The Marcellus Shale Energy and Environment Laboratory (MSEEL)*

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Search and Discovery Article #42024 (2017)**
Posted March 20, 2017

*Adapted from oral presentation given at AAPG Eastern Section Meeting, Lexington, Kentucky, September 25-27, 2016
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Abstract

The Marcellus Shale Energy and Environment Laboratory (MSEEL) consists of a multidisciplinary and multi-institutional team undertaking integrated geoscience, engineering and social science research in cooperation with the operator, Northeast Natural Energy, numerous industrial partners and the National Energy Technology Laboratory of the US Department of Energy. MSEEL consists of two legacy horizontal production wells, two new instrumented horizontal production wells, a vertical pilot bore-hole, a microseismic observation well and surface geophysical and environmental monitoring stations. Production from the new horizontal wells began in December 2015. The MSEEL approach is data driven with a platform to store, manage, publish and share very large and diverse (multiple terabyte) datasets among researchers. MSEEL integrates drilling and fracture stimulation operations, geophysical observations, fiber-optic monitoring of high-resolution temporal and spatial flow of injected and produced fluids during completion and production, mechanical properties logs, microseismic and core data to better characterize subsurface rock properties, stimulated reservoir volumes, faults and fracture systems. Surface monitoring of operating machinery emissions was undertaken at the exhaust pipe, pad and regional scales. Produced fluids and gases are being

monitored during completion and production. The MSEEL goal is to develop and validate new knowledge and technology and identify best practices for field implementation that can optimize hydraulic fracture stimulation, and minimize environmental impacts of unconventional resource development.

We provide several examples that illustrate technologies and approaches that are being developed to store, query, display, and analyze large and diverse data sources and new data types derived from surface and subsurface to evaluate stimulation effectiveness, cluster-by-cluster and design innovative stage spacing and cluster density practices that can be used to optimize recovery efficiency.

MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

MSEEL

Department of Geology and Geography

Presented by: Tim Carr
West Virginia University
Lexington, KY – September 27, 2016

MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

MSEEL

AUTHORS

Carr, Timothy[1], Shikha Sharma[1], Thomas Wilson[1], Paul Ziemkiewicz[1], B.J. Carney[2], Jay Hewitt[2], Ian Costello[2], Emily Jordon[2], Zachary Arnold[2], Ryan Warner[2], Andy Travis[2], David Cole[3], Jeffery Daniels[3], Paula Mouser[4], Kelly Wrighton[5], Ray Boswell[6], Dustin Crandall[6], Robert Vagnetti[6]

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MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY
MSEEL

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term collaborative field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development

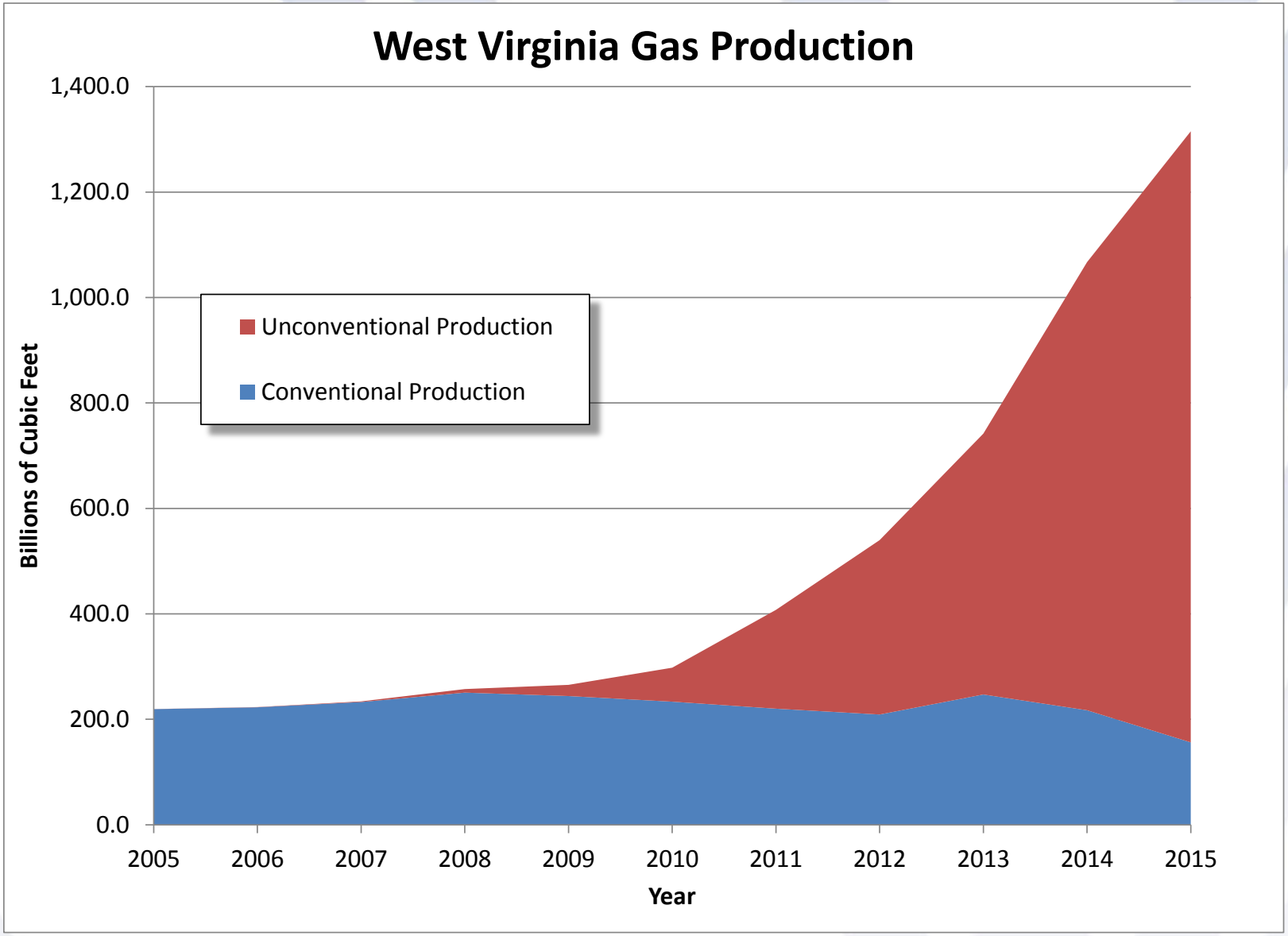
MSEEL
Marcellus Shale Energy & Environment Laboratory
Northeast Natural Energy
West Virginia University

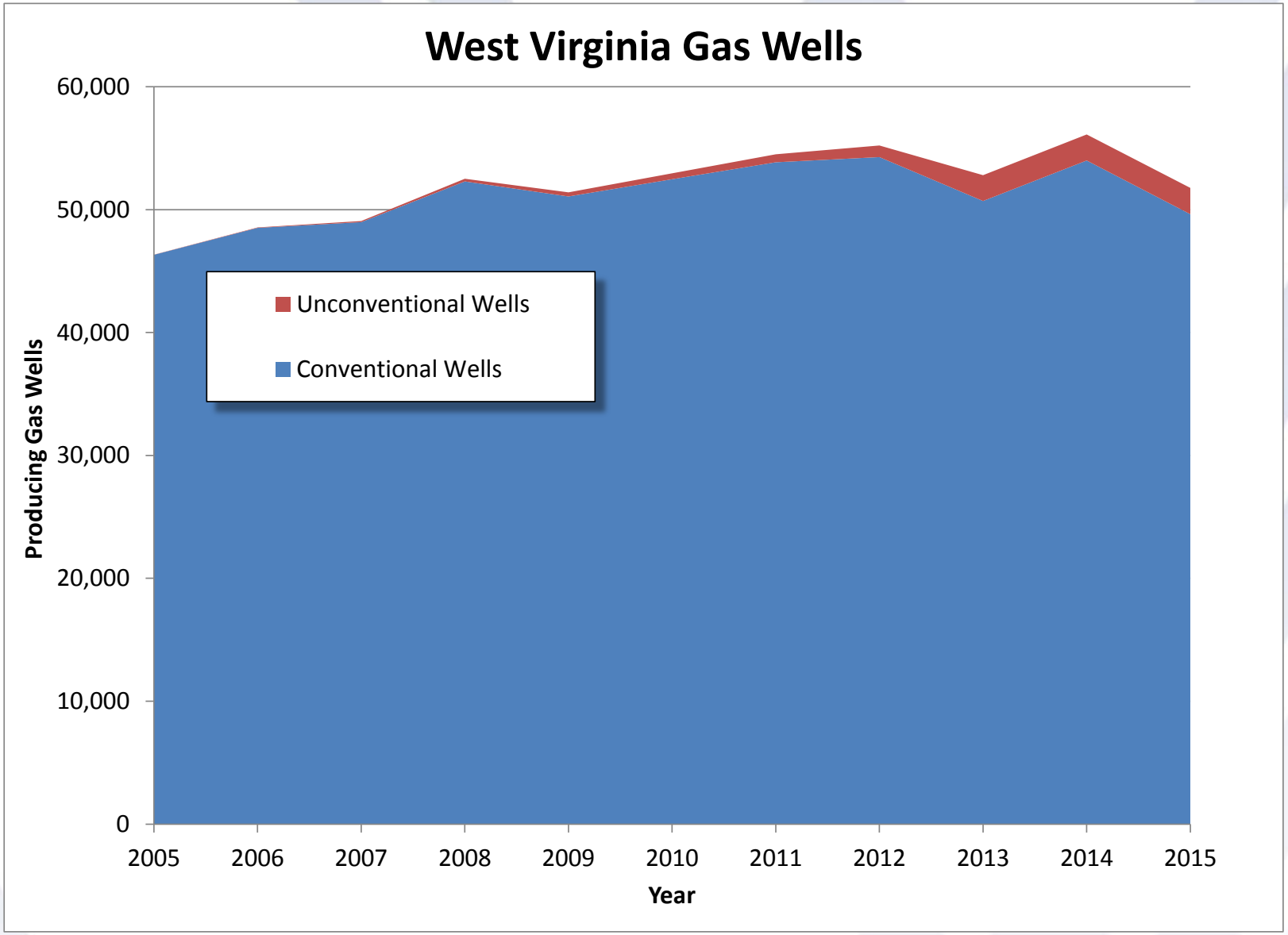
The Shale Revolution affects everything.
Technology has made quadrillions of BTUs of new energy resources available to humanity.

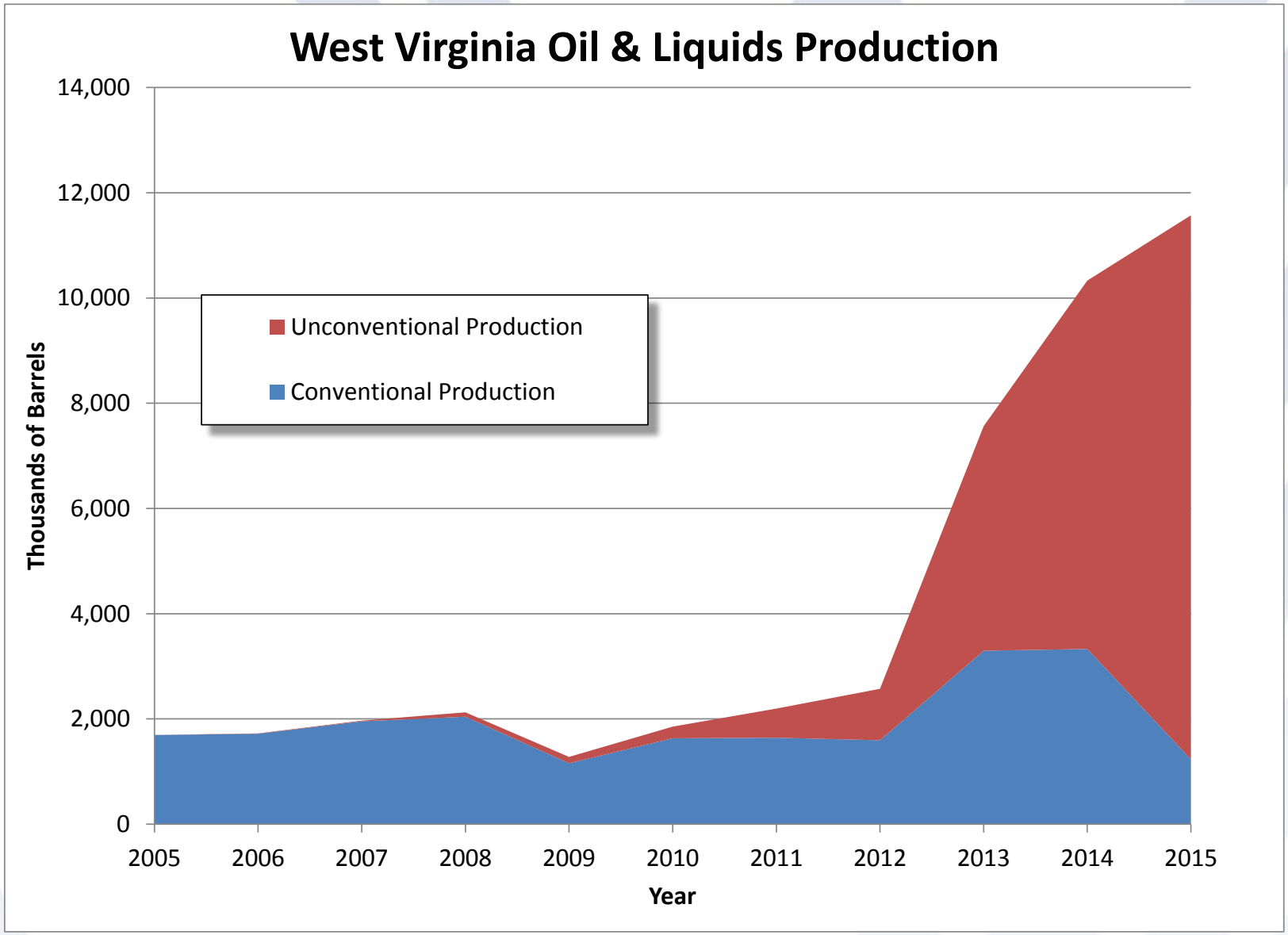
- Costs and Benefits
  - Largest Increase in Oil and Gas Production in the World
  - Decreased Energy Prices
  - Electrical Grid is changing at an unprecedented rate
  - Reduced CO2 Emissions
- Potential Environmental Challenges and Opportunities
  - Greenhouse Gas Emissions
  - Local Air, Noise and Water Pollution
  - Major Infrastructure Changes

