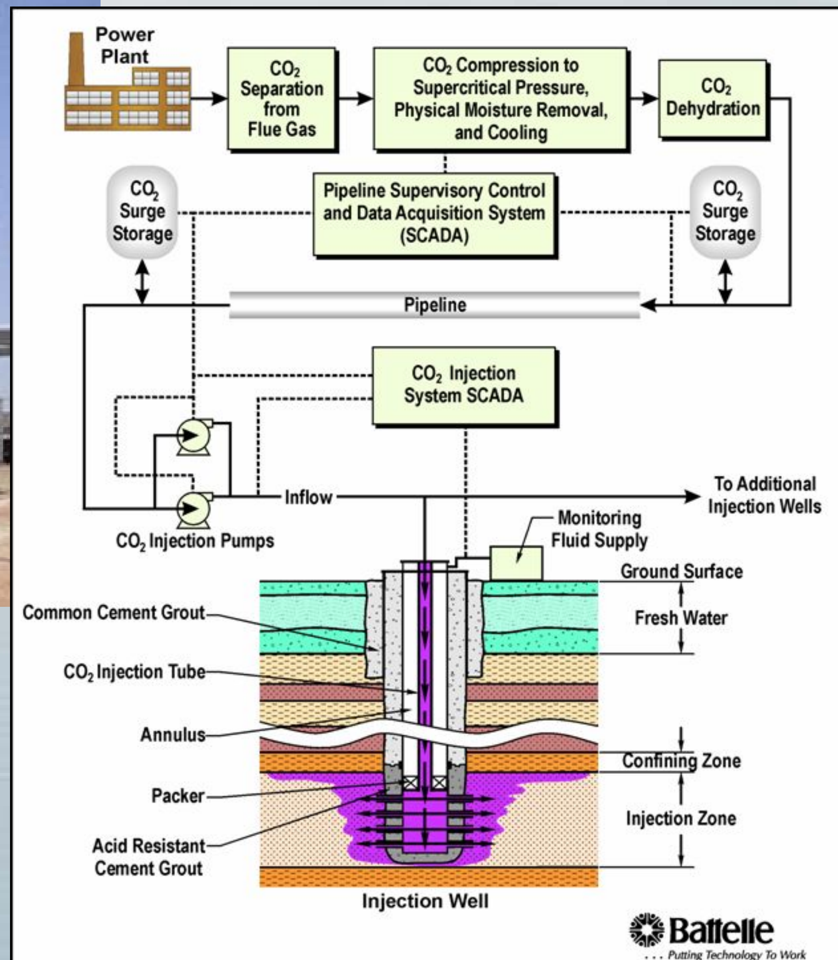
Preliminary Monitoring Schedule Example

Time (Months)	-12	-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Phase	Preinjection Baseline Monitoring						Active Injection																Post-Injection		
Capture System																									
Compression																									
Transport																									
Injection System																									
SCADA																									
Health and Safety																									
Mechanical Integrity Test						X							X						X						X
Well Workover													X						X						X
Passive Seismic																									
Groundwater Monitoring	X			X			X			X			X			X			X			X			X
Soil-gas	X			X			X			X			X			X			X			X			X
Atmospheric Flux				X			X						X						X						X
Wireline						X				X			X			X			X			X			X
VSP/X-well Sesimic						X							X						X						X
Tracer Testing																									
Reservoir Sampling						X							X						X						X
Well Indicator sensors																									

