CO_2 Sequestration in Unmineable Coal with Enhanced Coal Bed Methane Recovery

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CONSOL Energy Inc.

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CO_2 Storage

August 22, 2012

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Presentation Outline

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Benefit to the program

Project overview

Technical status

Accomplishments

Summary

Appendix

Benefit to the Program

This project will demonstrate the effectiveness and the economics of carbon sequestration in an unmineable coal seam with enhanced coal bed methane (ECBM) production.

Project Overview:
Goals and Objectives

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Demonstrate horizontal drilling in underground coal seams, ✓

Define effective CO_2 injection methods and procedures, ✓

Evaluate the CO_2 adsorption capacity of in-situ coal, ✓

Devise economical drilling strategies to maximize both CO_2 sequestration potential and CBM recovery, ✓

Measure the impact of CO_2 injection on CBM recovery,

Monitor the CO_2 concentrations in the water and gas phases to determine the stability of sequestered CO_2 over an extended period of time, and

Assess the overall economics of CO_2 sequestration ($/ton), including the co-benefit of methane production in coal seams.

Project Overview: Tasks

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20,000 short ton injection goal

- Examine effective methodology for injecting CO_2 gas into an unmineable coal seam
- Evaluate the CO_2 adsorption capacity of in-situ coal
- Determine the impact of CO_2 injection on ECBM

Environmental Monitoring

- Deep well gas & produced water
- USDW zone monitoring well gas & water
- Residential drinking well water
- Stream water
- Soil gas, surface gas, & tracer gas monitoring

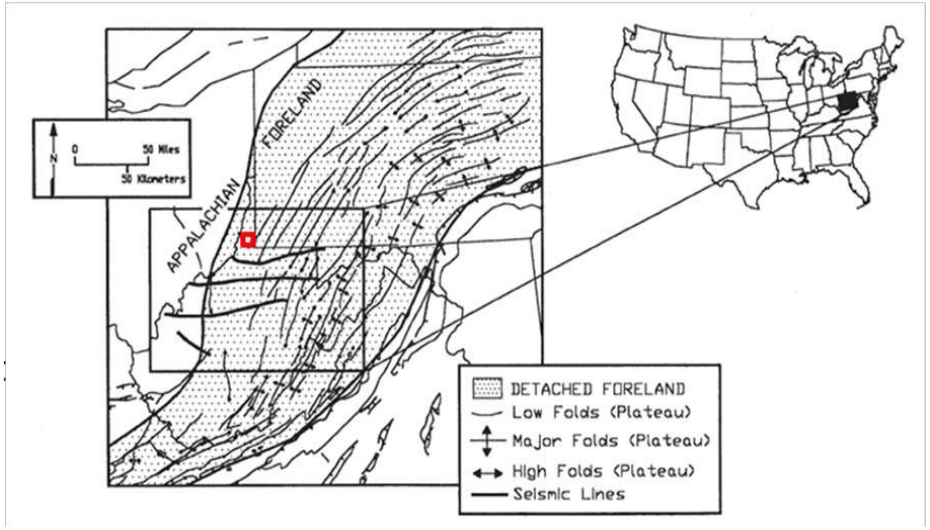
Geophysical Work

- Seismic surveys
- Cleat & fracture model development
- Reservoir modeling
- Tilt meter monitoring

Technical Status: Background

Project Location

- Marshall County, West Virginia, USA
- Regional stratigraphy:
  - Clastic sedimentary
  - Limestone
  - Coal



Target Formation

- Upper Freeport coal seam (1,200-1,800 deep)
  - Thicker to the north & west
  - Tapering to pods to the south and east
- Pittsburgh coal seam overlying ~600 ft.

Technical Status: Timeline

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Technical Status: Site Layout