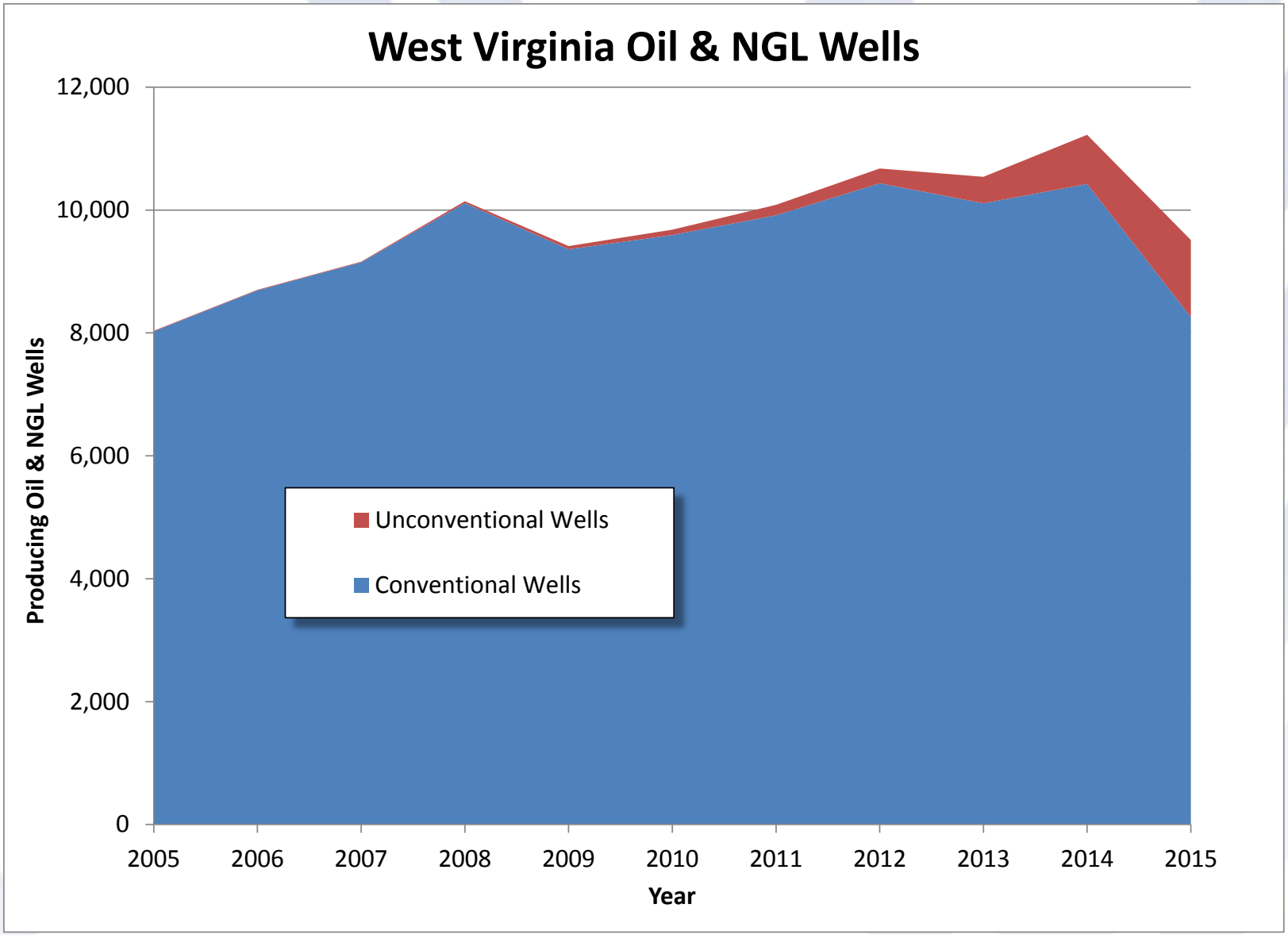
Goal: Minimize Environment Costs While Maximizing Benefits

While energy markets are complex, energy predictions are simplified representations of energy production and consumption, regulations, and producer and consumer behavior, and are subject to much uncertainty.


West Virginia Gas Production
1,400.0
1,200.0
1,000.0
800.0
600.0
400.0
200.0
0.0
Billions of Cubic Feet
Unconventional Production
Conventional Production
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

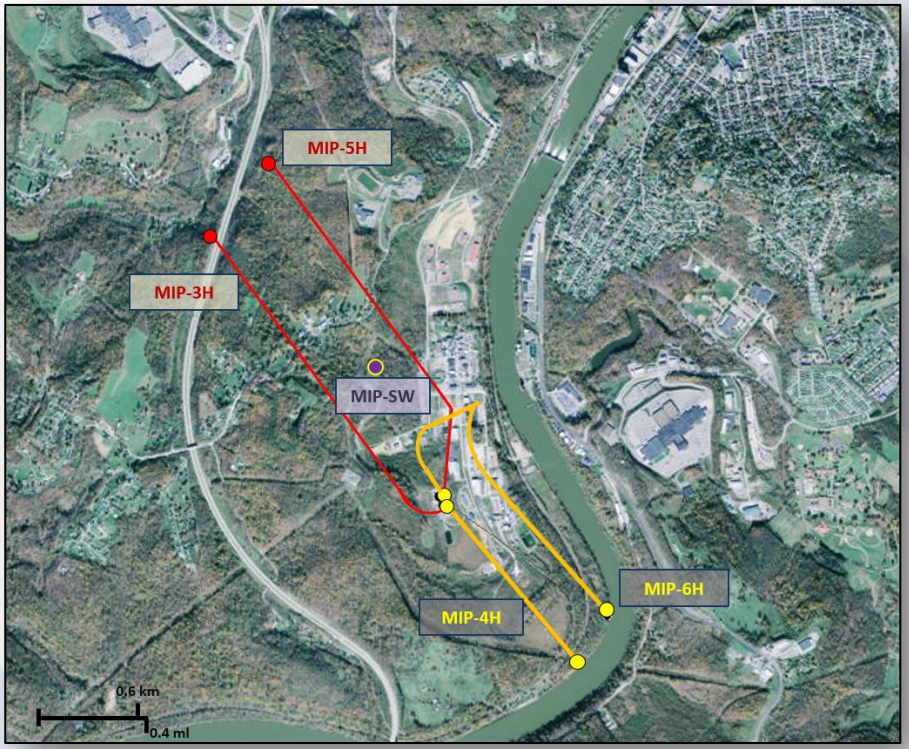

West Virginia Gas Wells
60,000
50,000
40,000
30,000
20,000
10,000
0
Producing Gas Wells
Unconventional Wells
Conventional Wells
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

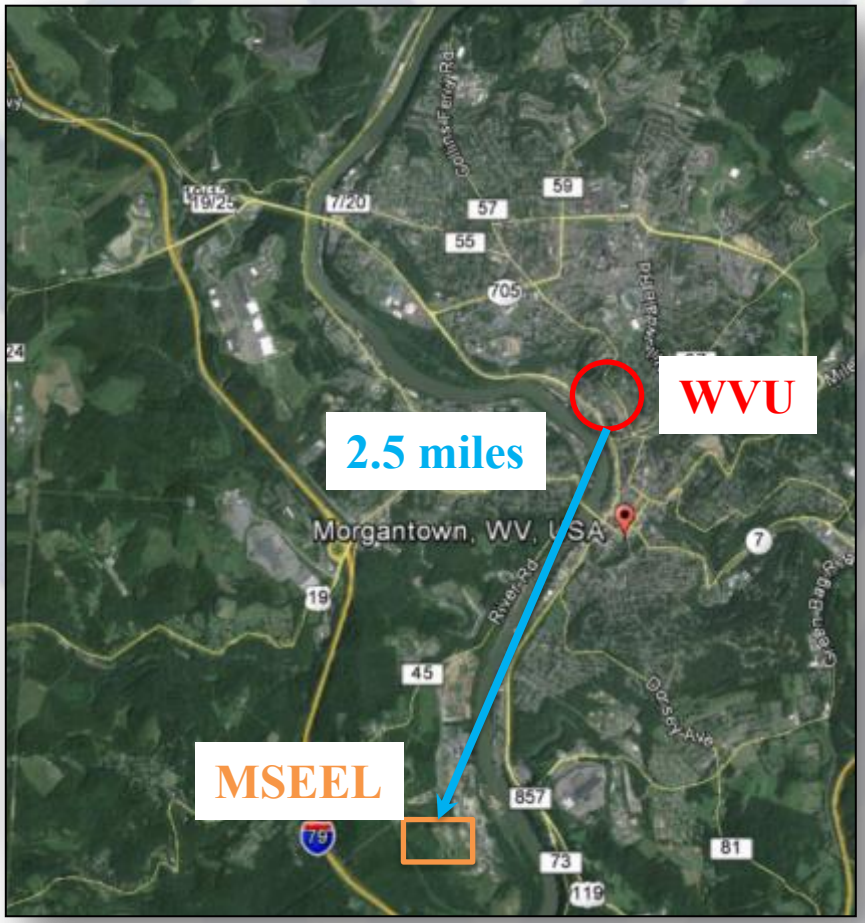

West Virginia Oil & Liquids Production
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Thousands of Barrels
Unconventional Production
Conventional Production
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year


West Virginia Oil & NGL Wells
12,000
10,000
8,000
6,000
4,000
2,000
0
Producing Oil & NGL Wells
Unconventional Wells
Conventional Wells
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