X = sampling event

CO_2 Source and Surface Completion





- **Create capture system for slipstream from existing plant**

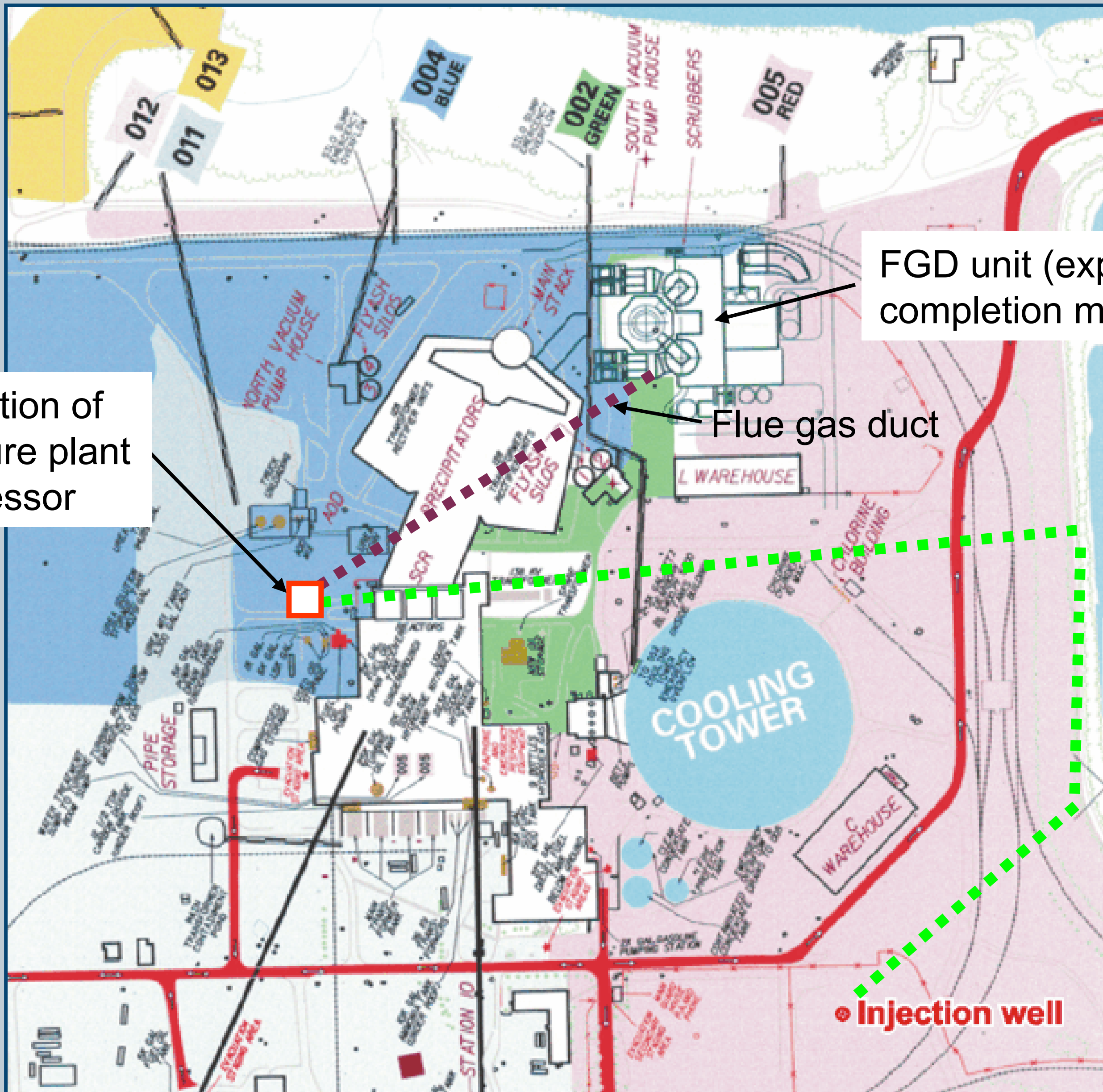
Status Update on CO_2 Capture & Transport Demonstration Plan

- The next phase of the project envisions integration of CO_2 capture, compression, pipeline transport, and deep well injection at the power plant
- Despite limitations, amine-based solvent systems are the most cost effective and reliable technologies at this time for post-combustion capture of CO_2
- With help from AEP plant engineers, Battelle developed an approximate configuration for ductwork to obtain a flue gas slipstream from the FGD unit, placement of the pilot capture unit, and routing a high-pressure CO_2 line to the injection well.

Status Update on CO_2 Capture & Transport Demonstration Plan

- Worked with Trimeric to develop a screening level (±40%) cost estimate for a generic pilot-scale CO_2 capture and compression plant; various MPS configurations were considered.
- Worked with MHI to evaluate material and energy balance information for a capture system based on KS-1 and testing of Appalachian Basin coal samples.
- Worked with Fluor to develop basic design for Economine FG+sm
- Next step is to develop more detailed (±15%) design and estimates and select the approach that provides the needed ***reliability and innovation***

