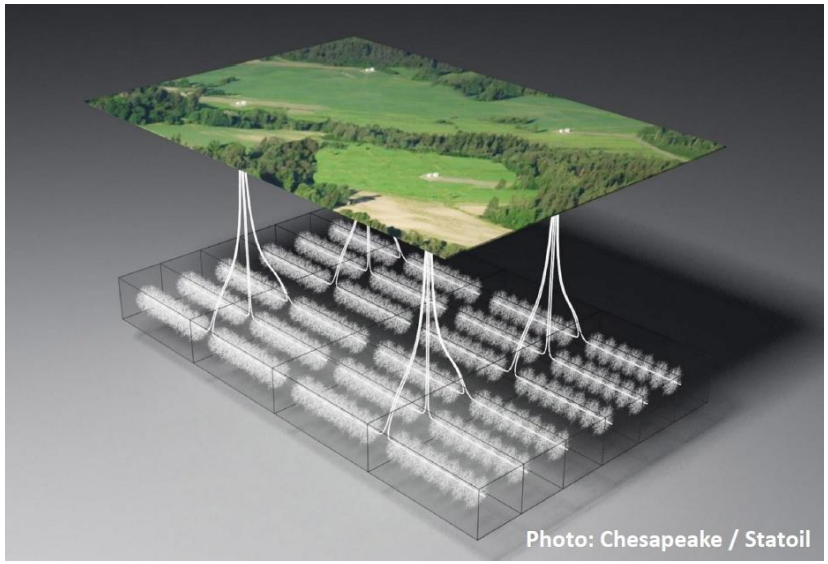

Industrialization and the Shale Gas/Oil Operation

A. R. Ingraffea

Dwight C. Baum Professor
Cornell University
and
Physicians, Scientists, and Engineers for Healthy Energy, Inc.

Northwestern University
April 17, 2013

Outline of Presentation

- **Geology Rules !: Why Is the Process Called Unconventional, and Why Does It Require Heavy Industrialization?**
- What Industrialization Is Needed: Upstream, Midstream, Downstream
- What Shale Gas/Oil Might Look Like in Illinois: Is It Worth It? Are There Constraints and Alternatives?

USGS Estimates of Oil/Gas in Illinois Basin

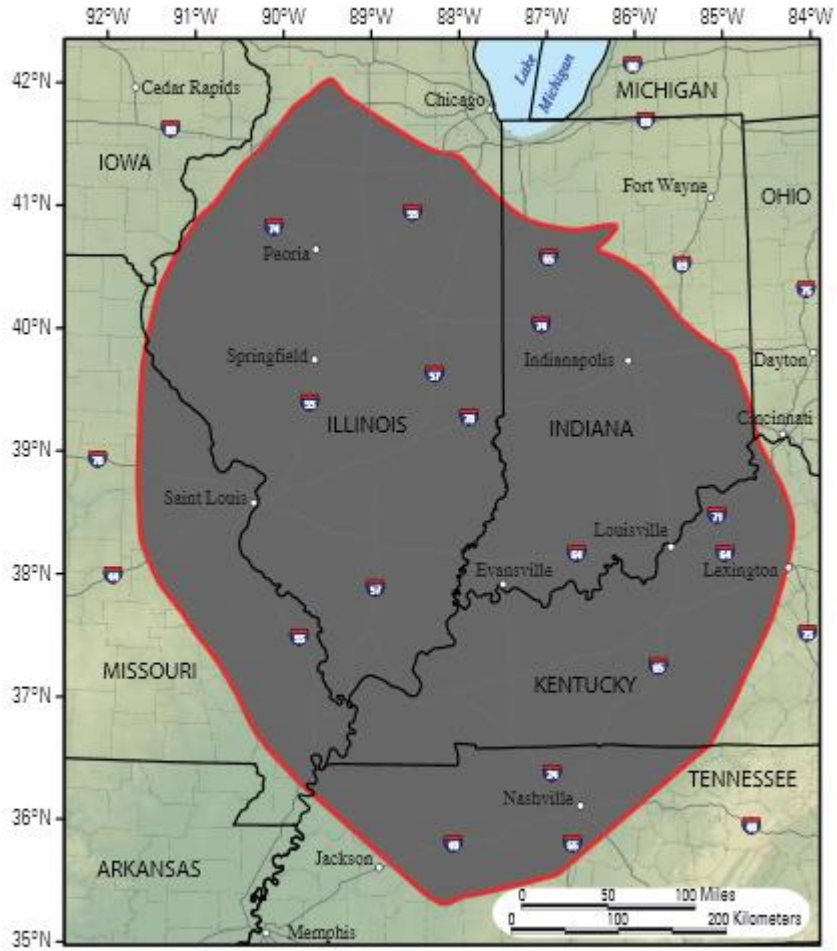

Figure 1. Location of the Illinois Basin (assessed area is within the red boundary).

"For the Illinois Basin, the USGS estimated the quantities of undiscovered, technically recoverable oil and gas resources as follows:
(1) a mean of 214 million barrels of oil,
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(3) a mean of 24 million barrels of natural gas liquids."