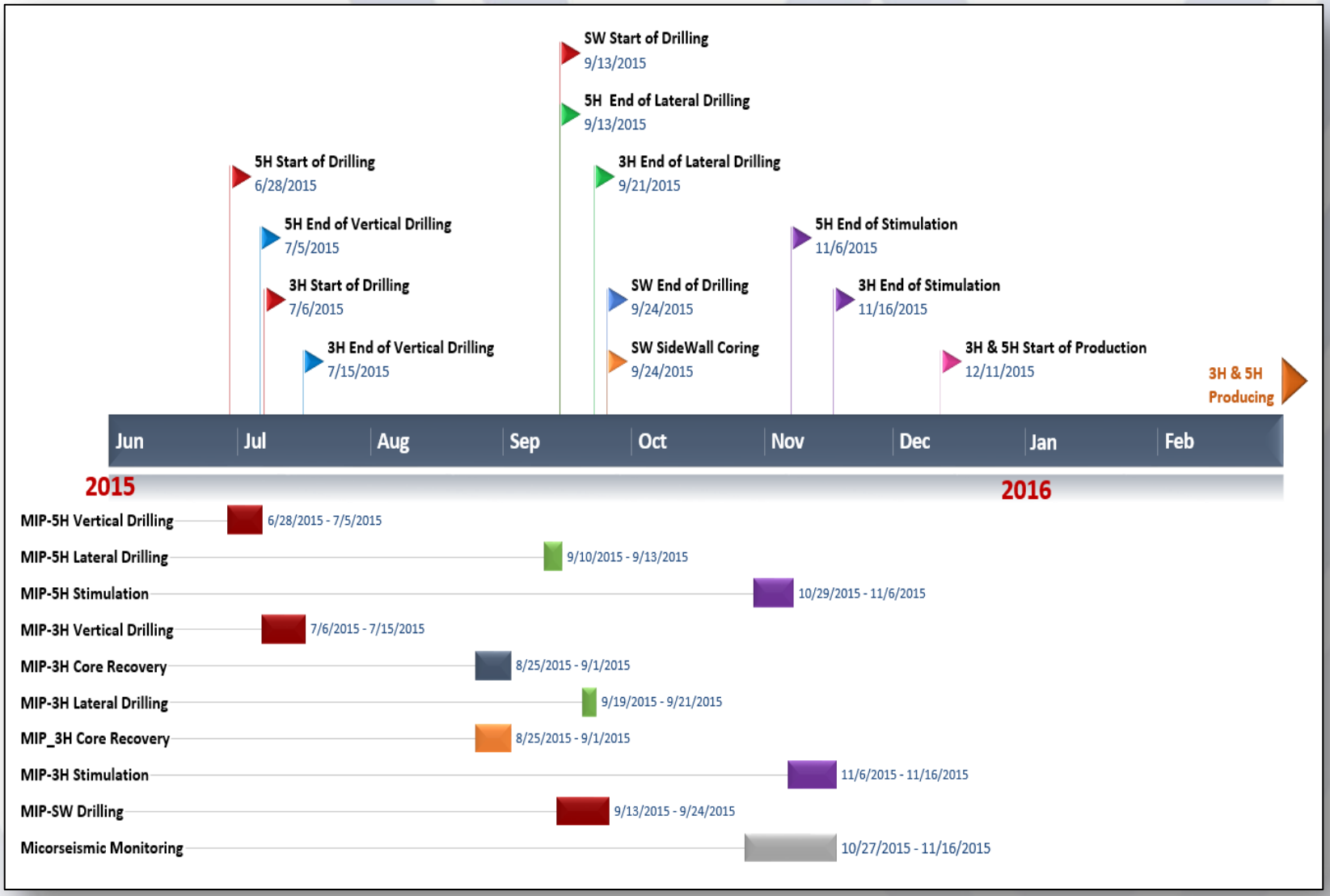
MSEEL Site

MSEEL Site

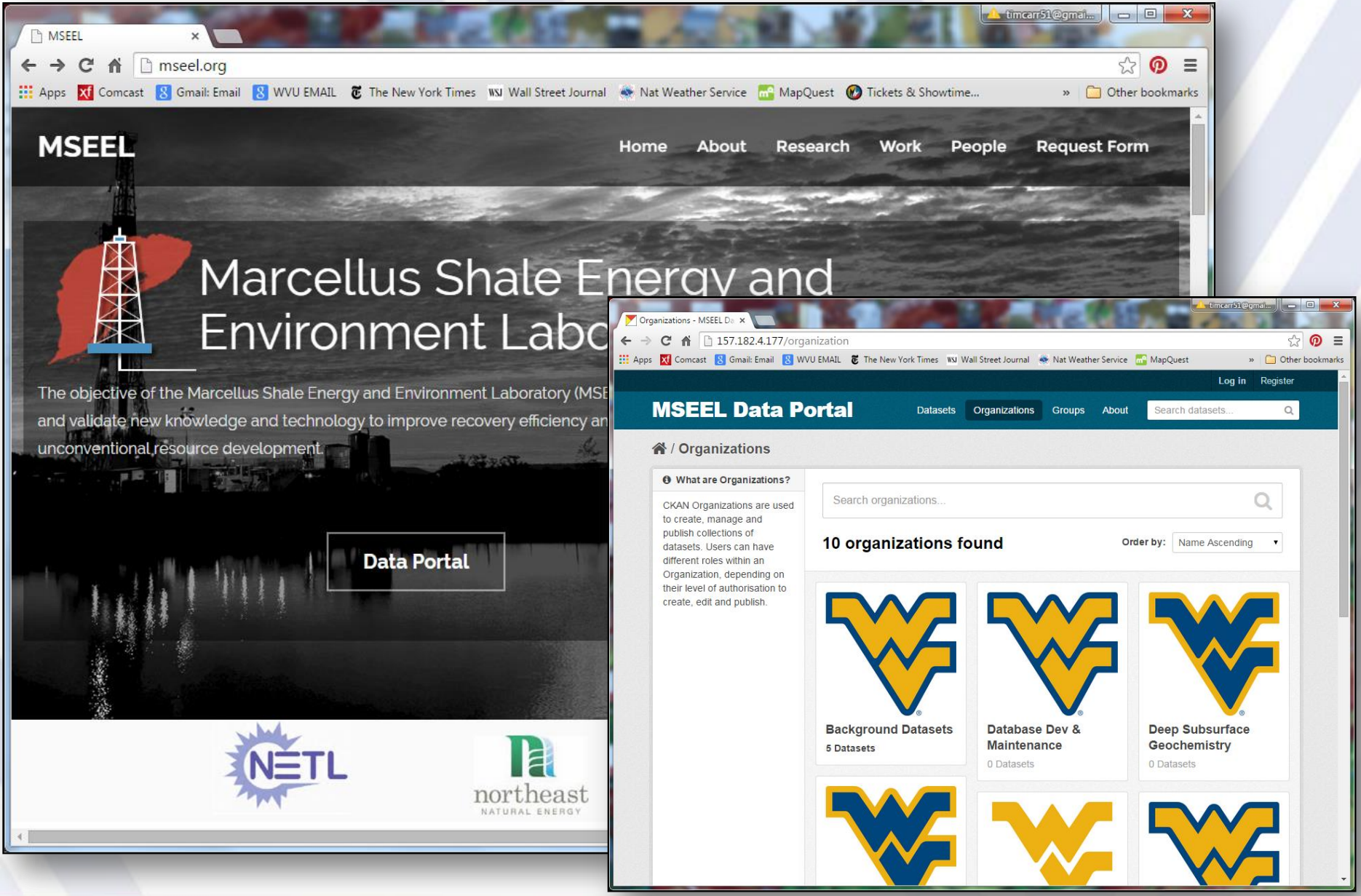

MIP-5H
MIP-3H
MIP-SW
MIP-6H
MIP-4H
0,6 km
0.4 mi


WVU
2.5 miles
Morgantown, WV, USA
MSEEL

MSEEL Field Schedule



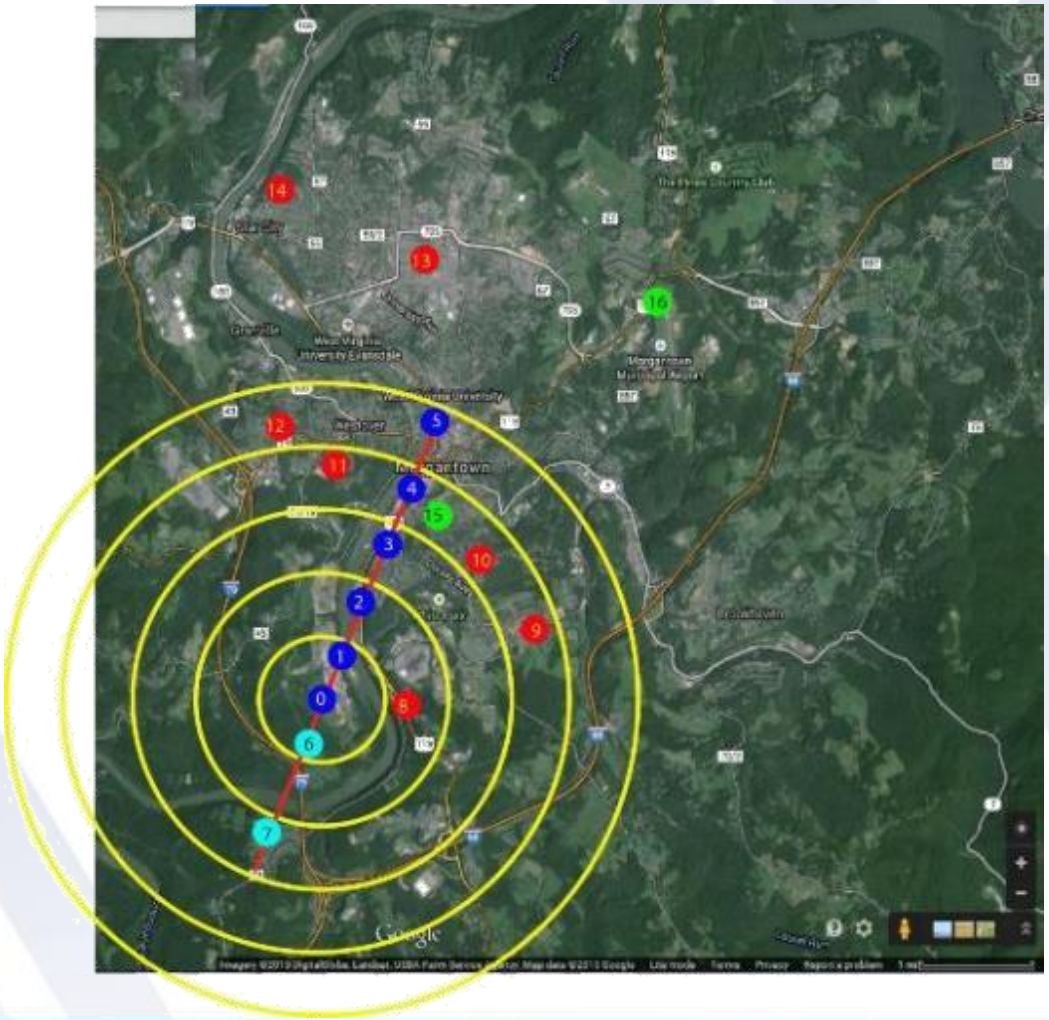
MSEEL
Drilling MIPU 3H and 5H

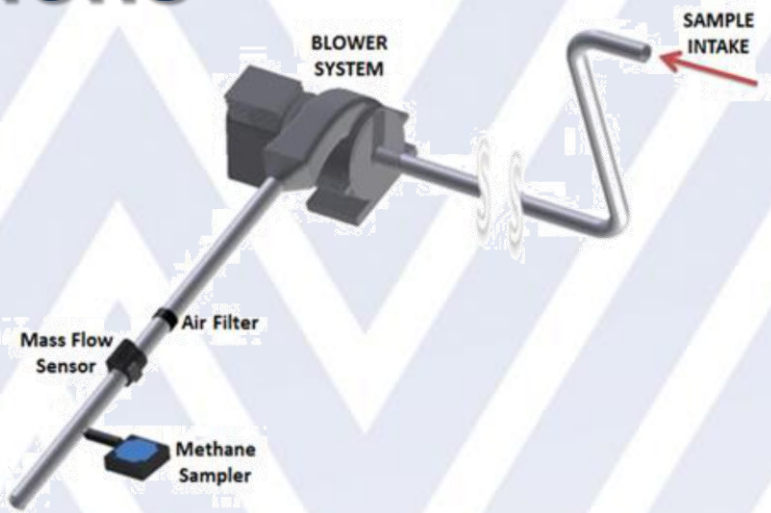


Department of Geology and Geography

Maneesh Sharma – WVU
Frank Lafone – WVU

MSEEL Environmental Monitoring Air Emissions





Department of Geology and Geography

Michael McCawley – WVU
Derek Johnson – WVU

Drilling Waste Monitoring

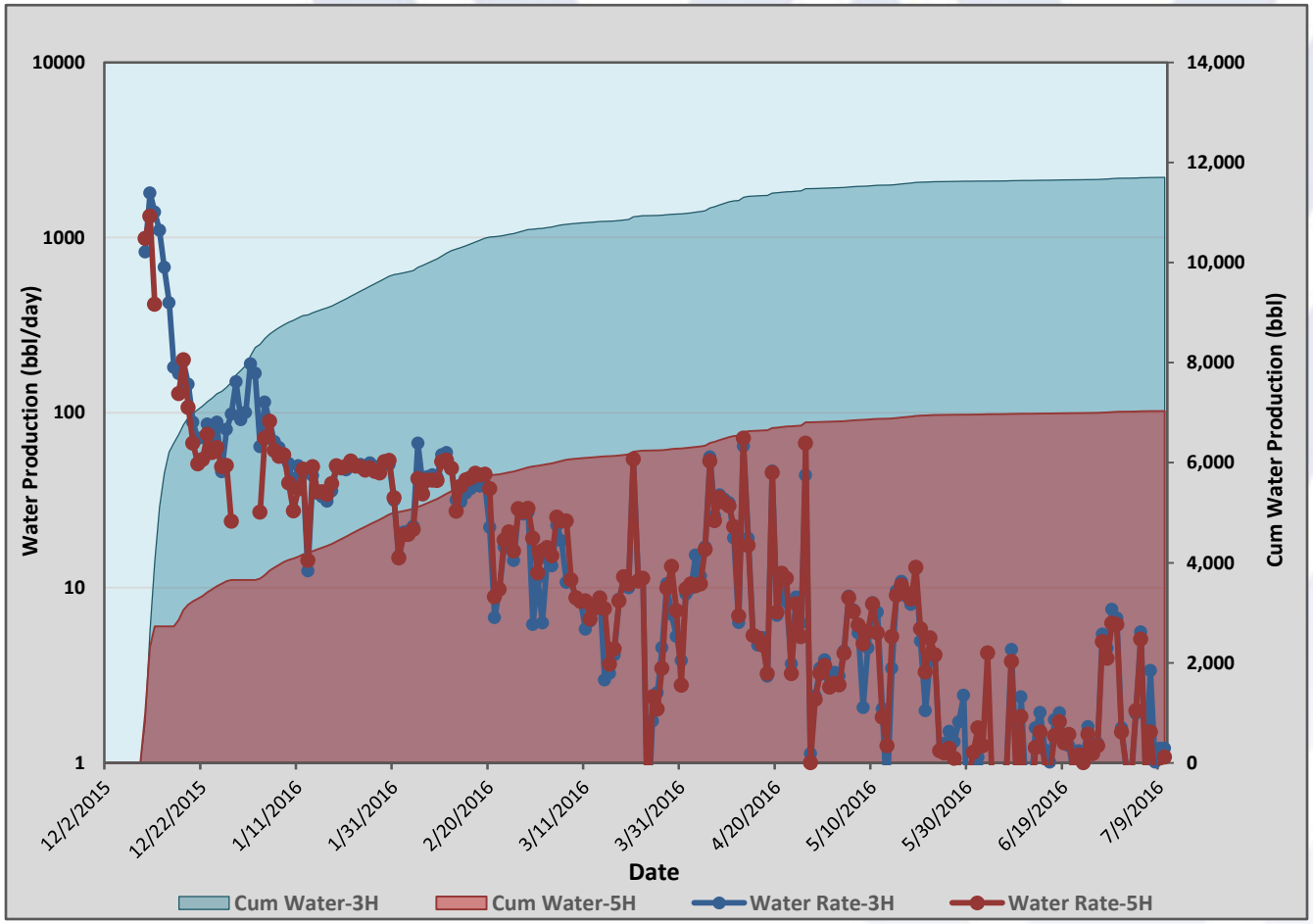
Cuttings

Mud

Environmental Monitoring
Surface Water

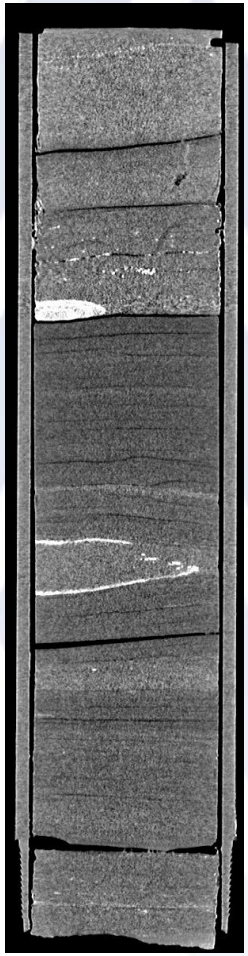