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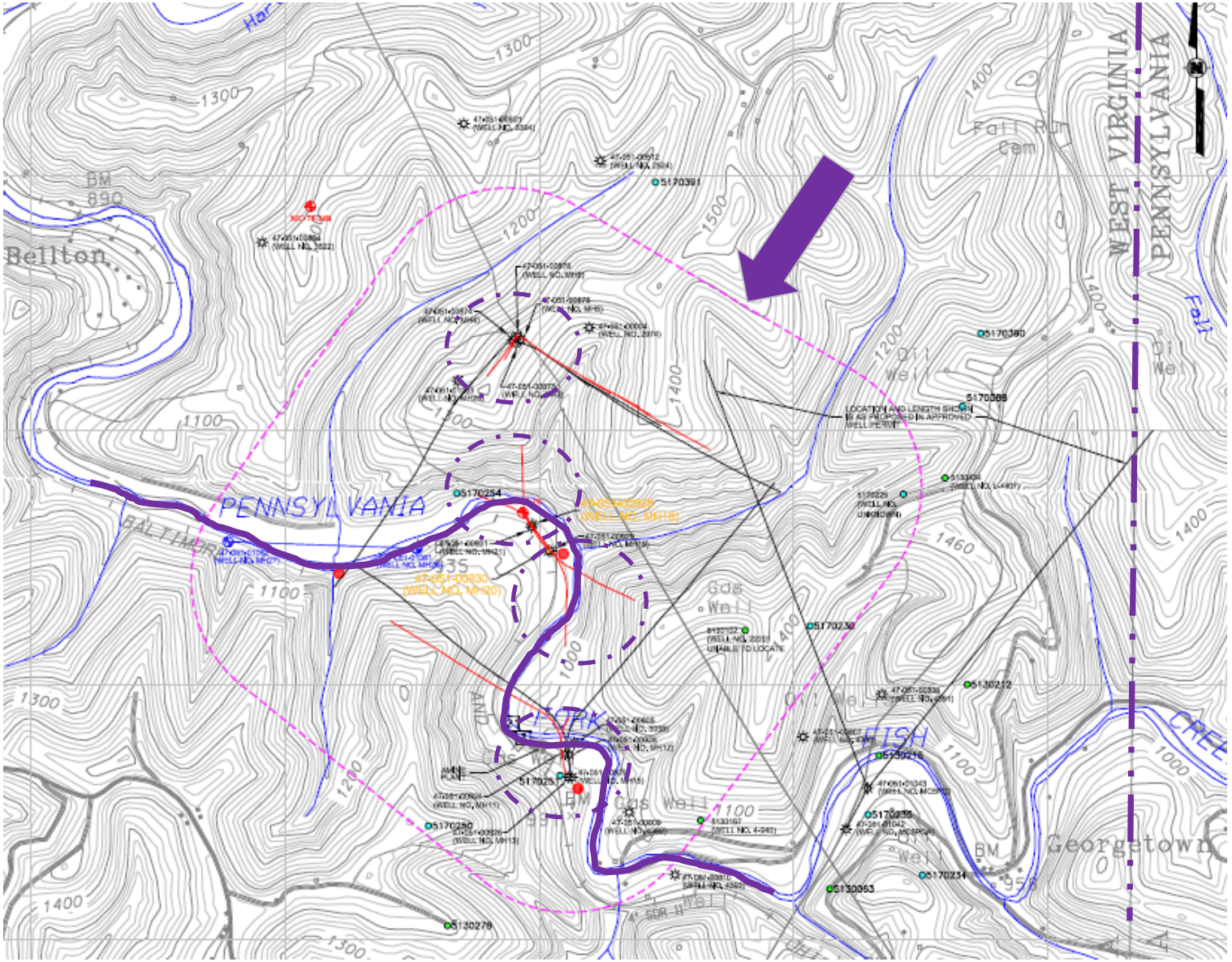

Technical Status: Injection

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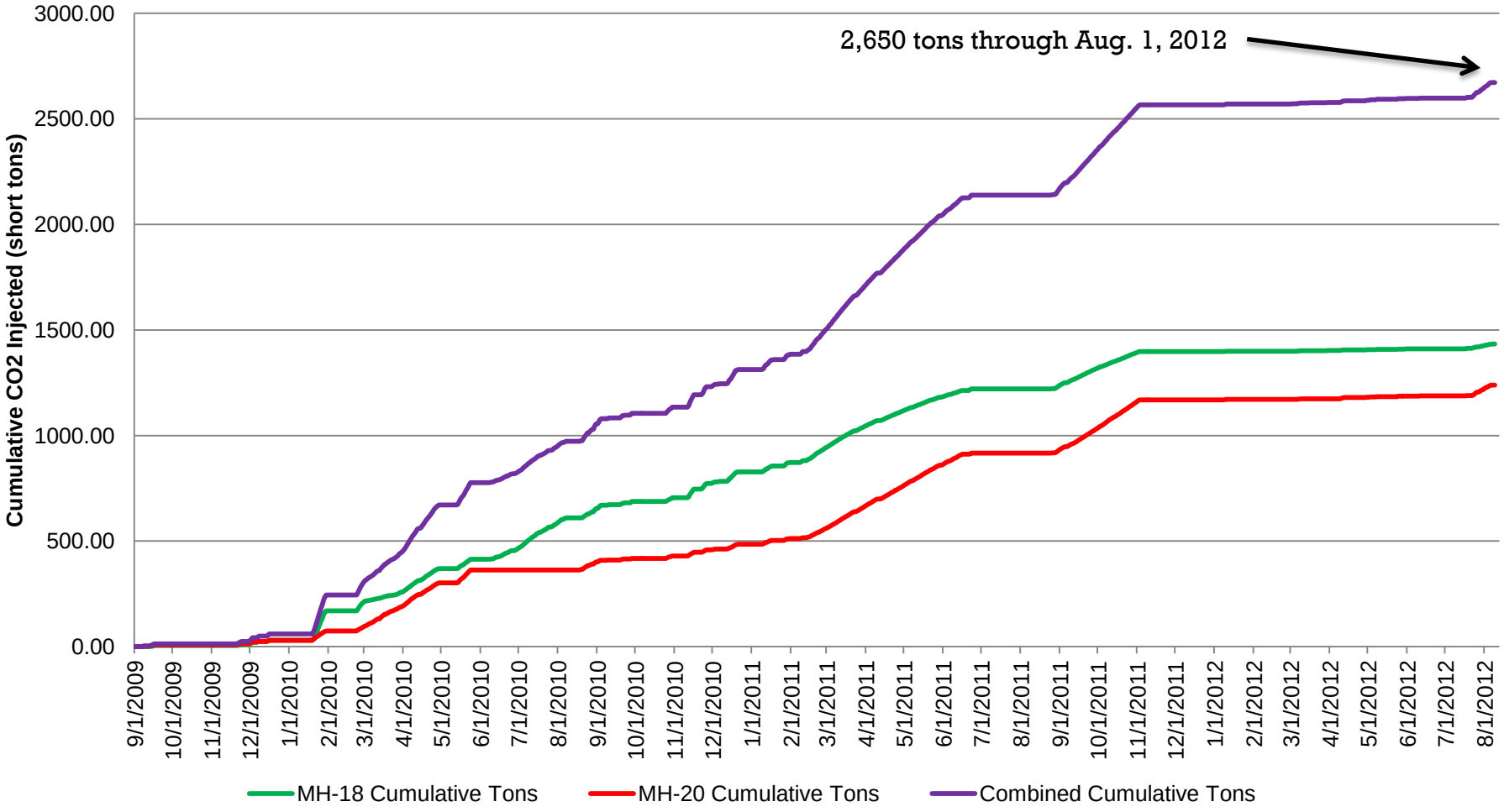
Daily Cumulative Tons of CO_2 Injected