214 million barrels of oil is about 10 DAYS of U.S. consumption

4.65 TCF of nat gas is about 2 MONTHS of U.S. consumption

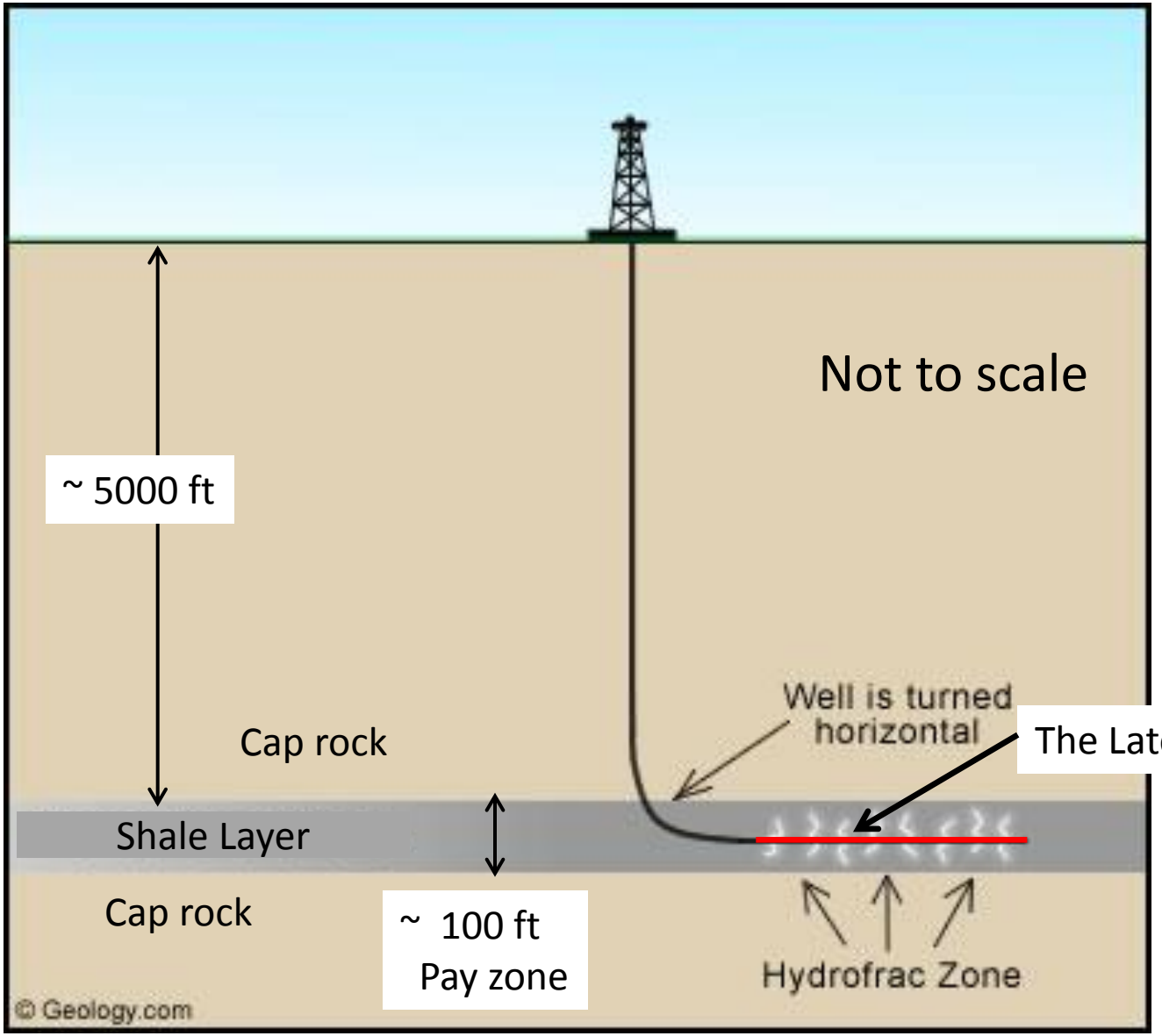
http://pubs.usgs.gov/fs/2007/3058/fs2007-3058.pdf

Why Is Shale Gas/Oil Development "Unconventional"?

Because it requires 4 technologies only recently combined to make gas/oil production from impermeable shales technically and economically feasible:

- Directional drilling: needed to access a thin layer of shale with long laterals.
- High frac fluid volumes: needed to stimulate hydrocarbon release from many natural fractures.
- Slickwater: needed to control the amount of power needed to pump large volumes of frac fluids, at high pressures, quickly, over long distances, through small diameter casing.
- Multi-well Pads and Cluster Drilling: needed to access as much of the inventory as possible, under constraints of leasing and capital.