Paul Ziemkiewicz / WVU-WVWRI

Produced Water Monitoring



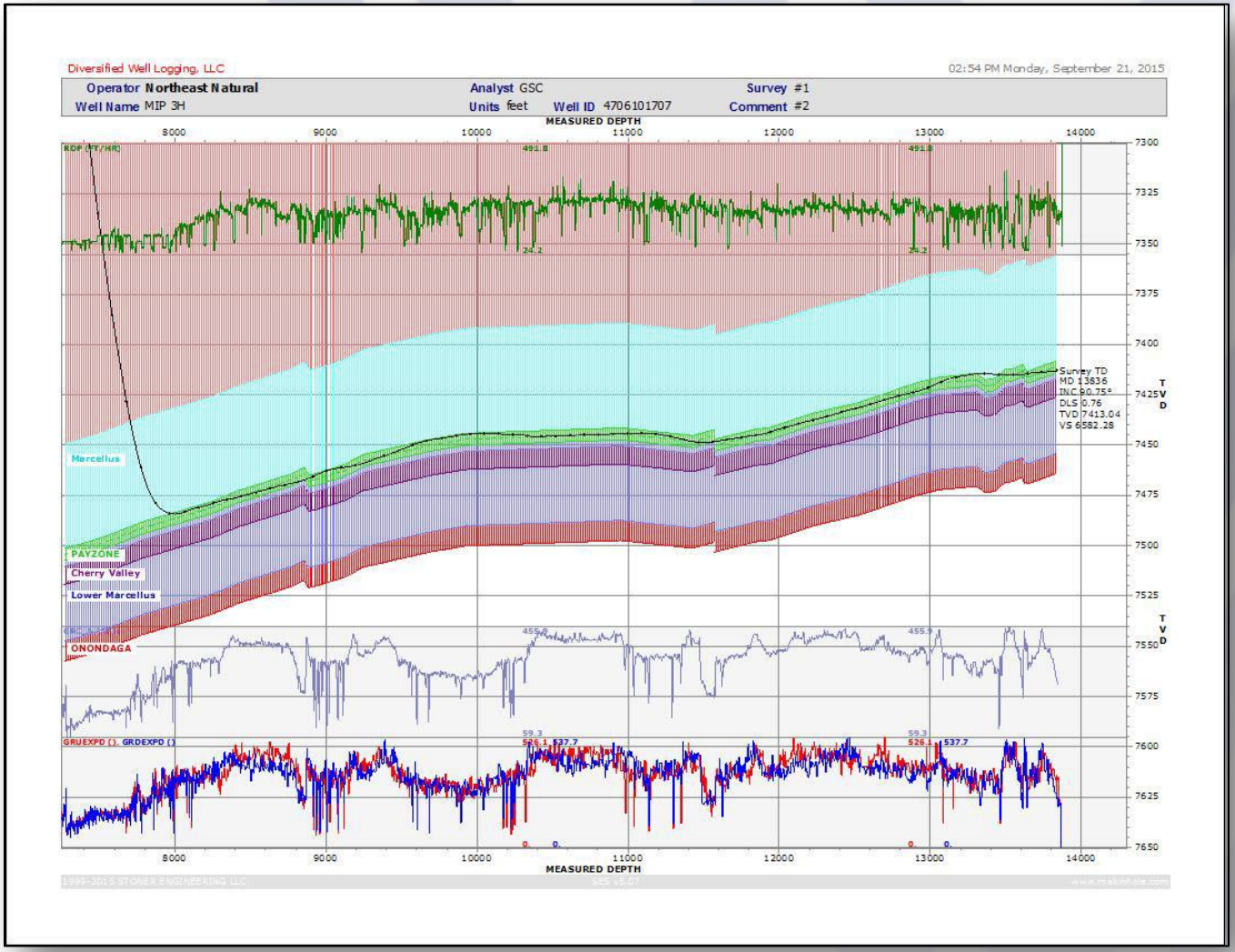
Subsurface Sampling

Retrieved 111’ of a targeted 120’ whole core

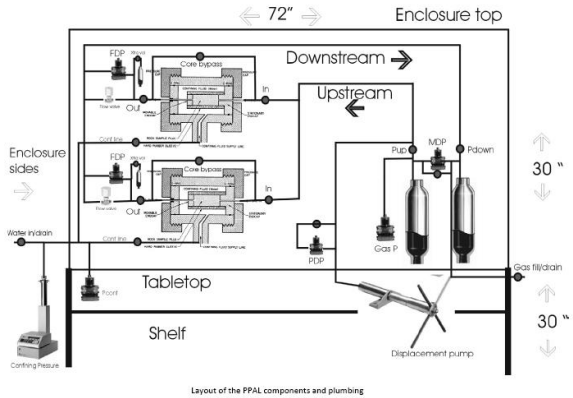


Collected 197 sidewall cores from the SW and 3H well

Geosteering MIP-3H



Precision Petrophysical Analysis Laboratory (PPAL) at WVU



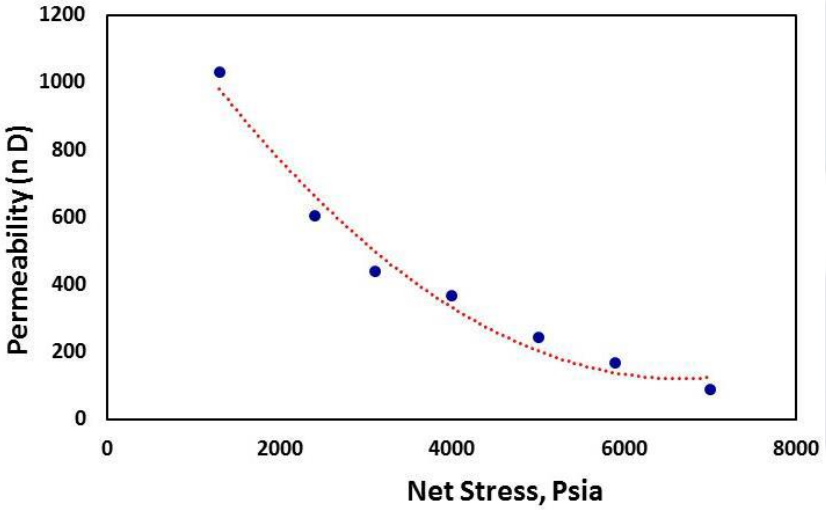
Layout of the PPAL components and plumbing

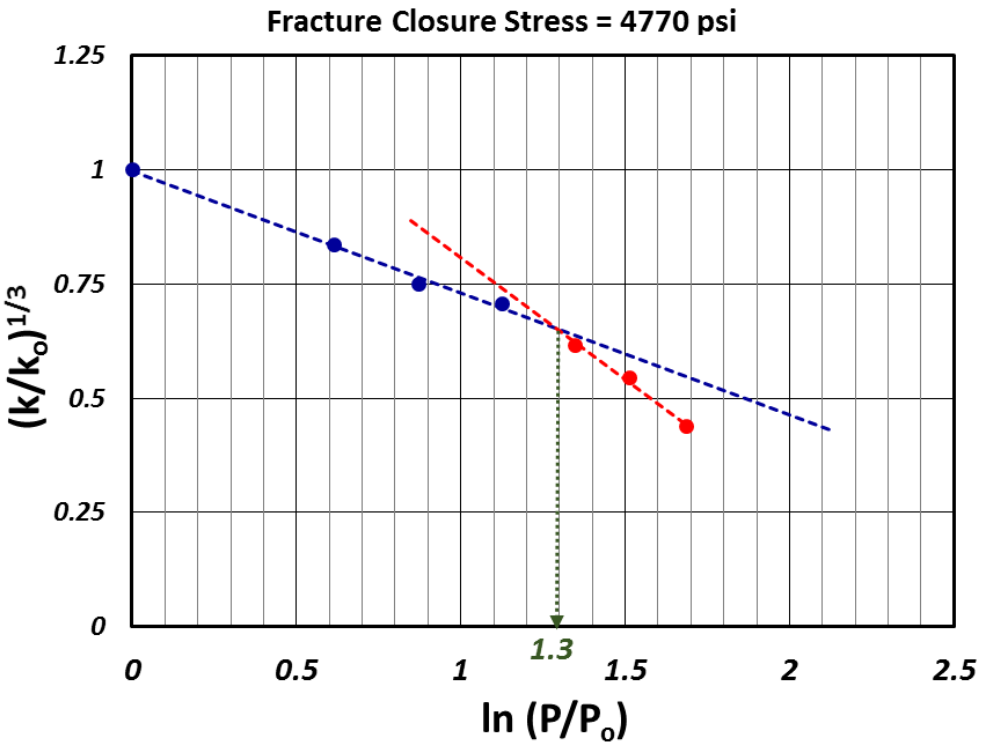
Measurement Capabilities

- Permeability (nano-darcy range).
- Pore volume (0.1% accuracy).
- Absolute Permeability (Gas Pressure Correction)
- Impact of Stress (Reservoir Conditions).
- Impact of Adsorption
- Pore structure characterization