Plan View of AEP's Mountaineer Power Plant



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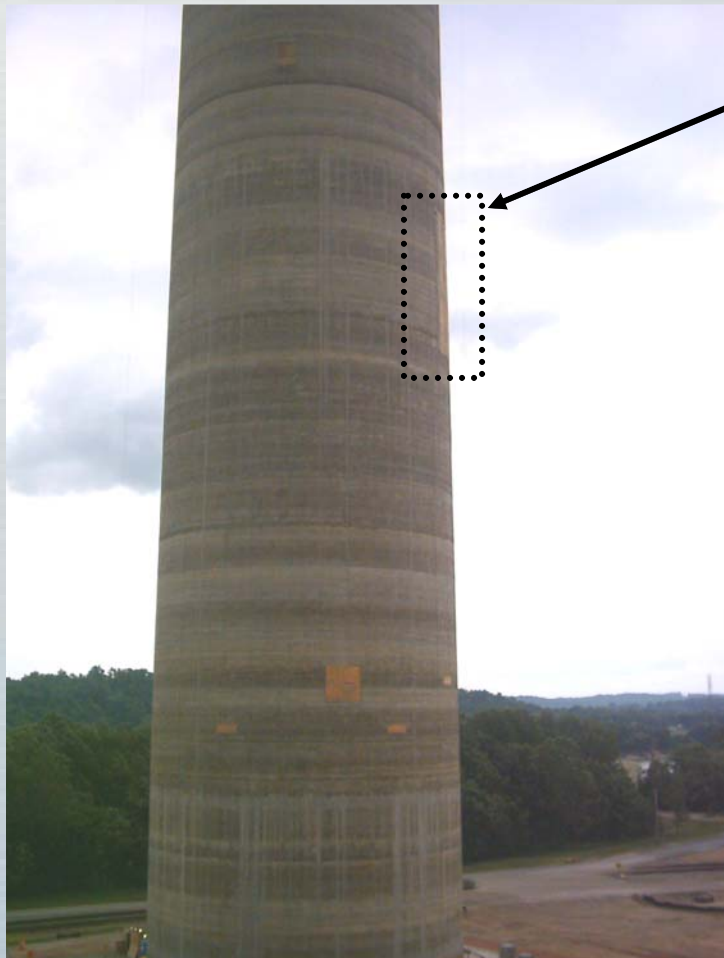
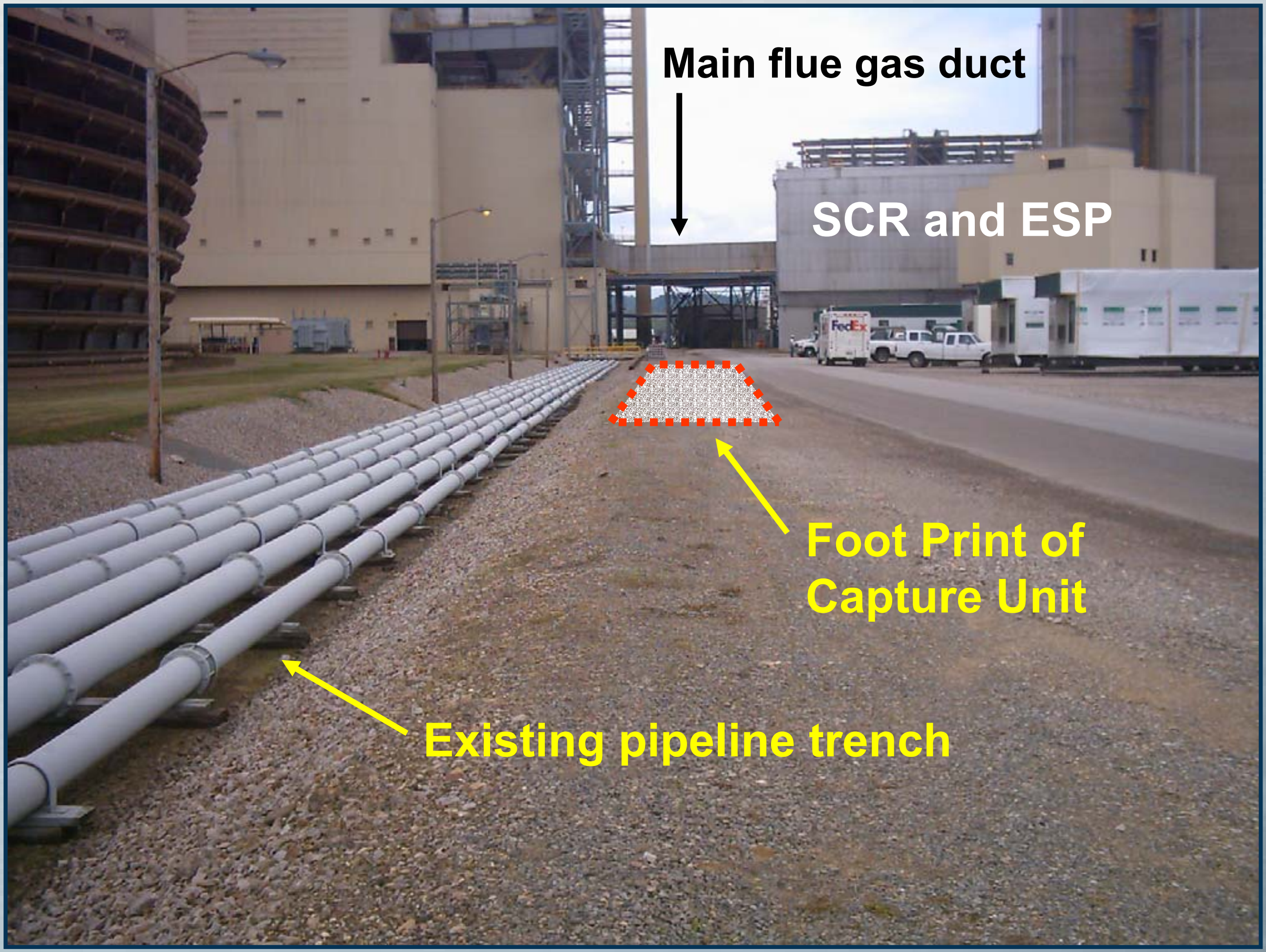
Slipstream Access from New FGD Unit