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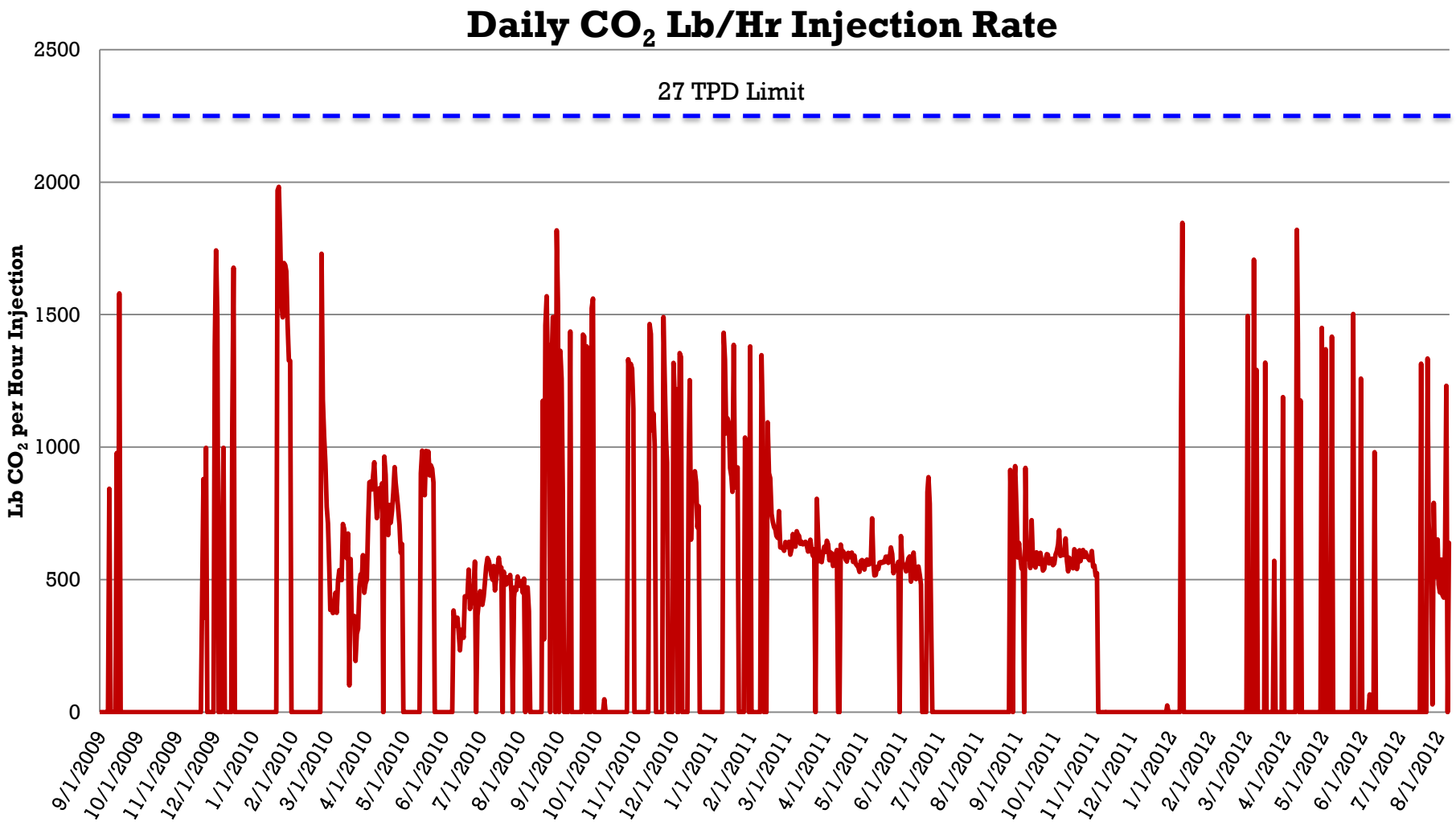