Accurate, Consistent, and Repeatable Results

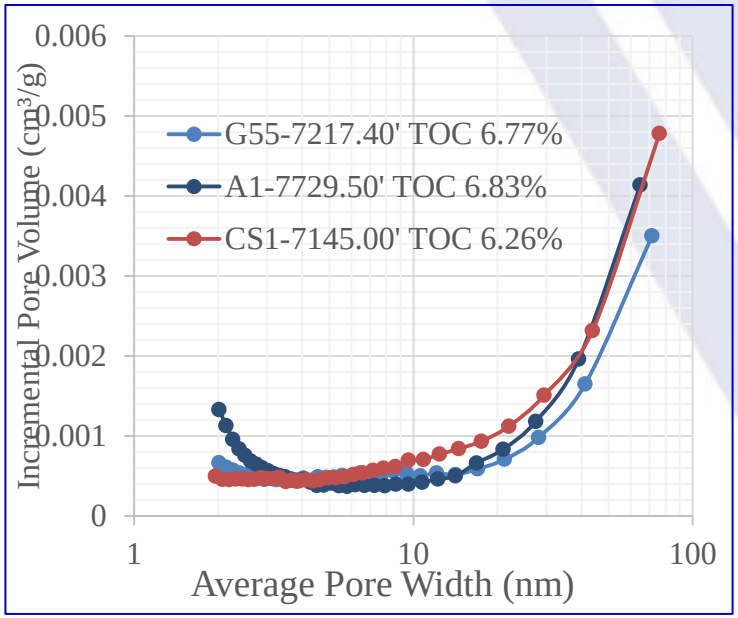
IMPACT OF STRESS

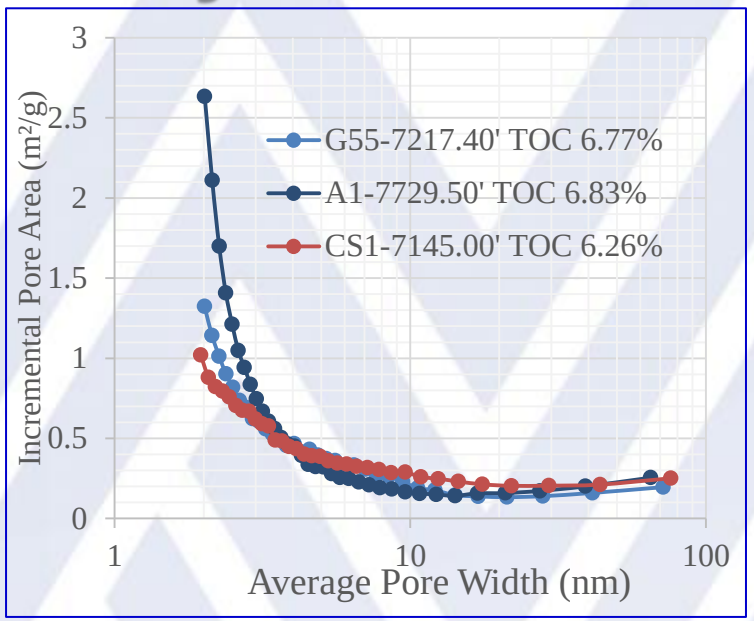


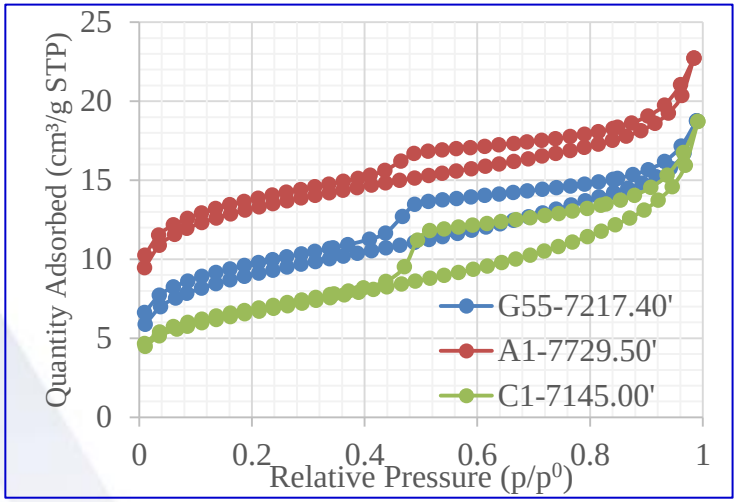


SAMPLE 7547.03

BET Core Analysis







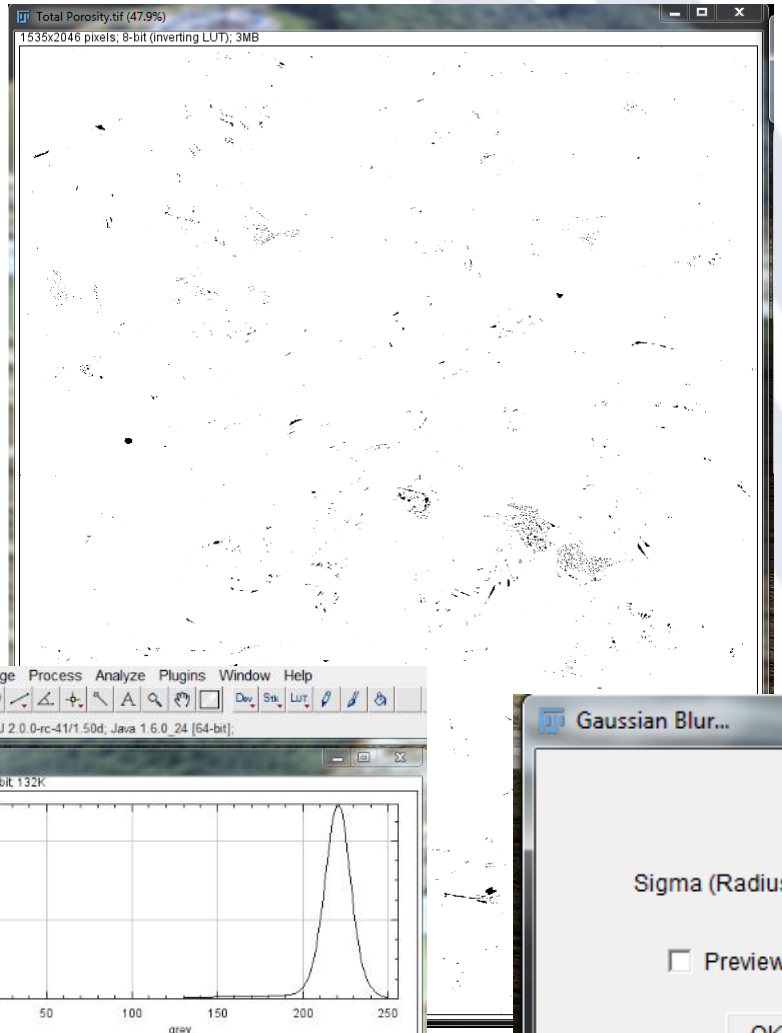
Brunauer–Emmett–Teller (BET) theory - The Type H4 loop, which does not exhibit any limiting adsorption at high p/p0, is observedas aggregates of plate-like particles and slit-shaped pores, often associated with microporosity (*IUPAC Recommendation 1984*).

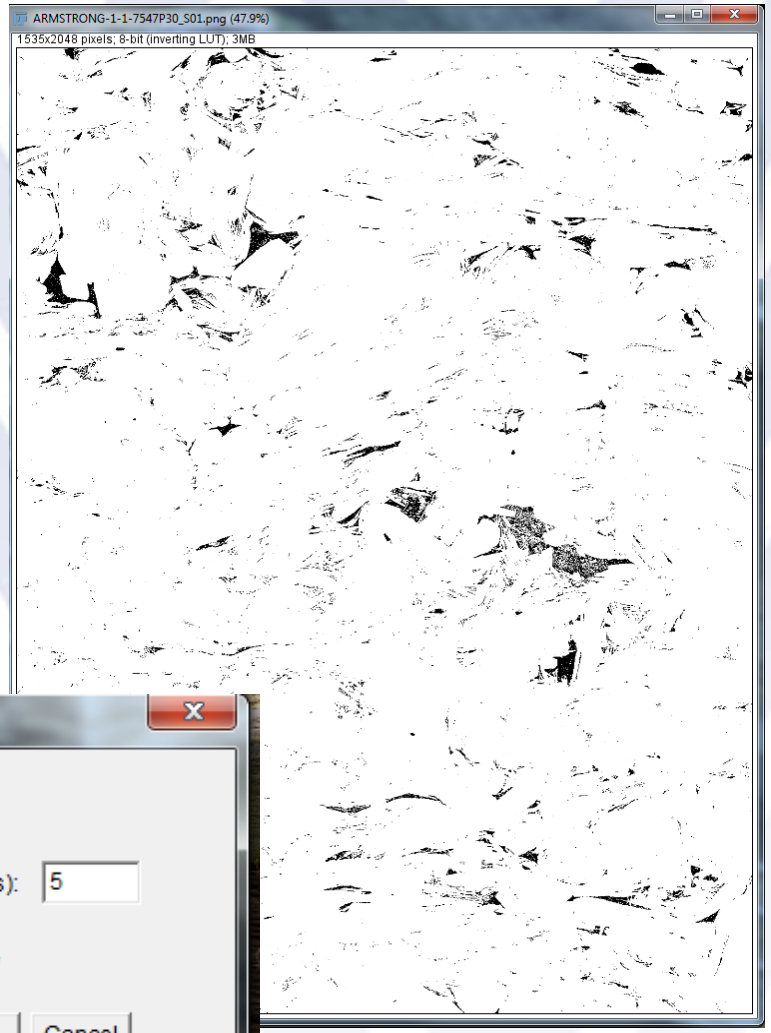
Pores of diameters less than 5 nm make the greatest contribution to SSA, whereas pore volumes are affected by larger pores. Samples with higher thermal maturity have less smaller pores (pore diameter less than 5 nm).

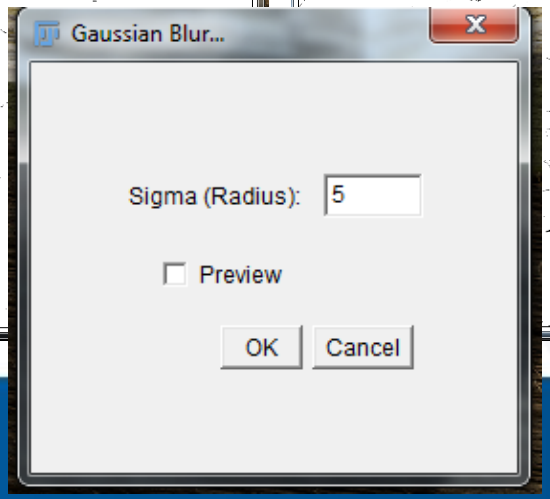
SEM Core Analysis

Porosity

Organic Matter







SEM Core Analysis

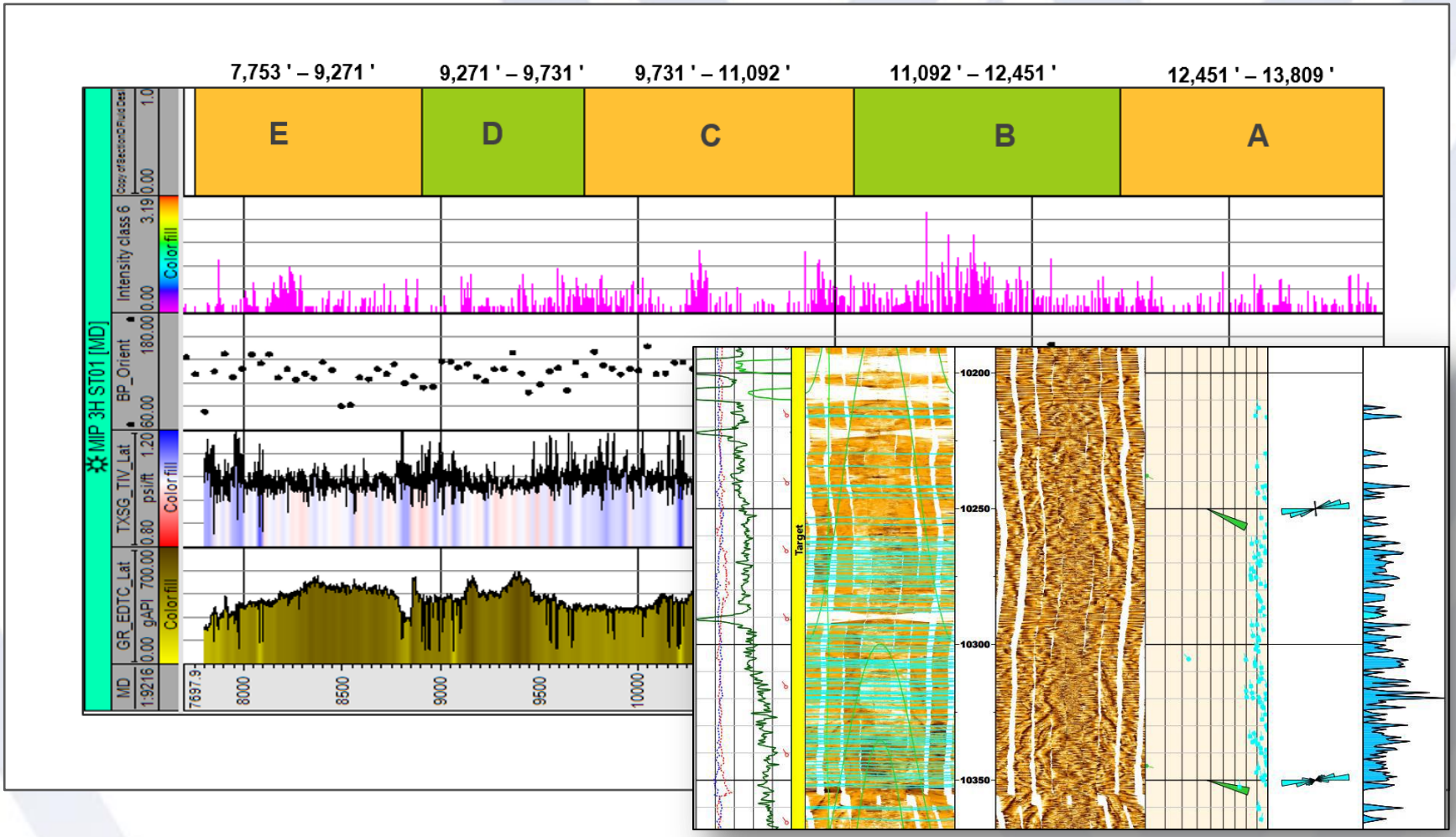
Organic porosity

Inorganic porosity

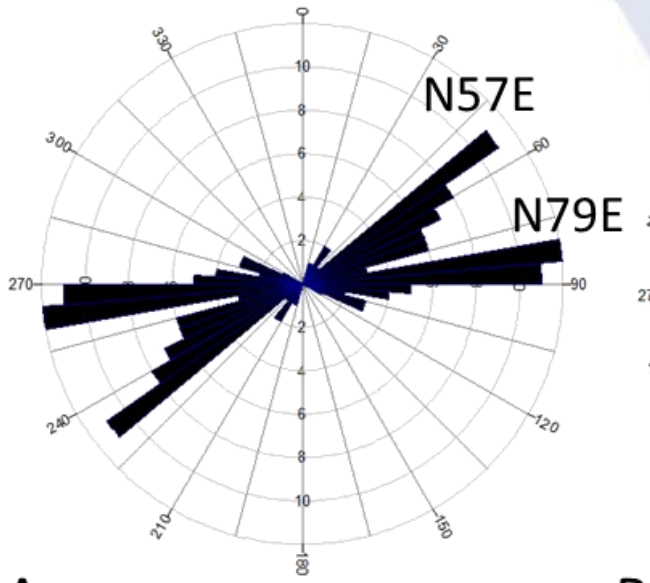
MSEEL
Completion MIPU 3H and 5H

MSEEL - LOGGING LATERAL

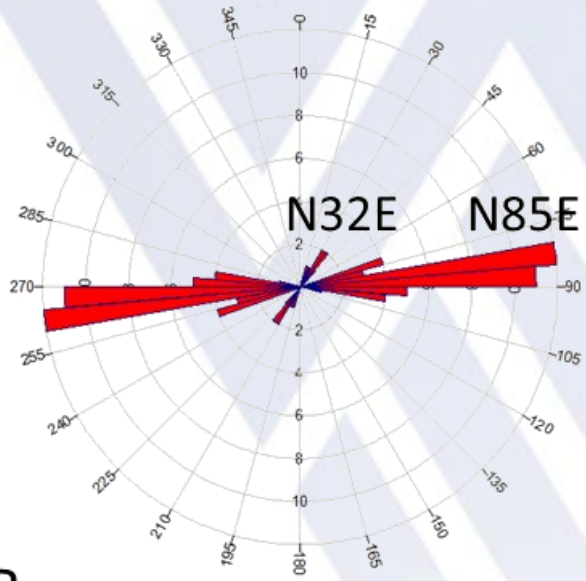
High Definition open hole logs in lateral with synthetic mud