Location of duct for flue gas slip stream

Similar overhead raceway to support slipstream duct

Possible Location for a Small CO_2 Capture Unit at Mountaineer Plant



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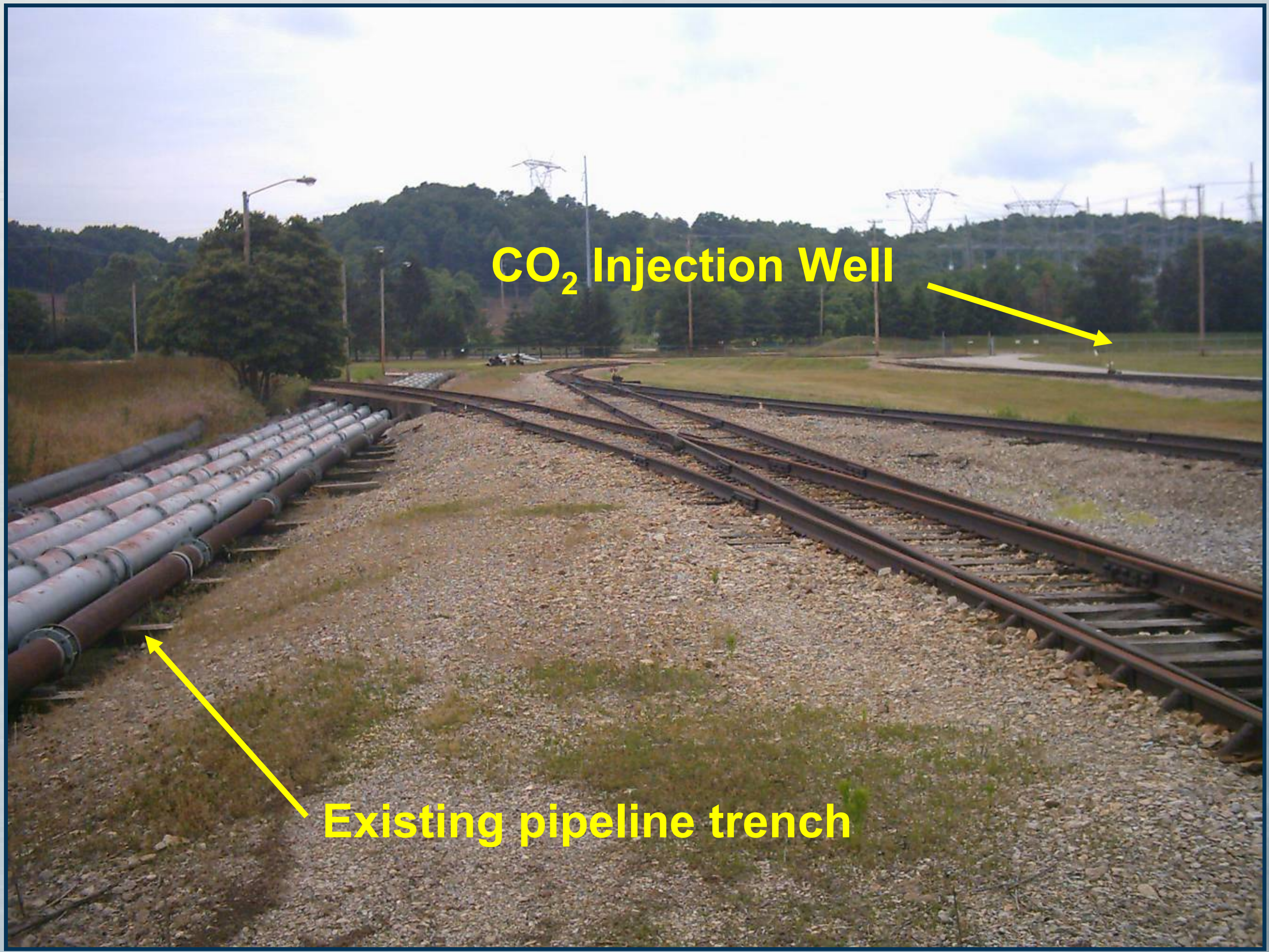
Location of Injection Well