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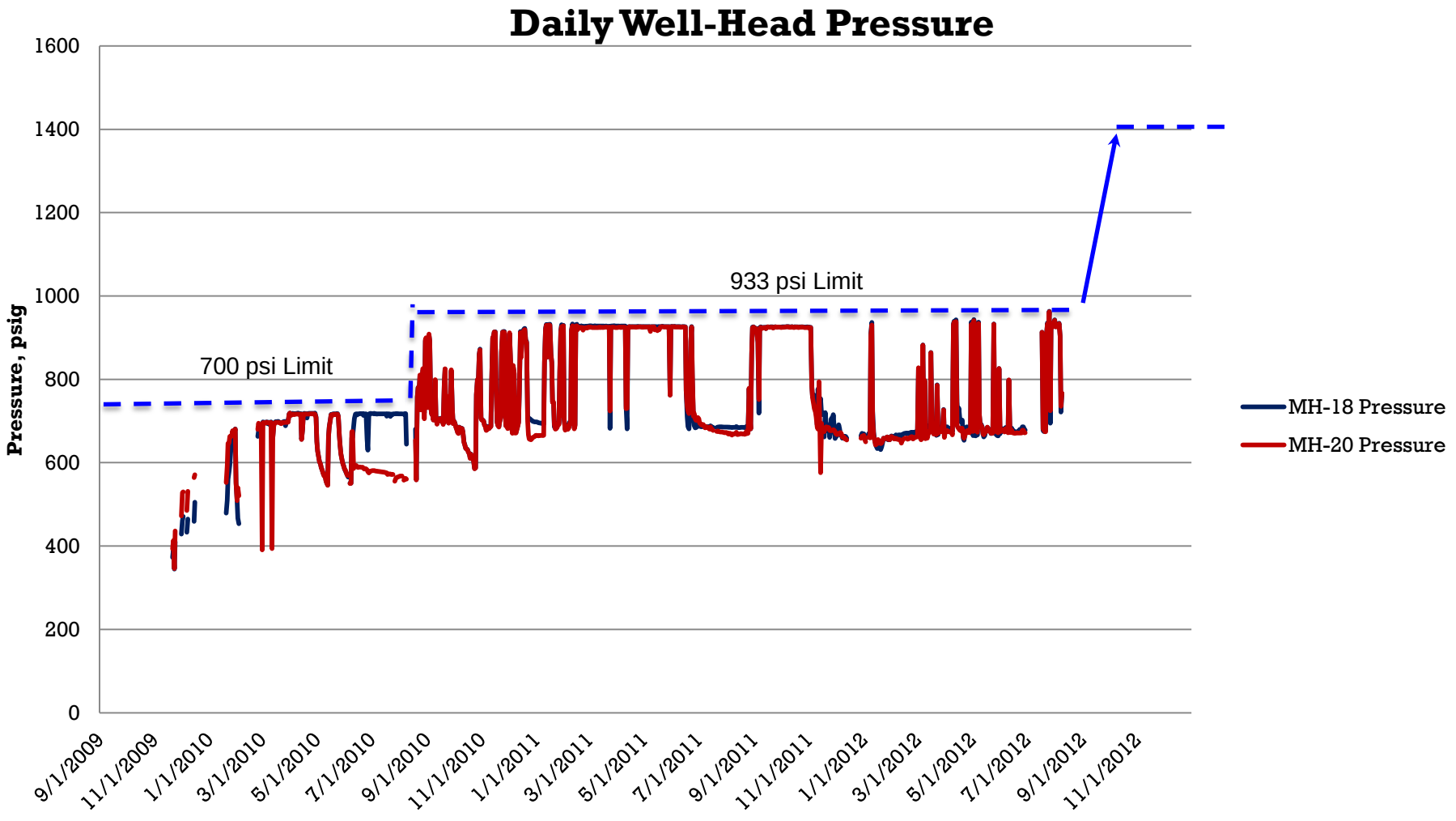