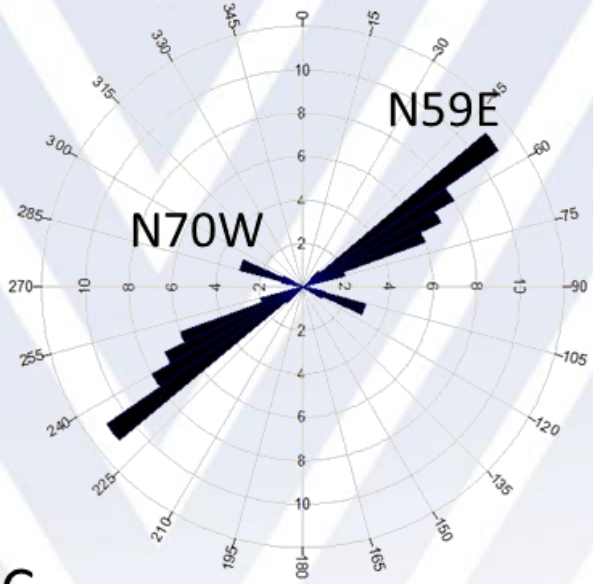
MSEEL – Microseismic and Borehole



A.

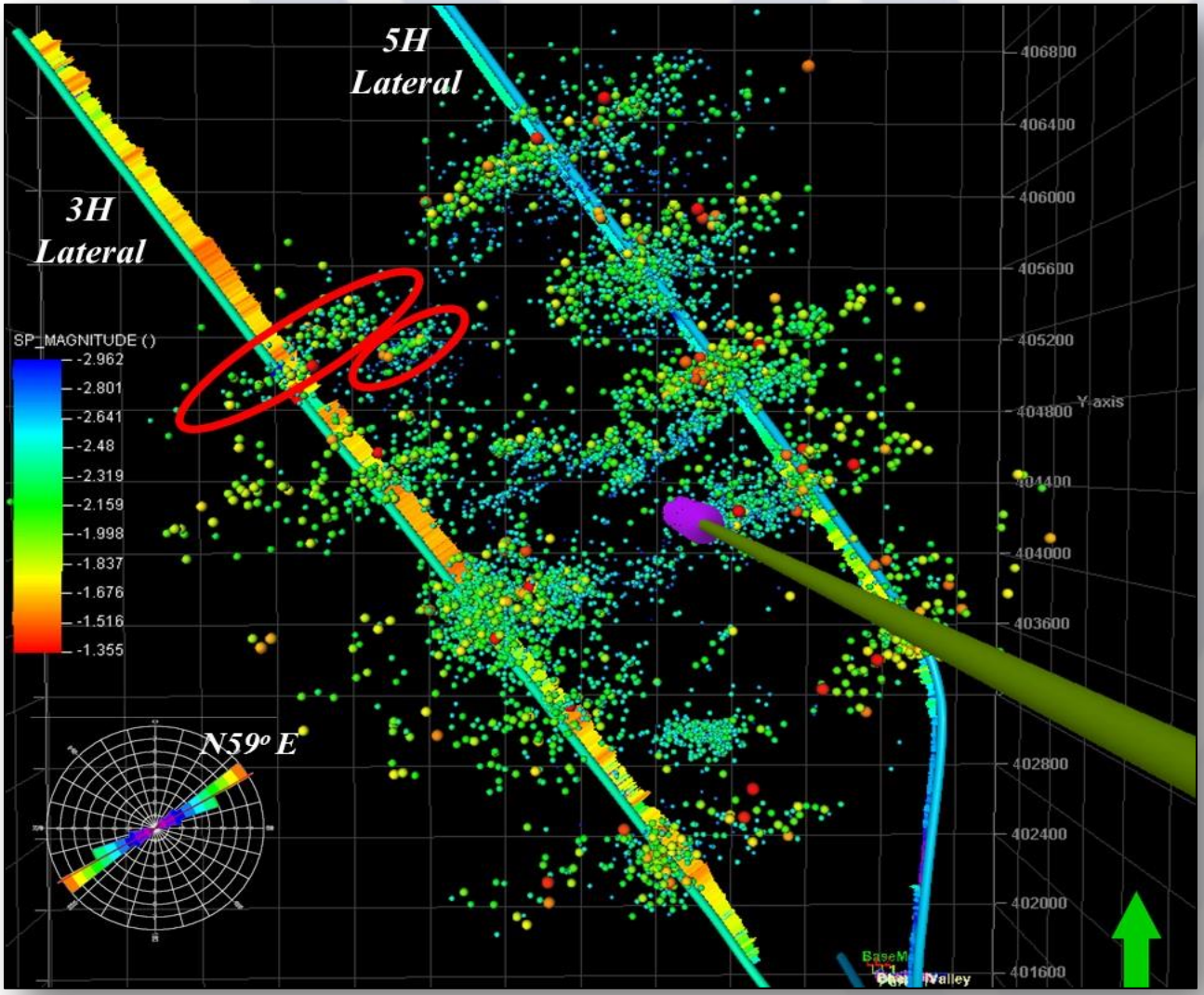


B.

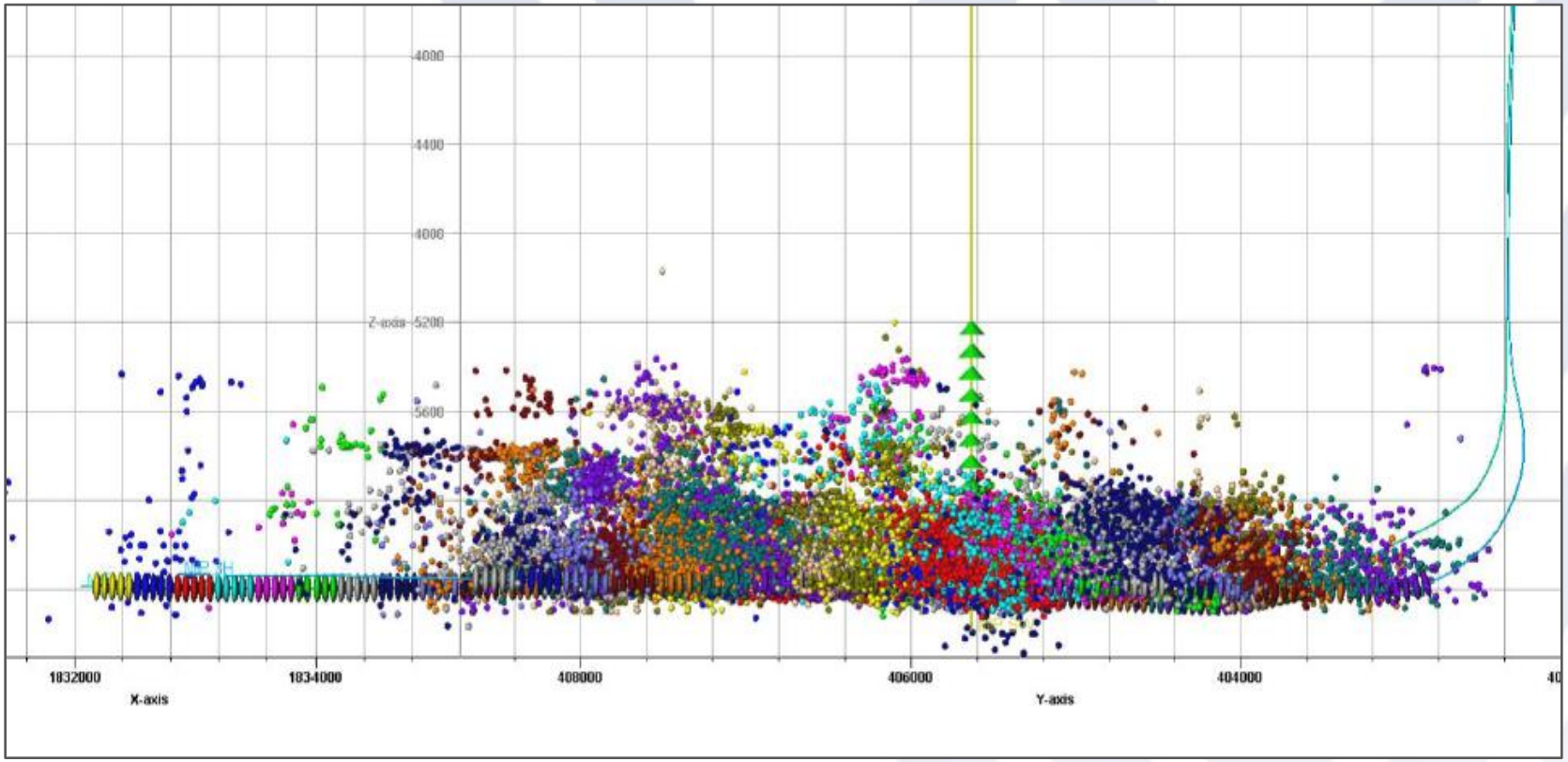


C.