High Volume, Slickwater Frac'ing from Long Laterals: The Concept



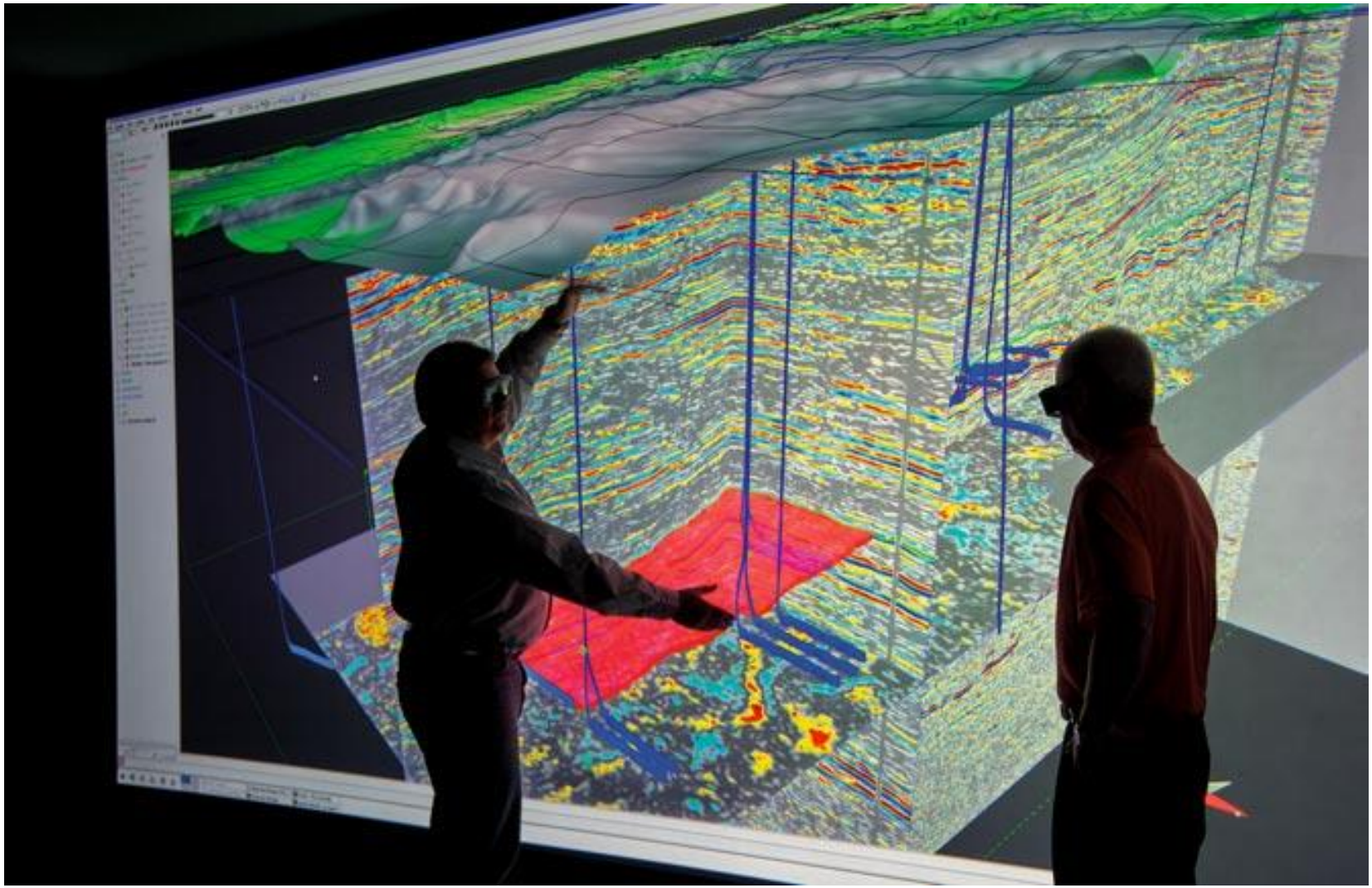
Producing Shales are Heavily Fractured Naturally

Geneseo-Burket (Devonian black shale)

Taughannock Falls State Park, Trumansburg, N.Y.