Technical Status: Injection

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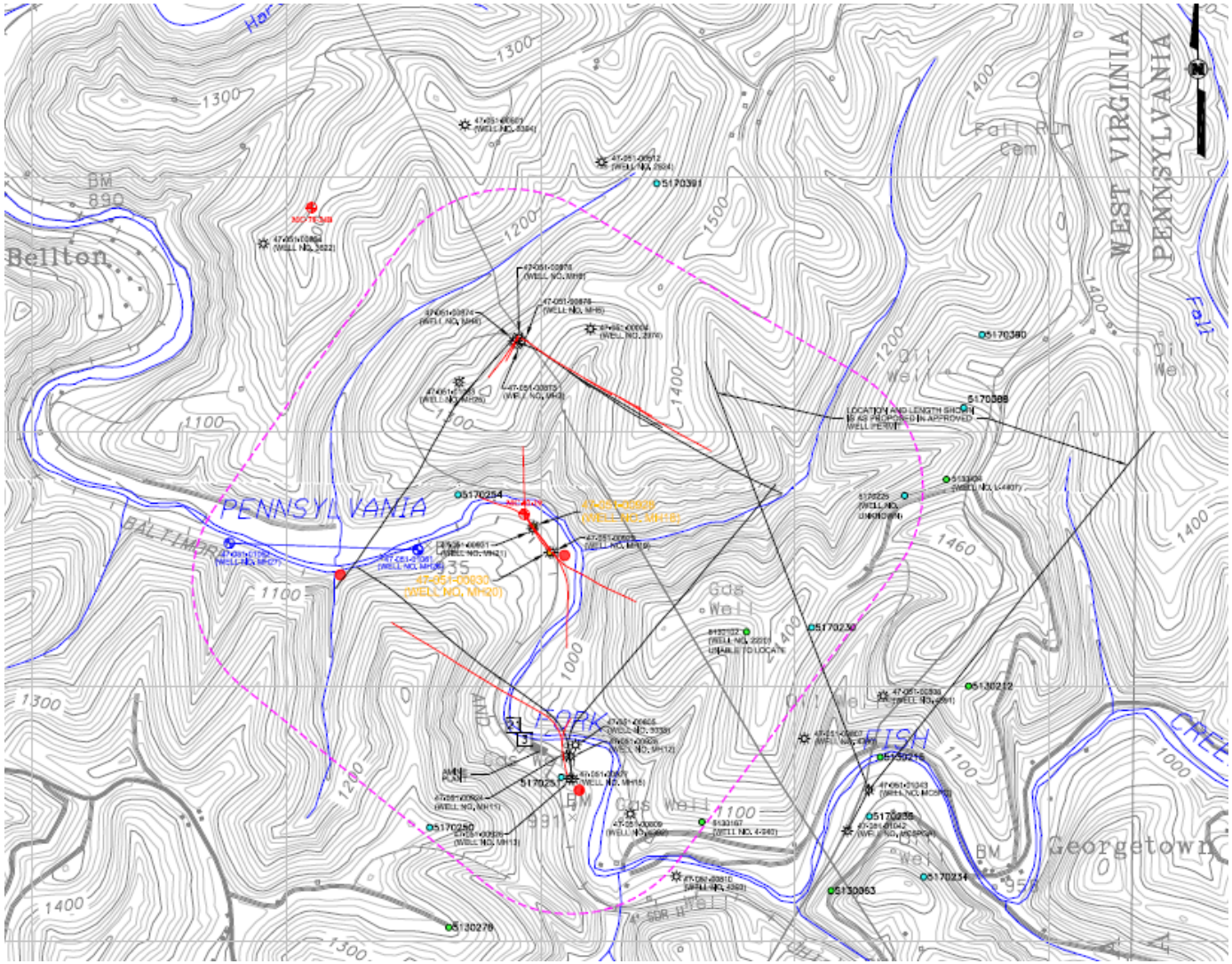
Original injection pump

- Cryomec 2-cylinder
- Removed from service Nov. 1, 2011

Replacement pump system

- Cat Pump triplex model
- Vapor lock troubleshooting

Technical Status: Monitoring



Technical Status: Monitoring

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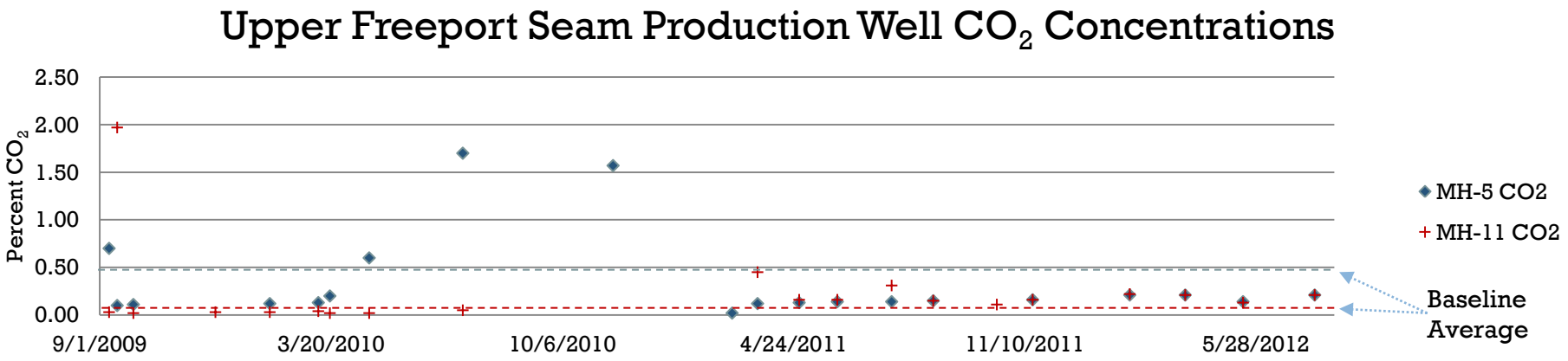
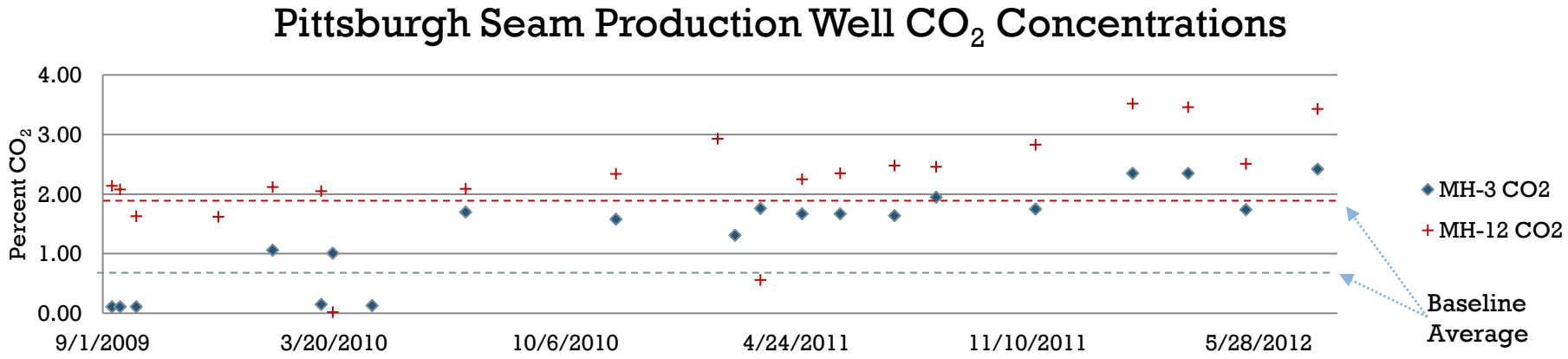
Environmental Monitoring