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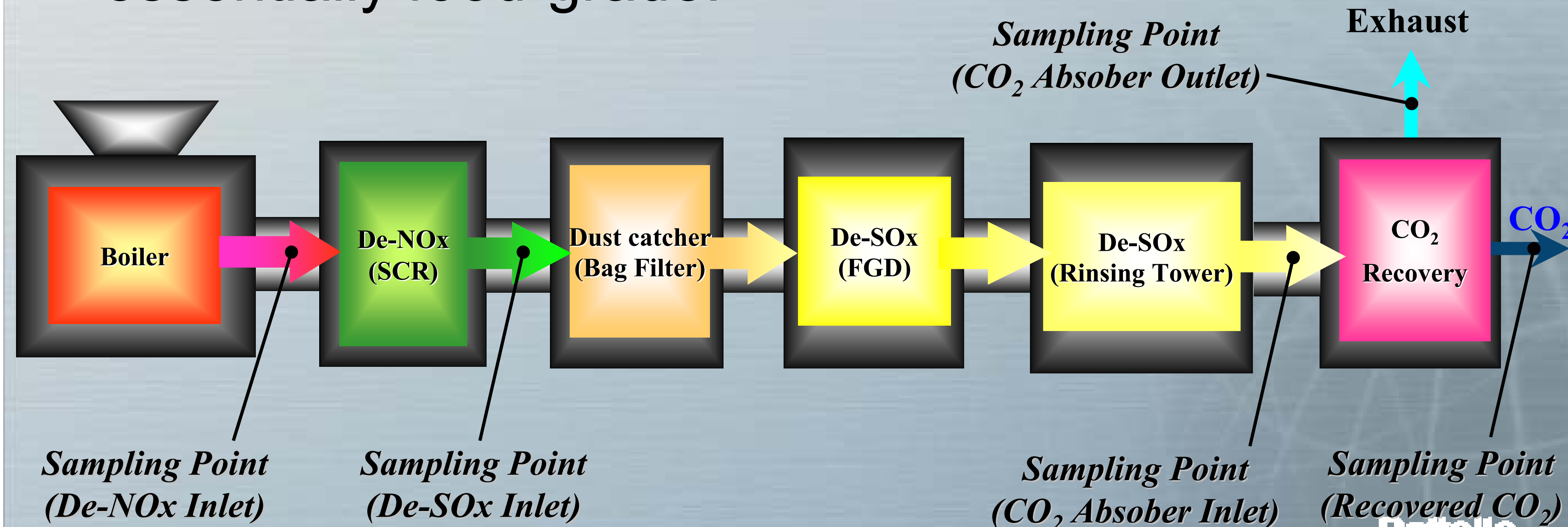
CO_2 Capture - Process Flow of CO_2 Recovery Pilot Plant at MHI Facility

- 4 tons of high-sulfur coal have been tested for site-specific capture optimization during 2005
- Preliminary basic design has been prepared
- The test result show that the captured CO2 is essentially food-grade.



Source: MHI

Econamine FG Plus^{SM}
(Source: Satish Reddy, Fluor)

- Recent Enhancements:
  - Improved solvent formulation
  - Flashed vapor thermo-compressor
  - Absorber intercooling
  - Low temperature reclaiming
  - Improved blower design
  - Cooling water minimization
- Results:
  - Steam consumption reduced by ~20 to 30%
  - Power consumption reduced by ~10%
  - Cooling water requirement reduced by ~20%
  - MEA consumption reduced by 70 – 90% depending on the flue gas

Summary - Progress in a Phased Manner

- Detailed site-characterization has been completed
- Substantial improvement in understanding features of relevant geologic formations in Midwestern USA with applicability to other mature basins
- Available evidence indicates sufficient injection potential for pilot and larger-scale storage in the region
- New storage reservoirs have been identified and their injection potential quantified
- Significant technical progress has been made to design an integrated demonstration of capture, local transport, storage, and monitoring test at a major power plant.
- Capture assessment and injection system design are nearing completion
- Will initiate outreach and regulatory planning for next phase ***pending sponsor approval***

Thank you!