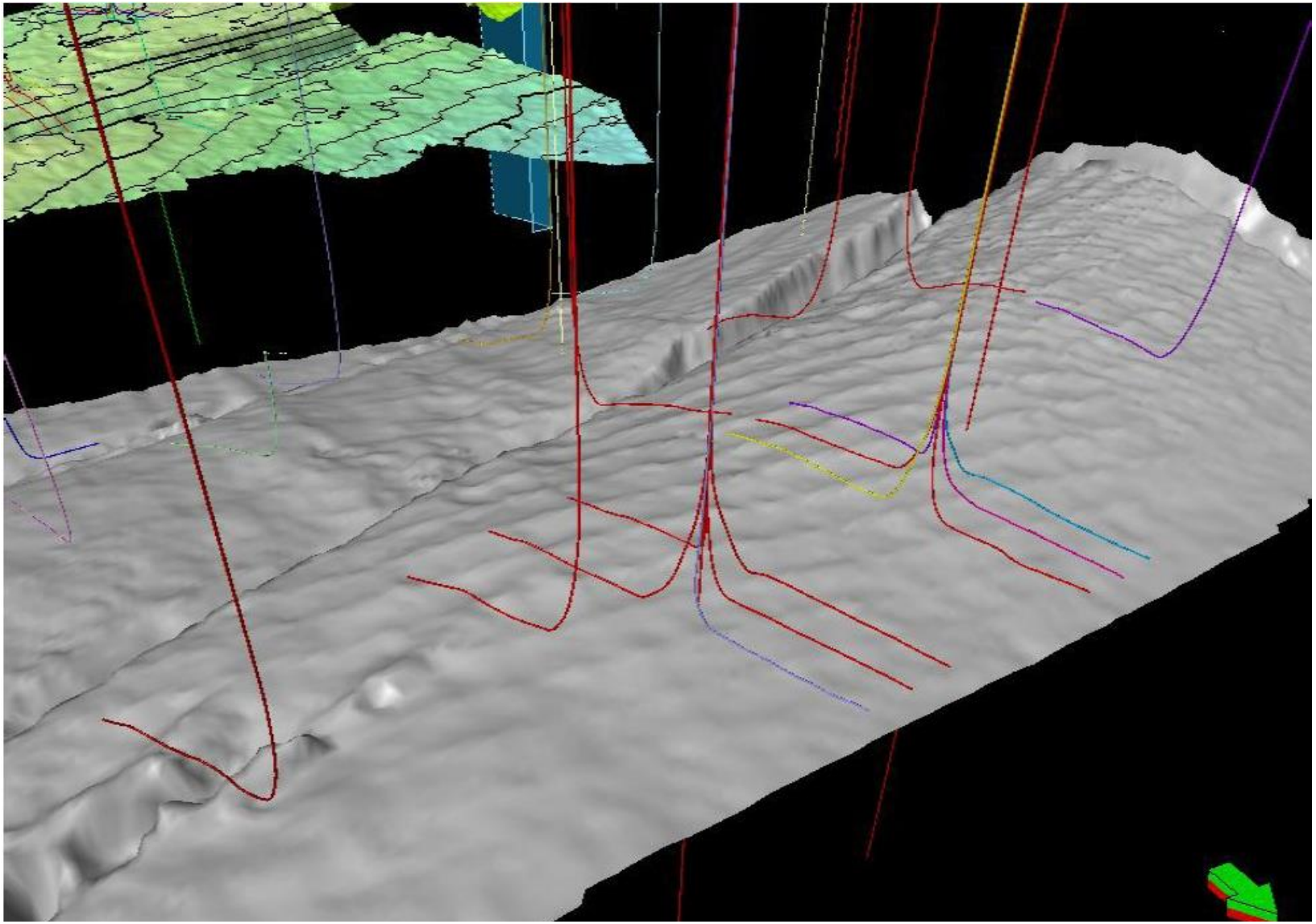
Photo Courtesy T. Engelder

3D Imaging of the Sub-Surface



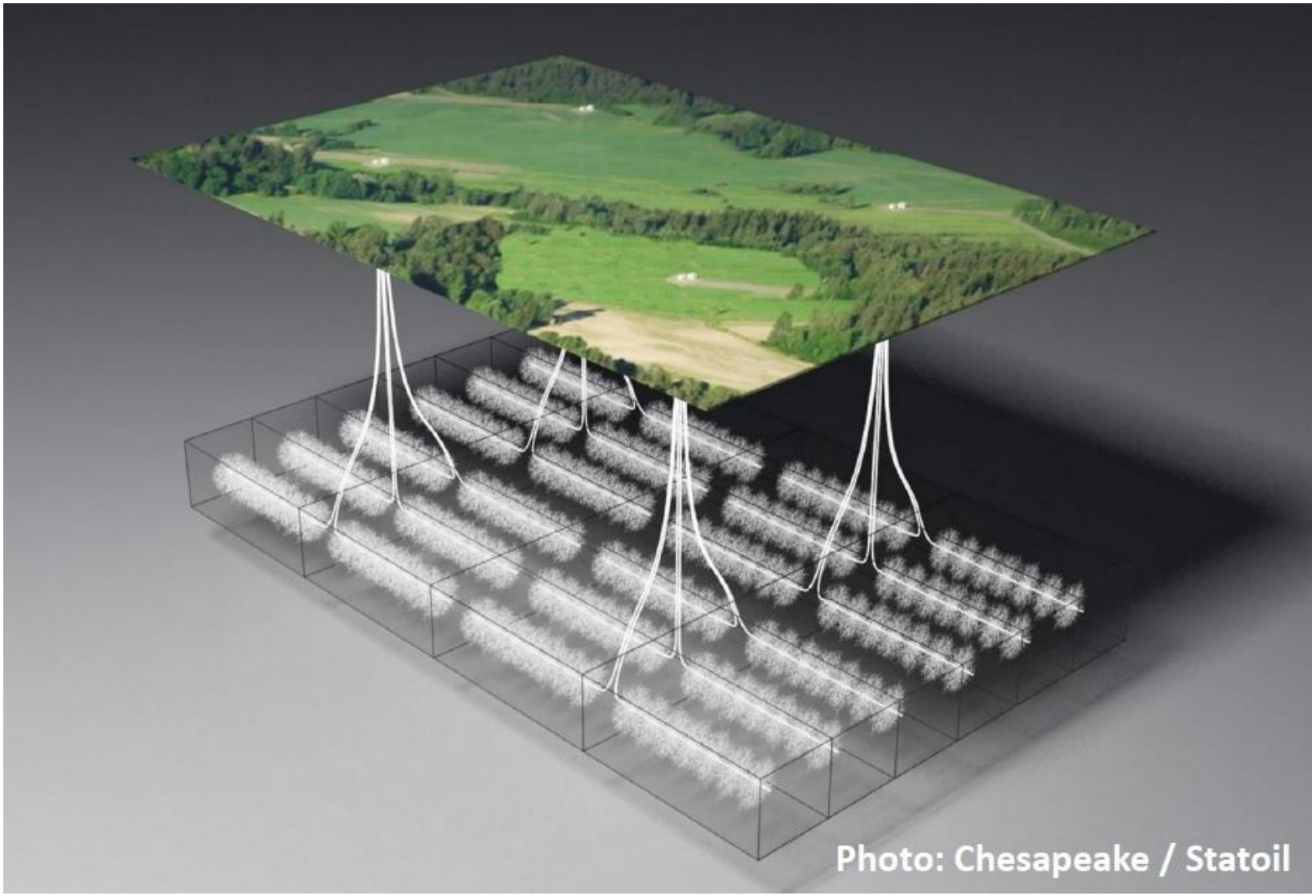
From *National Geographic*, December 2012