- Gas
  - Project CBM production wells (MH-3, MH-4, MH-5, MH-11, & MH-12)
  - AOR CBM production well (MC-5)
  - AOR monitoring wells
    - Upper Freeport observation wells (MH-26 & MH-27)
    - Three deep-well annuli
    - Three aquifer-zone wells (WVU-1, 2, & 3)
- Water
  - CBM production wells (MH-11 & MH-12)
  - AOR CBM production well (MC-5)
  - AOR USDW zone monitoring wells (WVU-1, 2, & 3)
  - Stream samples
  - Residential water wells

Technical Status: Monitoring





Technical Status: Monitoring

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AOR Gas Monitoring Results:

AOR Gas Wells

Well No.	% CO_2	SD
1588		
Baseline Average	0.31	0.04
Post injection average	0.41	0.11
Most recent value	0.37	
2974		
Baseline Average	0.70	0.05
Post injection average	1.16	0.55
Most recent value	2.12	
4407		
Baseline Average	0.79	0.05
Post injection average	0.70	0.25
Most recent value	0.30	
MC-5		
Baseline Average	2.82	0.38
Post injection average	3.35	0.43
Most recent value	4.05	

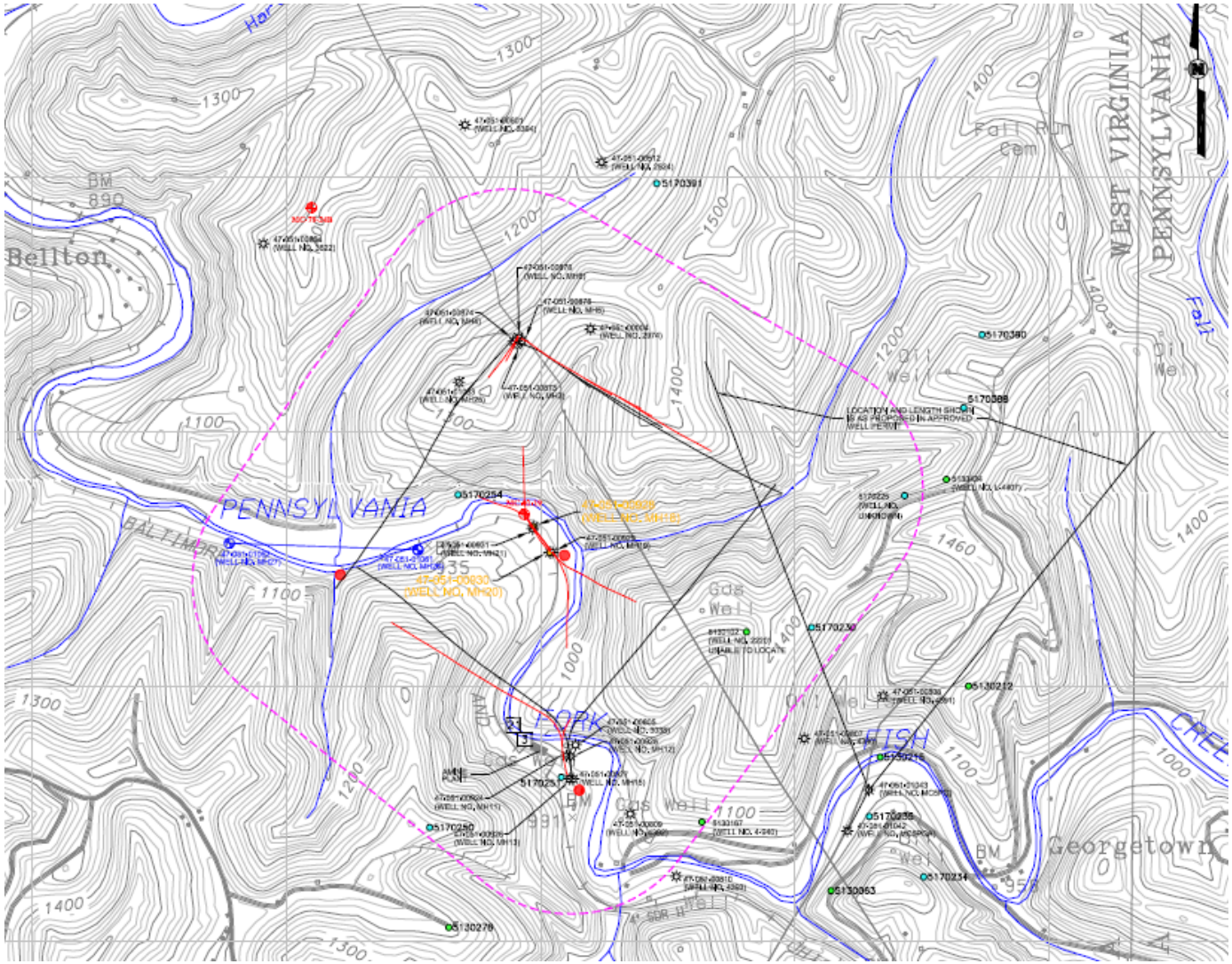
Aquifer-Zone Wells

Well No.	% CO_2	SD
WVU #1		
Baseline Average	0.05	0.02
Post injection average	0.09	0.05
Most recent value	0.19	
WVU #2		
Baseline Average	0.06	0.03
Post injection average	0.08	0.04
Most recent value	0.17	
WVU #3		
Baseline Average	0.05	0.01
Post injection average	0.21	0.15
Most recent value	0.45	