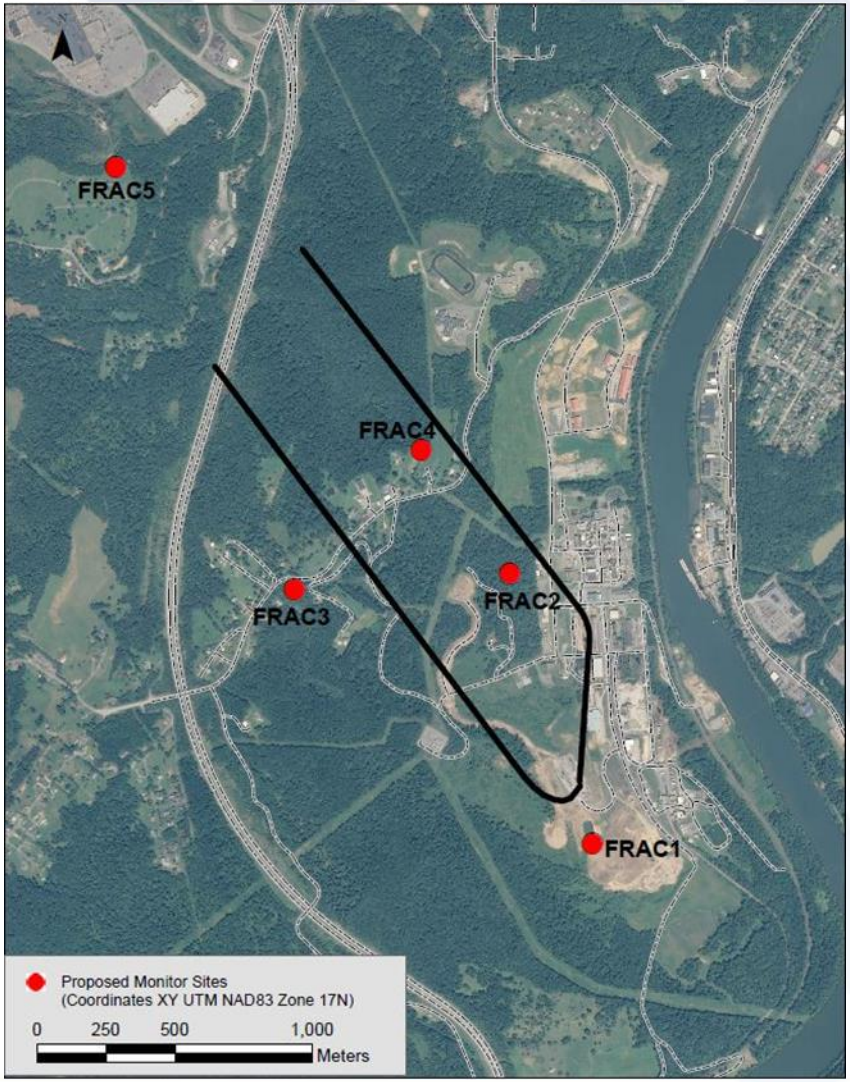
MSEEL - Microseismic



MSEEL - Microseismic

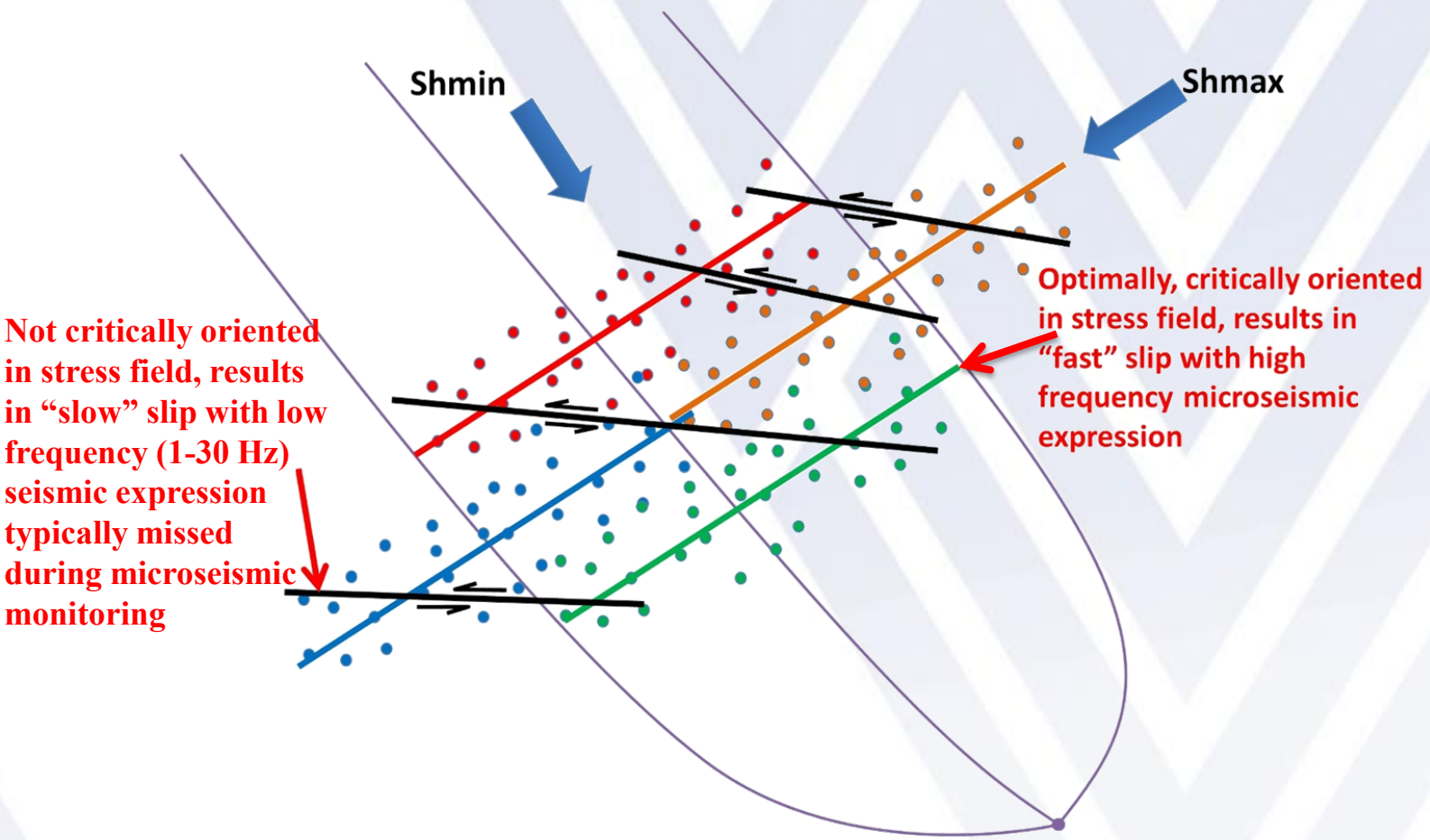


SURFACE MONITORING OF SLOW SLIP (LPLD)



SURFACE MONITORING OF SLOW SLIP (LPLD)

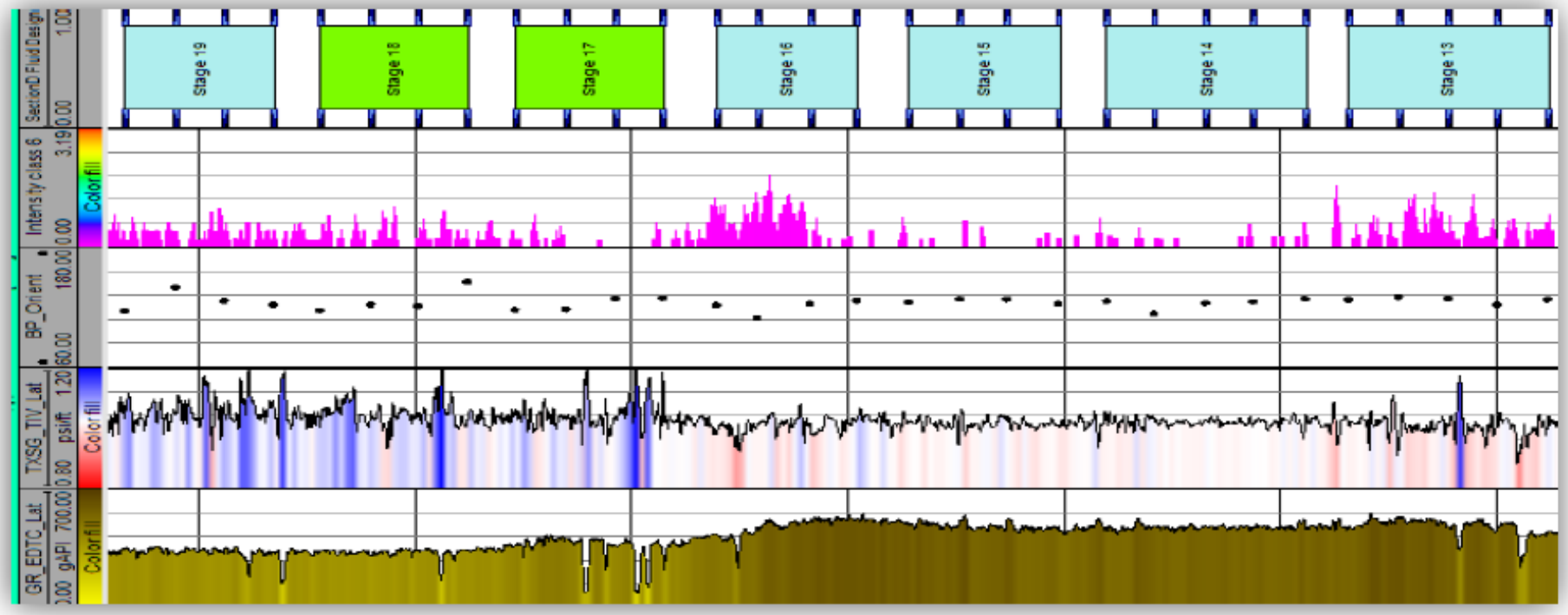
Synopsis of slow-slip deformation



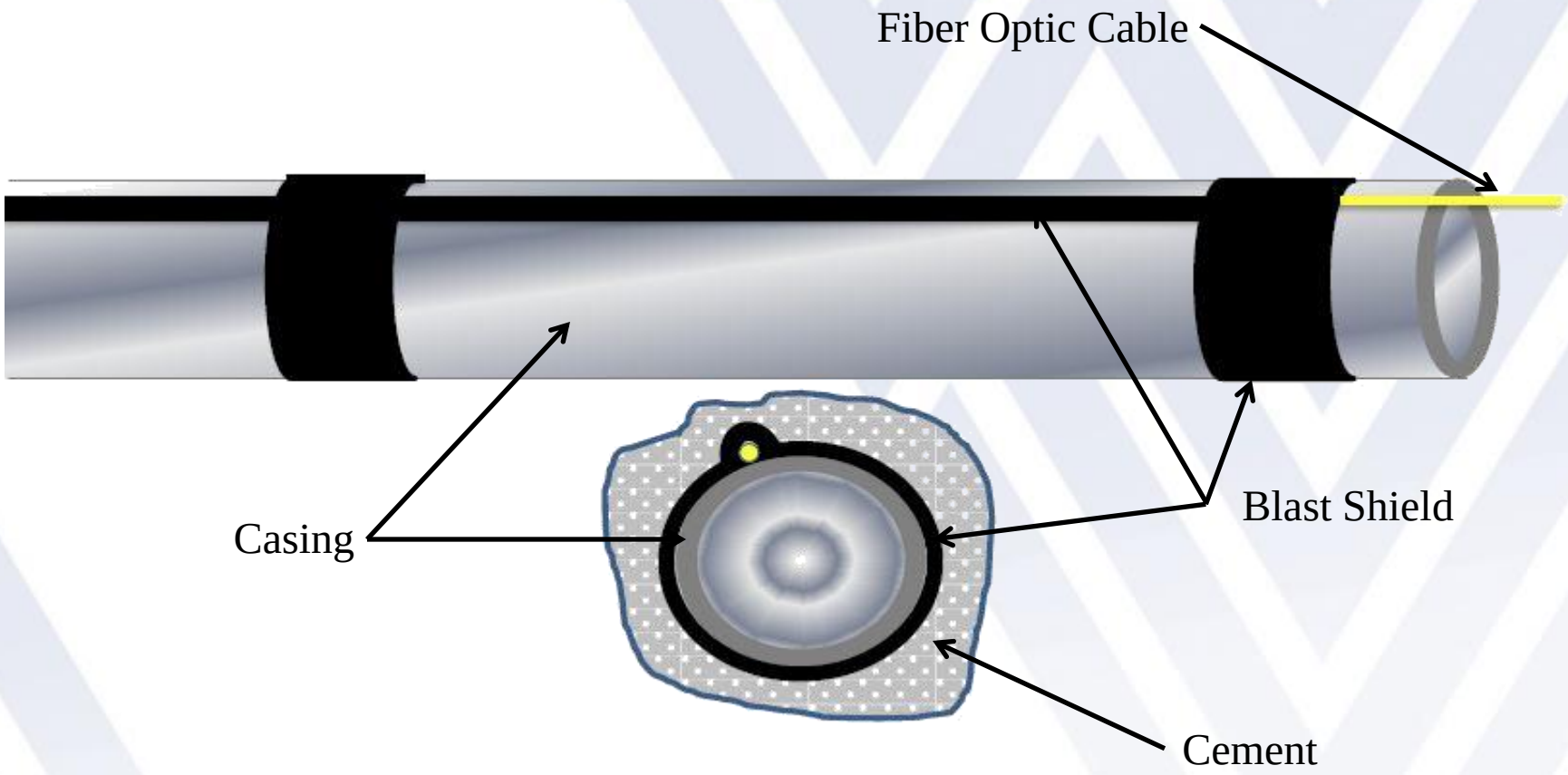
Adapted from Kumar et al. 2016 and Zoback et al., 2012

MSEEL - LOGGING LATERAL

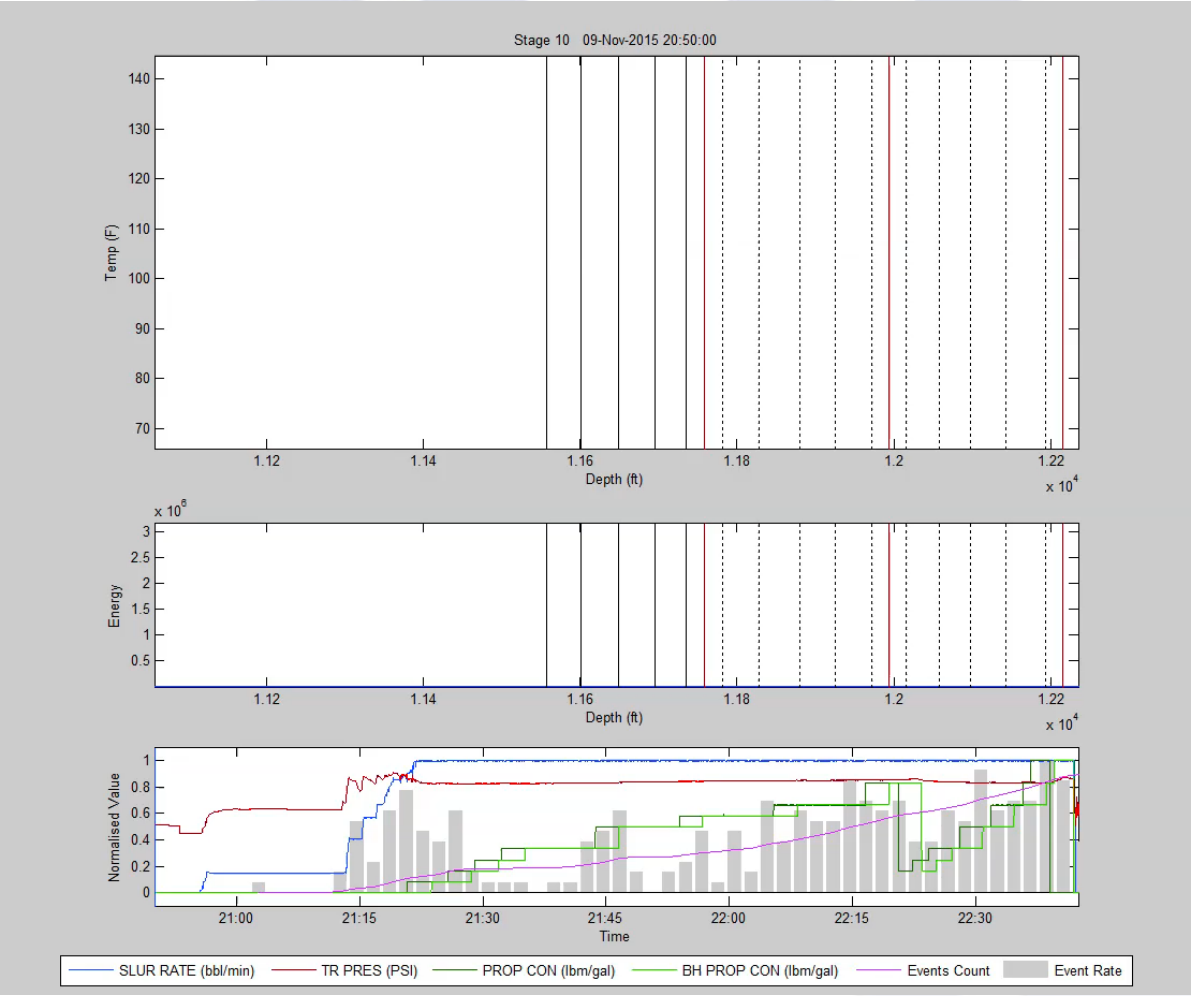
High Definition open hole logs in lateral with synthetic mud