Targeting the Shale Layer Via Multiple, “Horizontal” Wells from Clusters of Pads

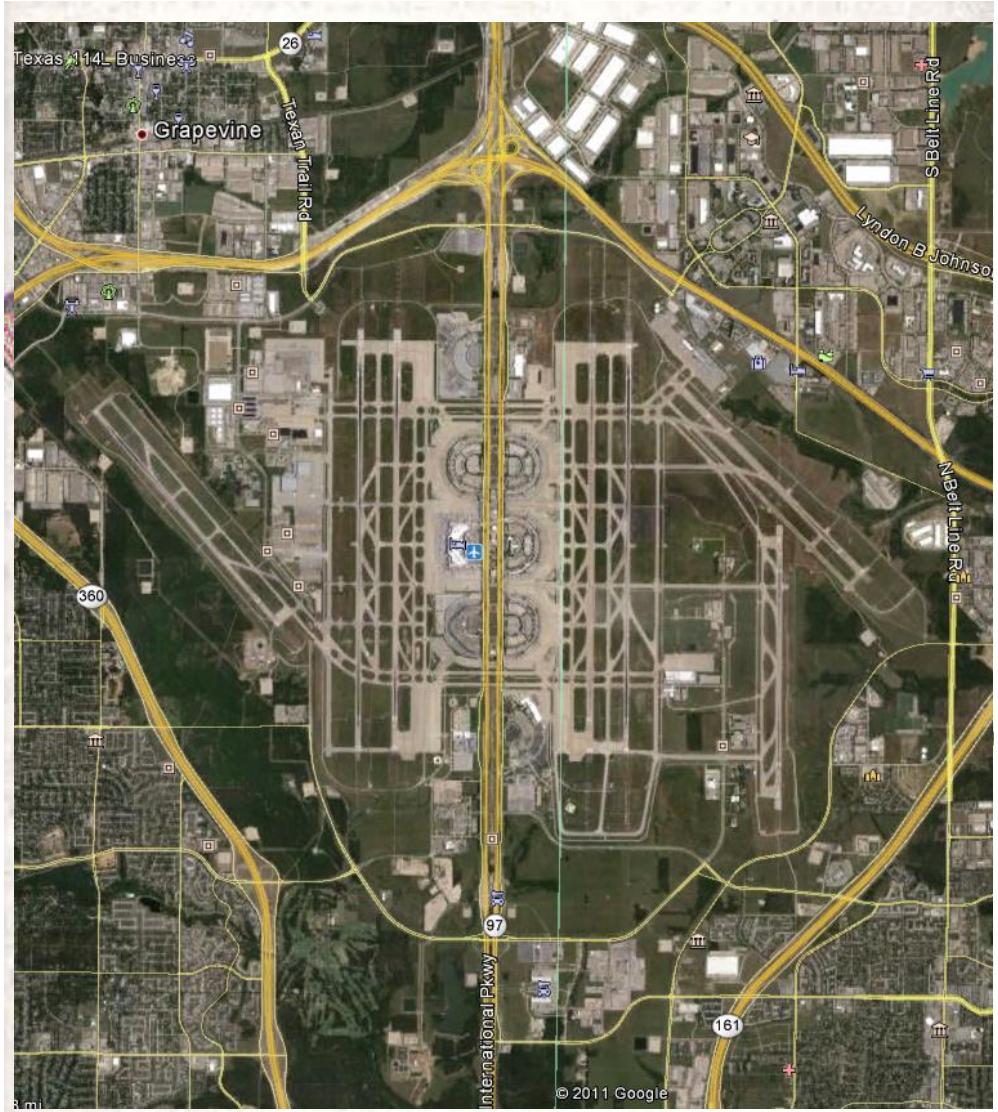


From Cody Teff, Shell Appalachia, WELL CONSTRUCTION PRACTICES IN THE MARCELLUS

Shale Gas/Oil Production Must Use Clustered, Multi-Well Pads and High-Volume Long Laterals



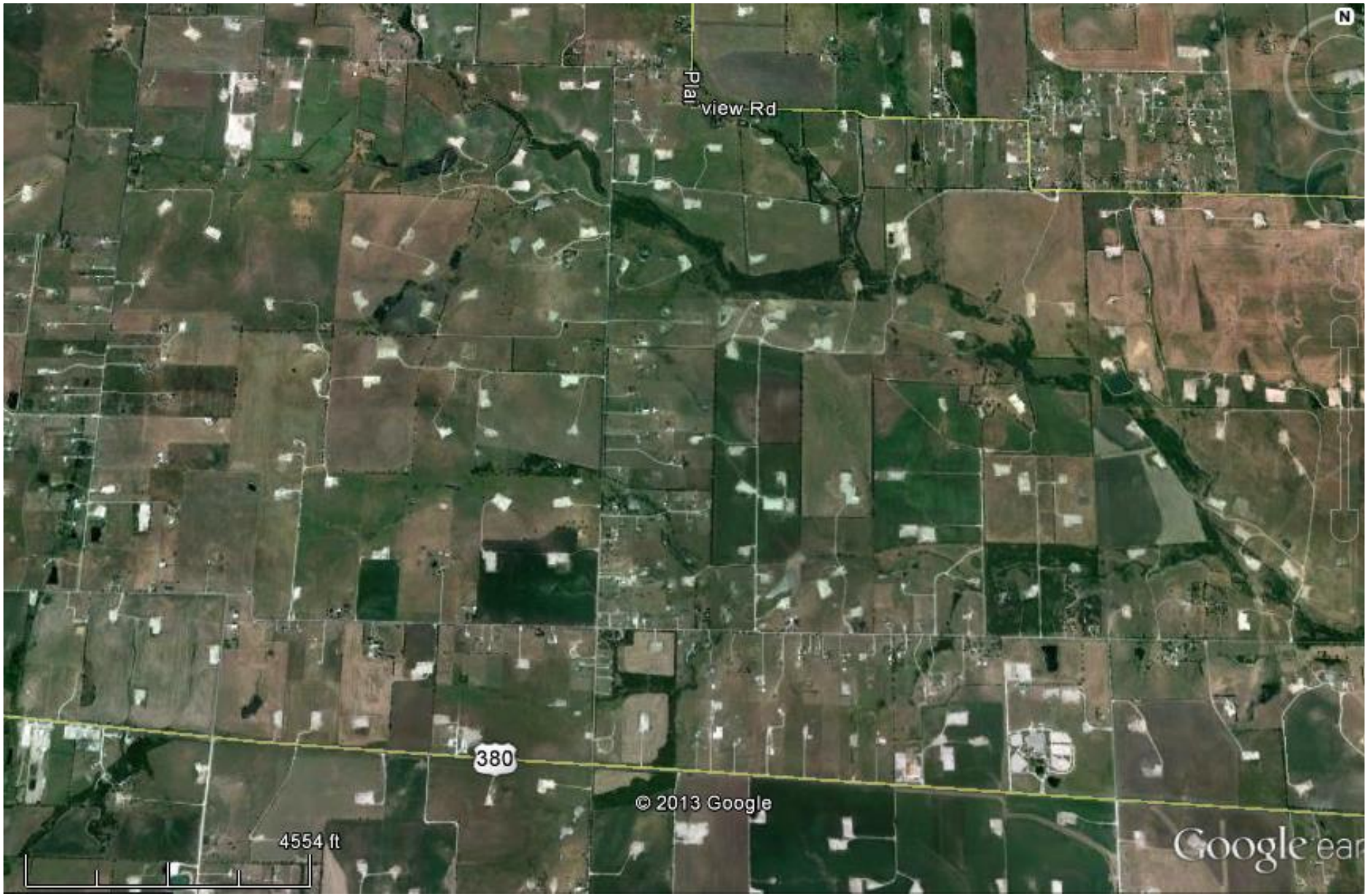
Example of Spatially Intense Development from Clustered, Multi-Well Pads:
Dallas/Fort Worth Airport Property, Barnett Shale Play