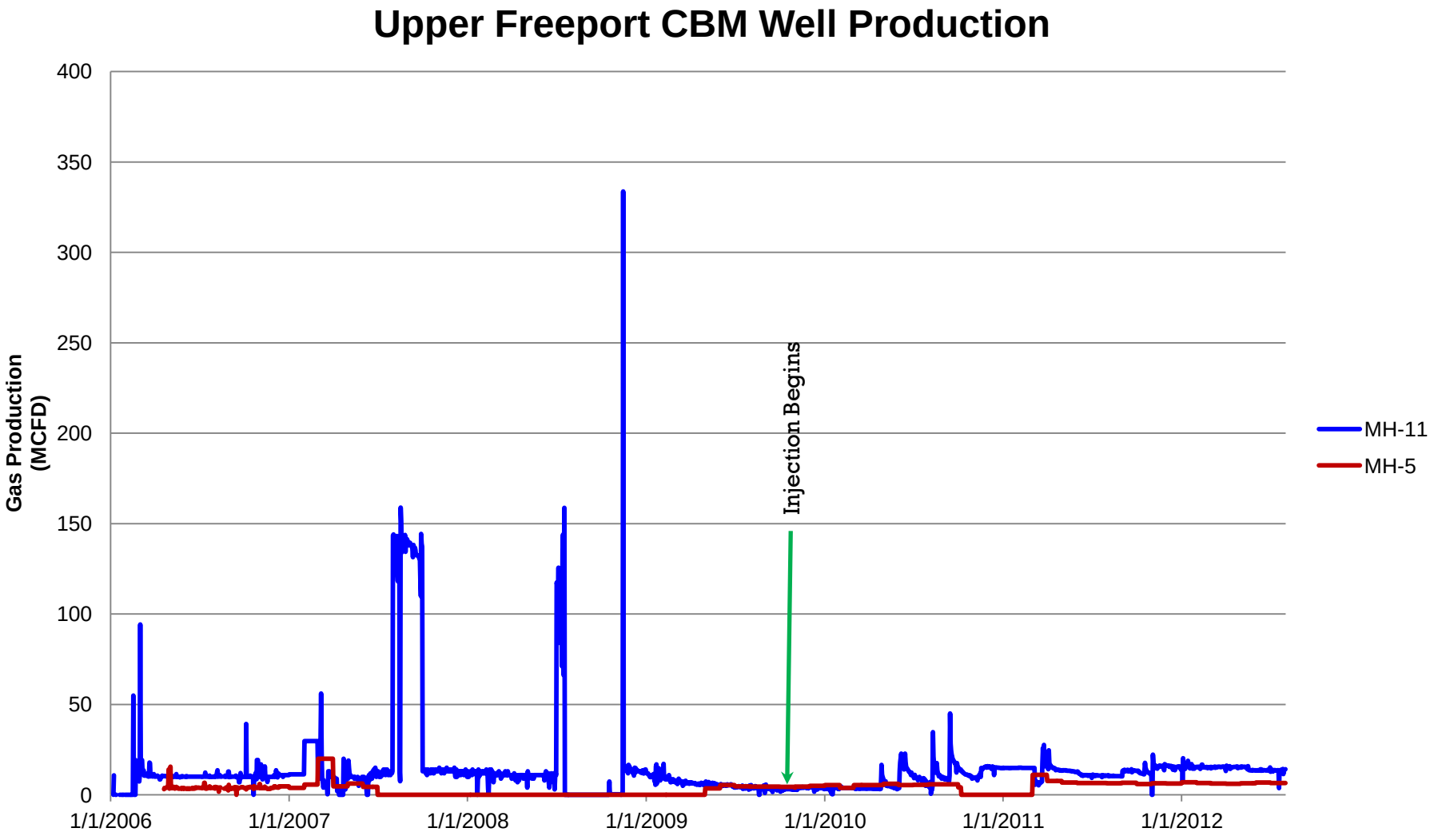
Upper Freeport Monitoring Wells

Well No.	% CO_2	SD
MH-26		
Baseline Average	0.20	0.27
Post injection average	0.04	0.04
Most recent value	0.05	
MH-27		
Baseline Average	0.53	0.72
Post injection average	0.05	0.04
Most recent value	0.10	

Technical Status: CBM Production



Technical Status: CBM Production



Accomplishments to Date

- **> 2,600 tons CO_2 injected**
- **Injection studied at 700 psi & 933 psi**
- **Improved injection system**
- **1,400 psi injection test to commence within 30 days**
- **> 762 mmcf CBM produced**
- **Extensive environmental and geophysical monitoring program throughout**
  - No conclusive signs of plume migration
  - Injection modeling
  - Cleat network model development
- **Worked closely with academia**
- **Provided a platform for Master's and Ph.D. research**

Summary

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Key findings

- Increased "at-rest" formation pressure over time