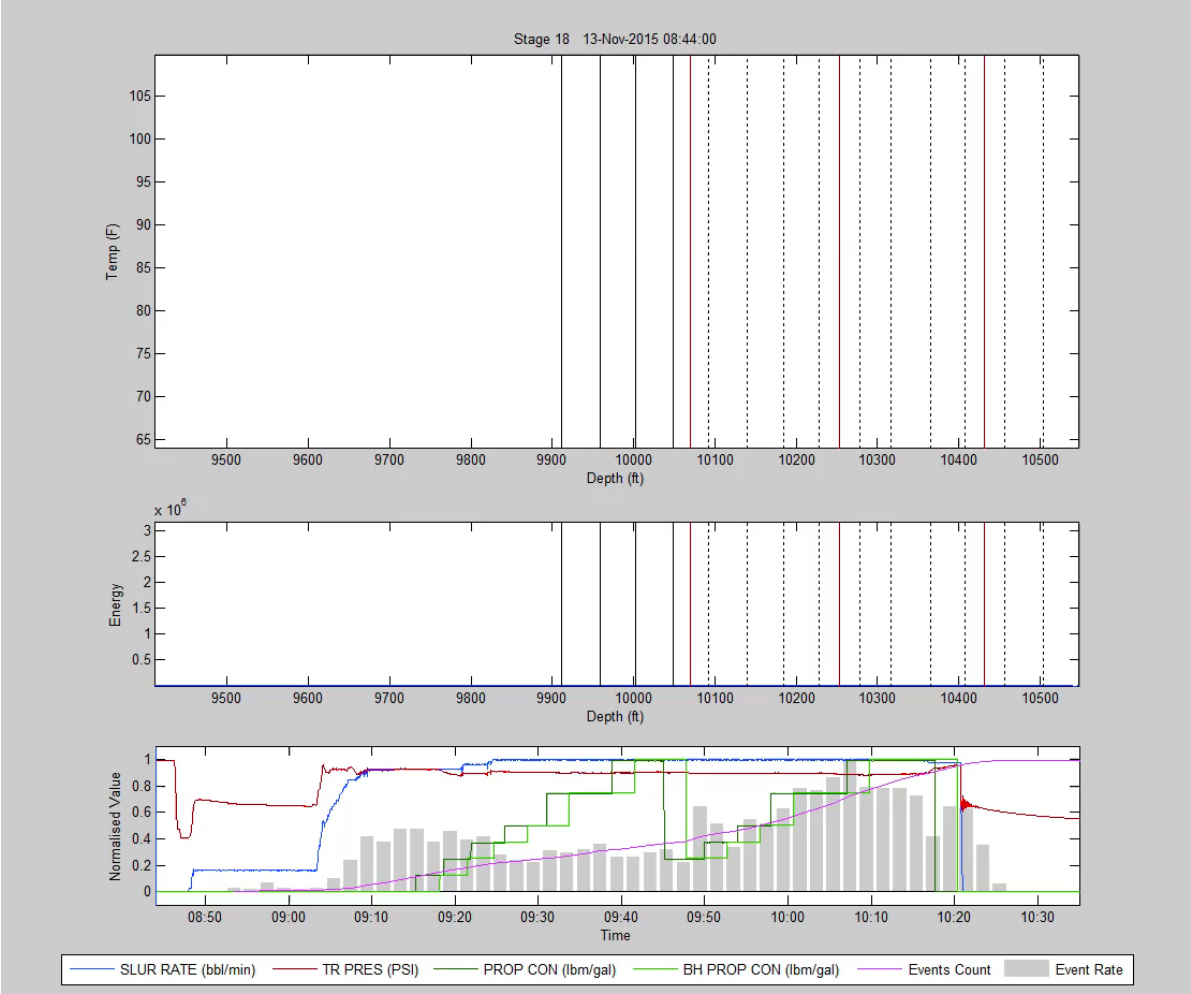
Fiber Optic Installation



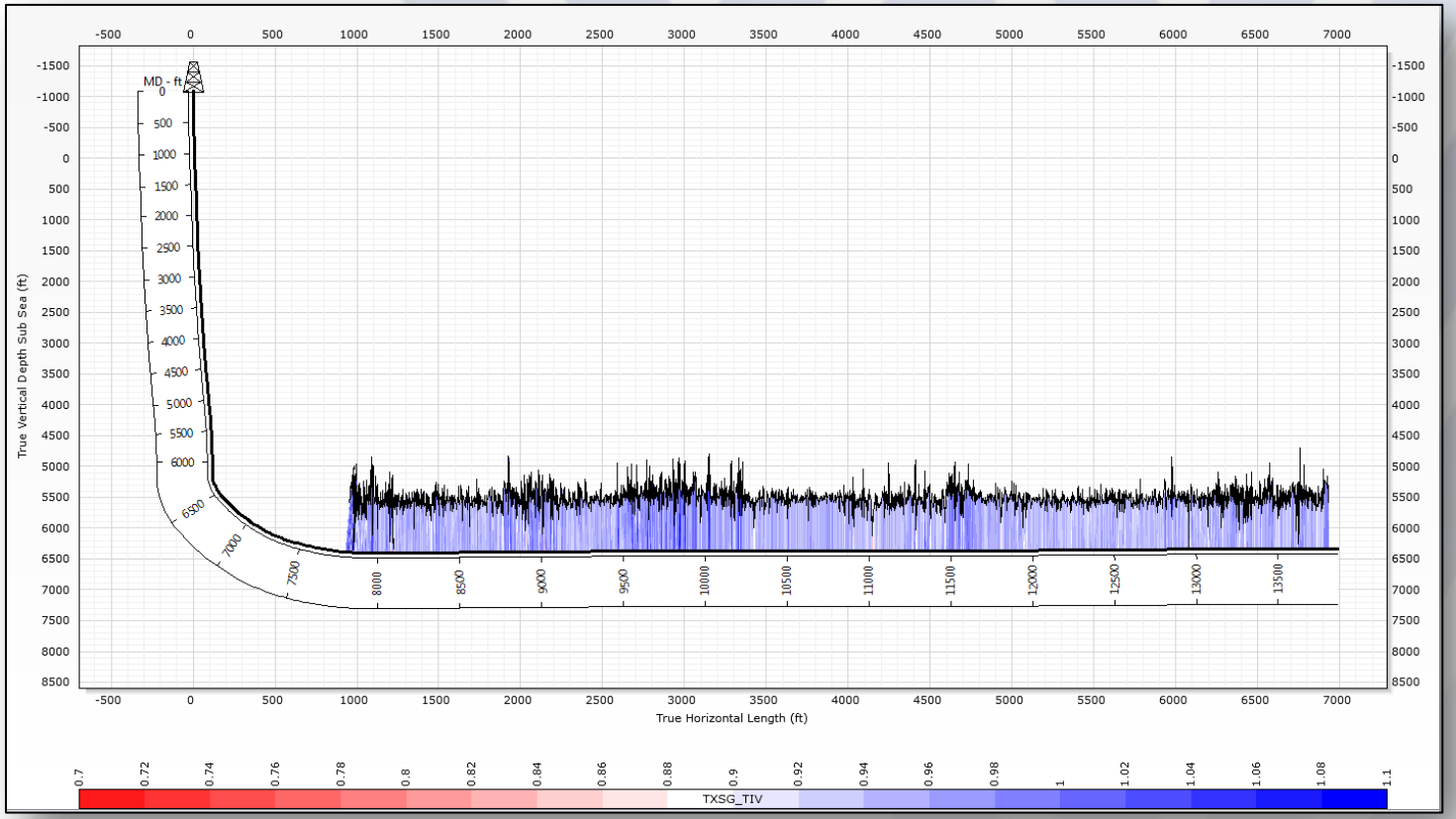
MIP3H - Stage 10: Uneven Distribution



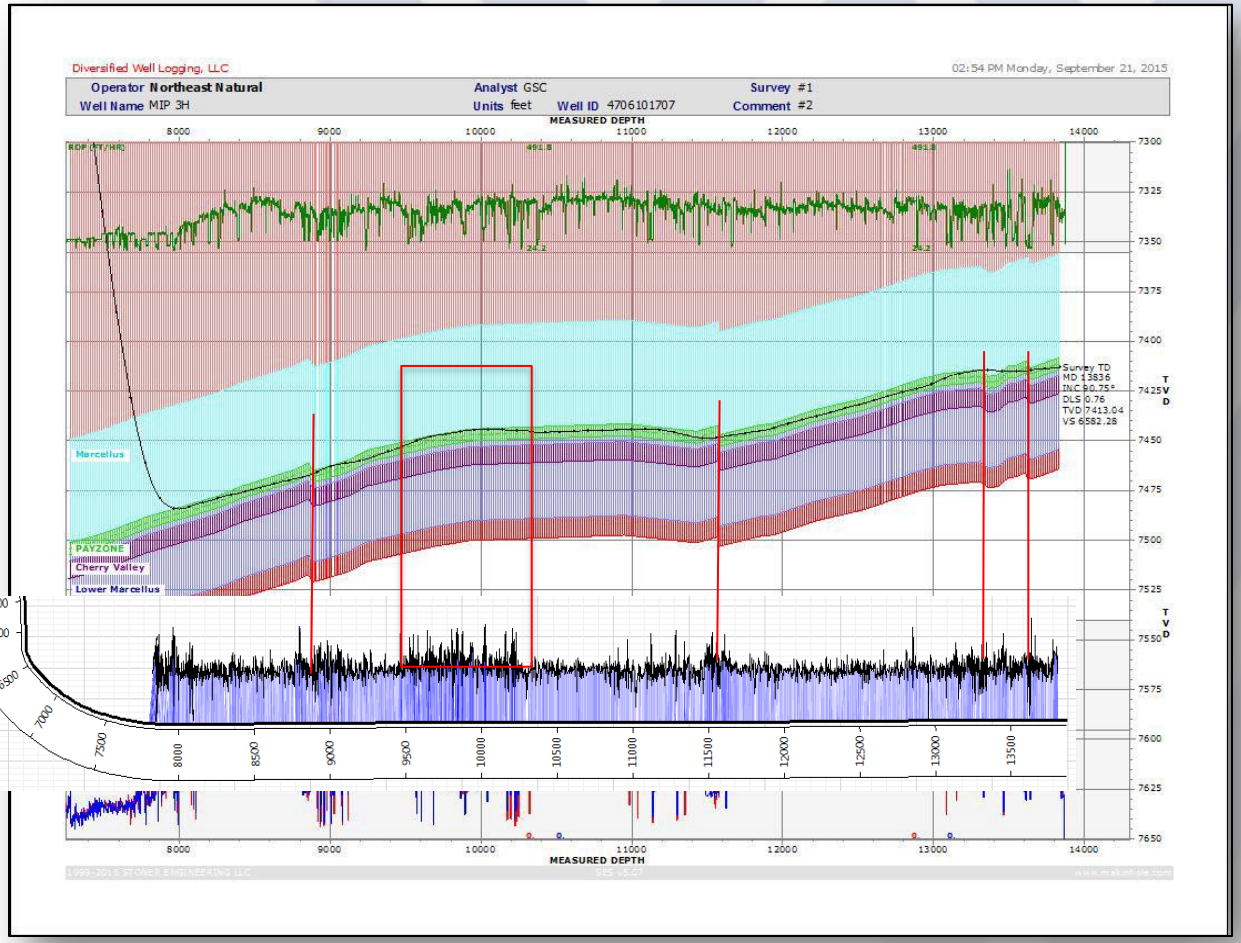
MIP 3H - Stage 18 Even Distribution



Anisotropic Closure Pressure



Anisotropic Closure Pressure Thin Data Prediction



Potential Future Work

- Continued Monitoring
  - Produced Fluids and Gas
  - Production
- Modeling
  - Reservoir Facies Quality
  - Completion Facies Quality
    - Fracture Development and Persistence
  - Multi-Scale Flow Modeling (Nano ➔ Reservoir Scales)
- Production Logging
  - Spinner Survey
  - DAS and DTS
- Big Data ➔ Thin Data Modeling
  - Lateral Facies Modeling
  - Regional Modeling
- Re-Stimulation – New Wells

Building Partnerships for Research, Education, and Outreach

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West Virginia University
MSEEL
Marcellus Shale Energy & Environment Laboratory
Northeast Natural Energy