SOURCE: CHESAPEAKE ENERGY

- 53 pads on 18,076 acres, 30 square miles
- Each red line is a well
- Each red dot is a pad
- Almost complete coverage
- Patchwork, mostly ideal units
- One leasor, One developer

Barnett Shale Play: Pad Density



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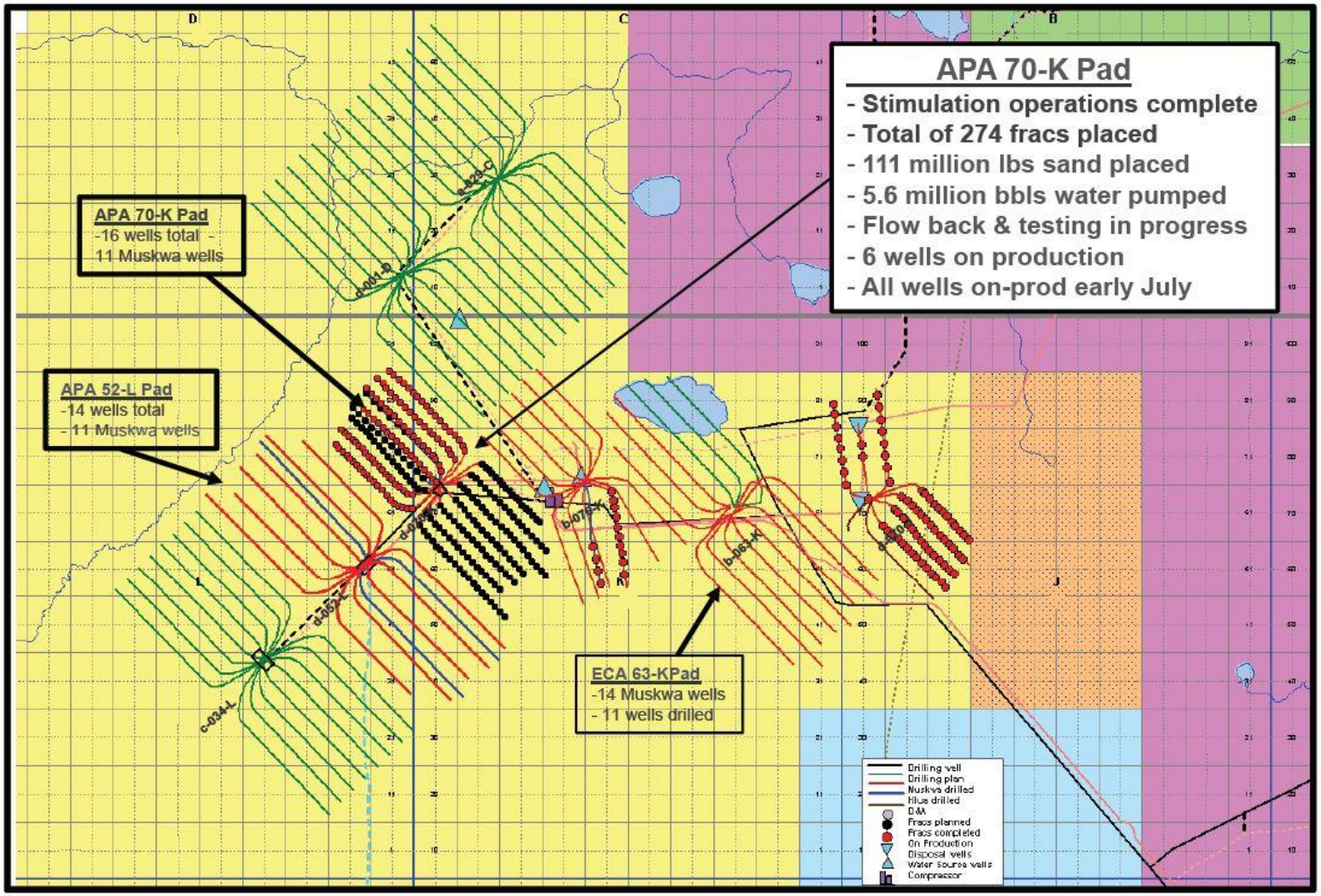
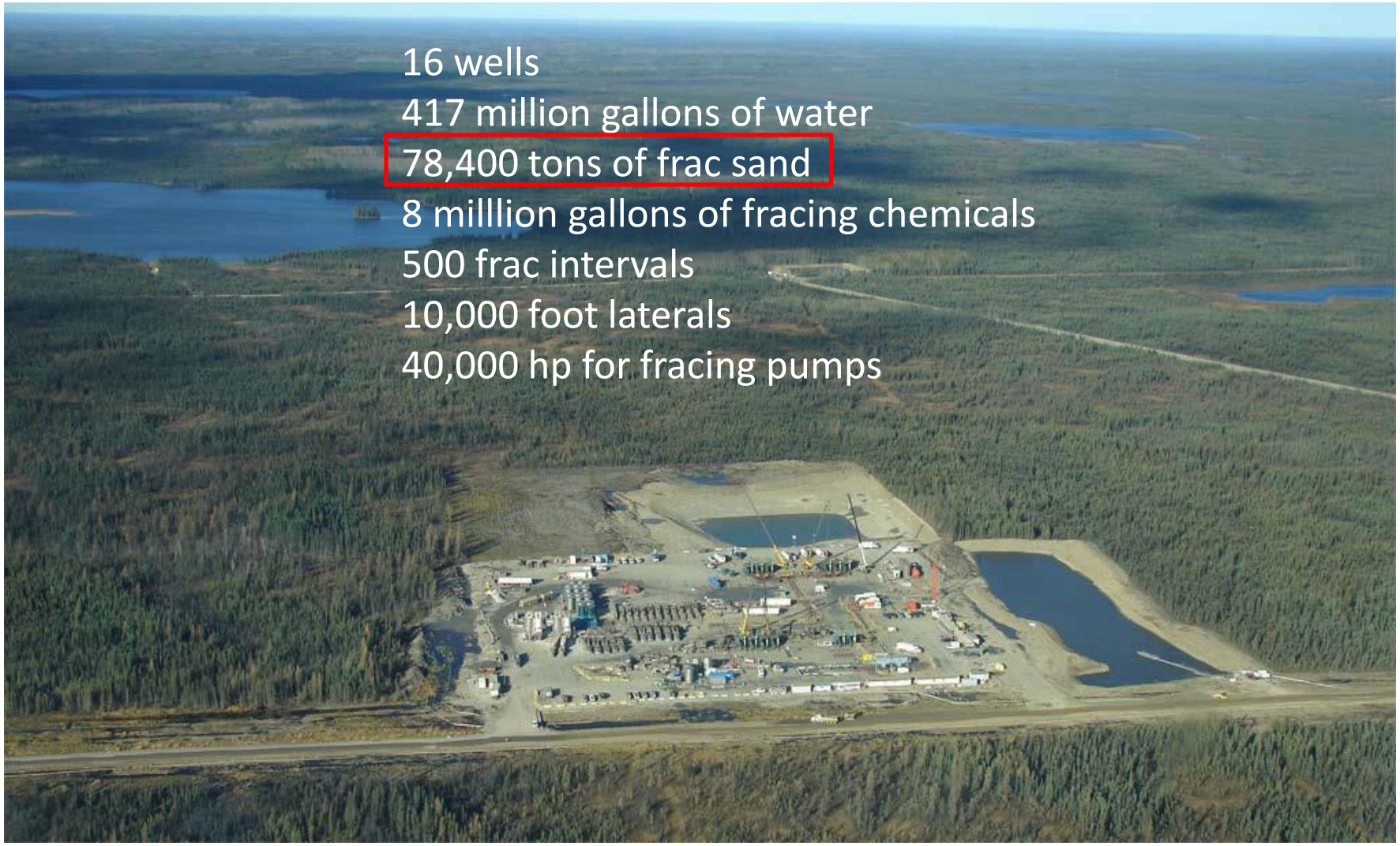
Horn River Area, NE British Columbia