- Longer-than-expected injection duration (supported by modeling)
- Minor positive tilt meter deflections recorded along MH-18 laterals
- Cleat network model shows areas of concentrated seismic discontinuities with some spatial association to tilt meter readings.

Lessons learned

- Down-dip drilling not suitable
- Injection operations for vapor lock control

Future plans

- Conduct step-rate testing
- Increase injection pressure to permitted 1400 psig
- Continue injection through December 2013
- Two years of post-injection monitoring

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Questions?

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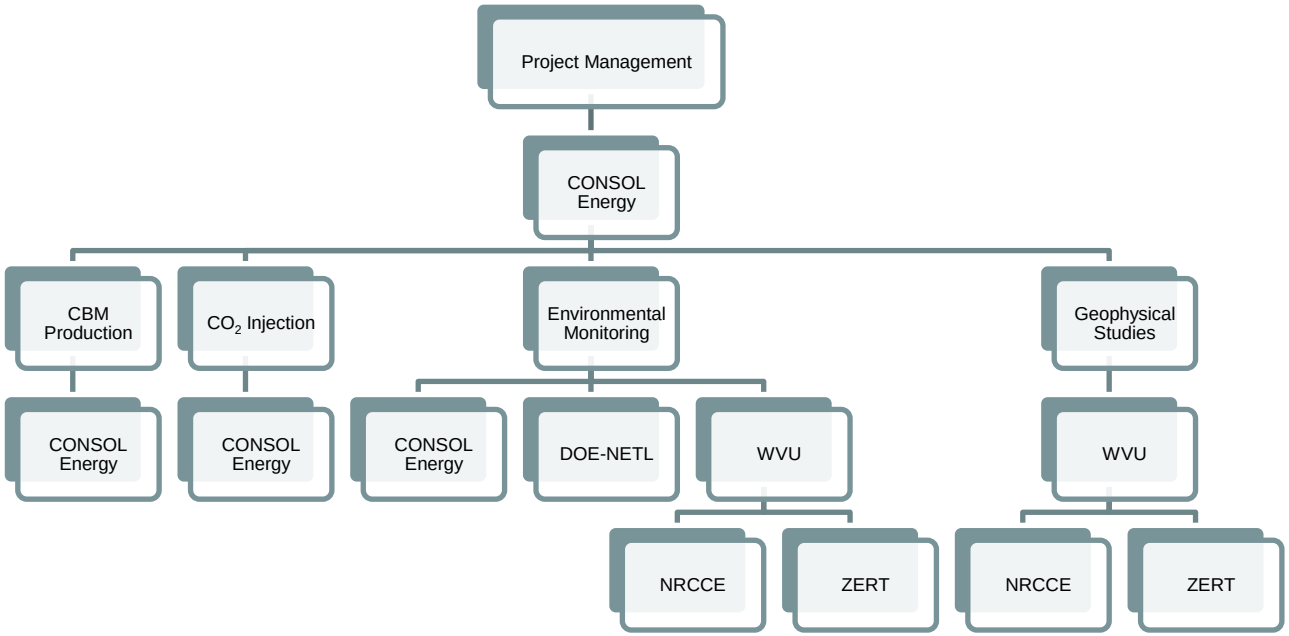
Appendix

Organization Chart



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Wilson, T. H.; Tallman, J.; Rauch, H.; Wells, A.; Smith, D.; 2003, Reconnaissance Studies of a Pilot Carbon Sequestration Site in the Central Appalachians of West Virginia, Northeastern Geology & Environmental Sciences, v. 25, no. 4, p. 330-345.