Two Island Lake Operations Status



World's Largest Frac Job (?), Encana, Horn River Area, NE British Columbia



Example of Upstream Industrialization: Frac Sand Mining in the Upper Midwest

A sand mine r

http://www.huffingtonpost.com/2012/12/07/frac-sand-mining-wisconsin-health_n_2256753.html#slide=more234188

Example of Midstream Industrialization: Frac Sand Unloading/Loading in Wyalusing, PA

Photos Courtesy Prof. Yuri Gorby
http://www.youtube.com/watch?v=-iTCRJ6I_zM

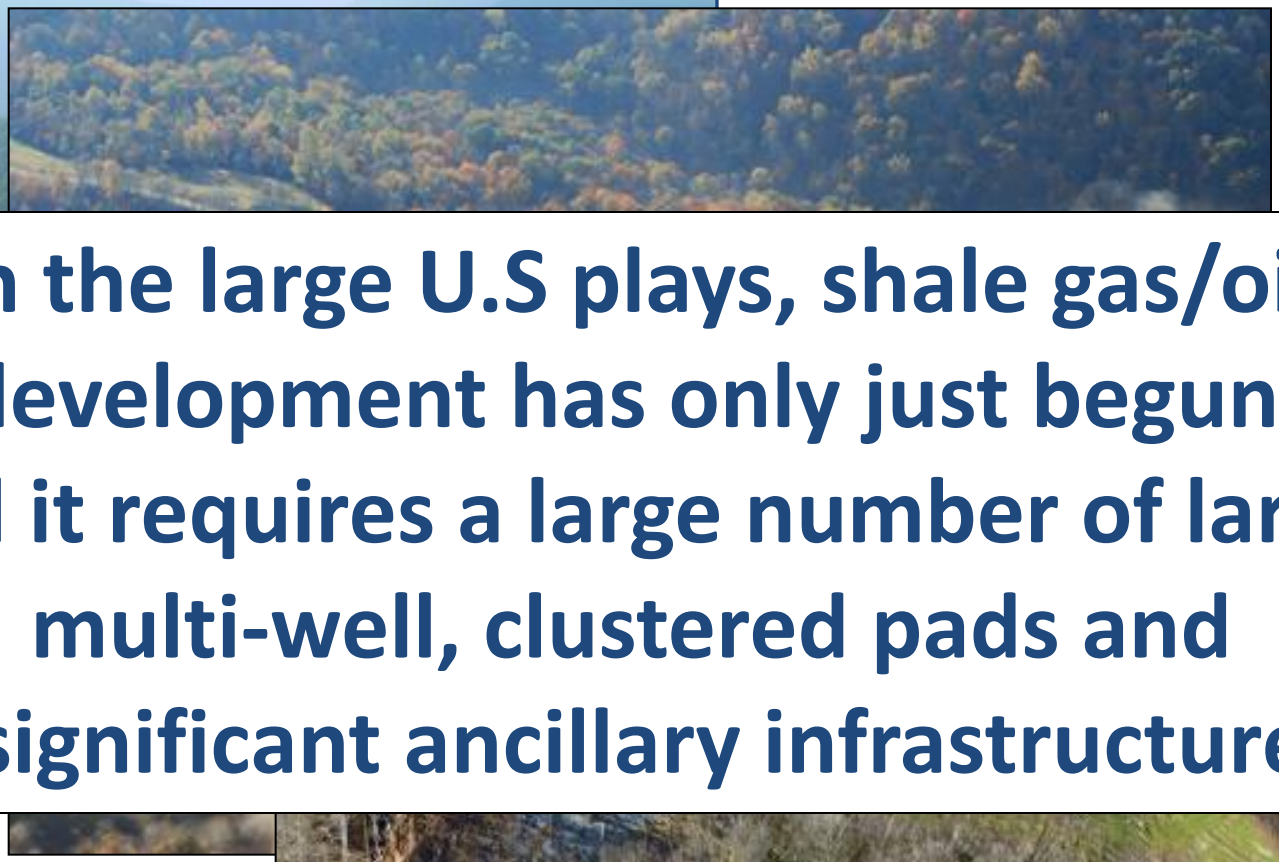
Example of Midstream Industrialization: Pad/Support Construction

Photos courtesy of Bob Donnan

Fracing a Multi-Well Pad Is an Intense Industrial Process, 24/7, 365

Evans City, Pa. N 40°46.196‘ W 80°6.285‘, 1/27/13
Photo courtesy Bob Donnan

Pads Can Be Constructed Regardless of Terrain



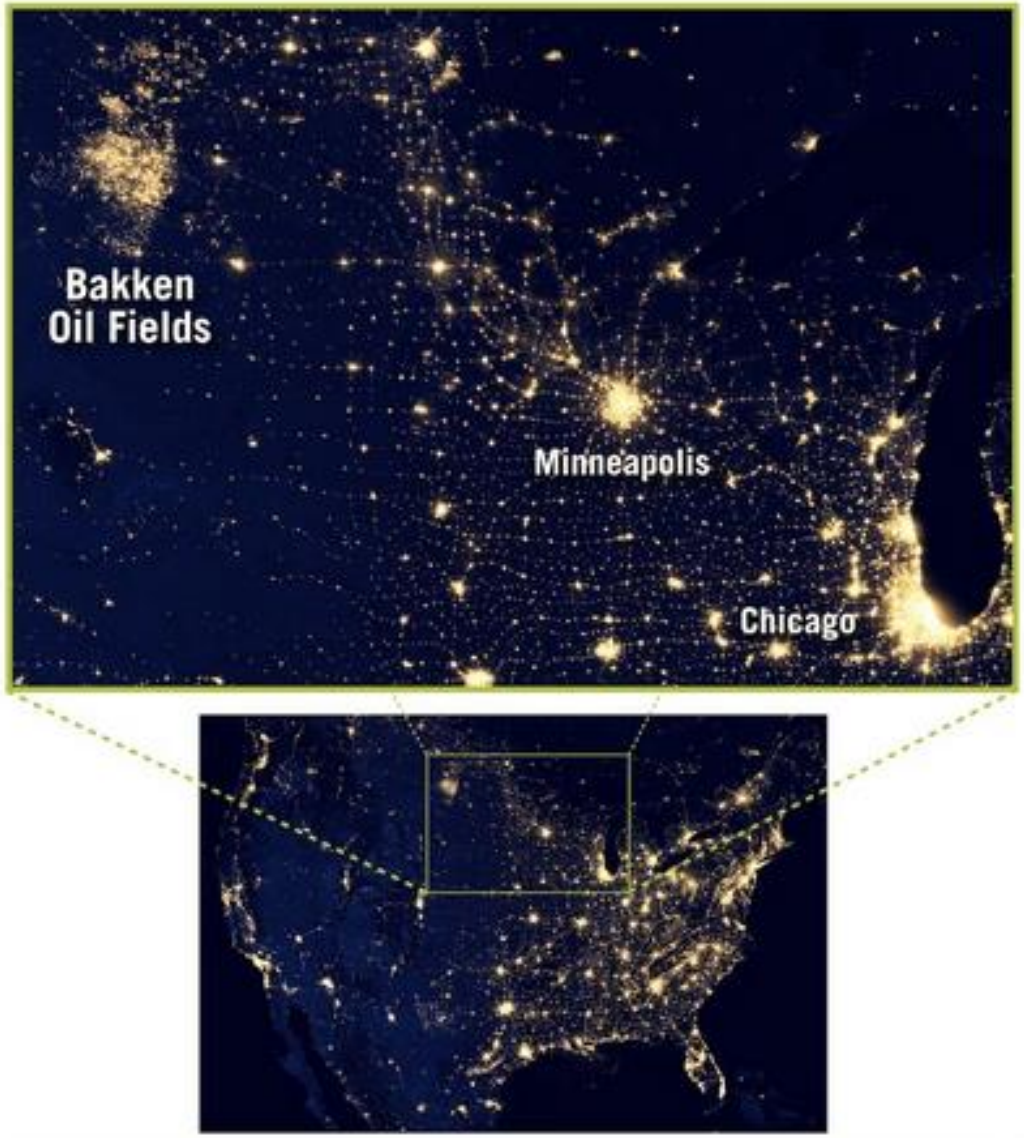
In the large U.S plays, shale gas/oil development has only just begun, and it requires a large number of large, multi-well, clustered pads and significant ancillary infrastructure

Photos Courtesy of Bob Donnan

Additional Midstream Surface Impacts: Flares

Photos Courtesy of Bob Donnan

Industrialization on a Global Scale: Light Pollution and Waste of a Natural Resource



Credit: NASA Earth Observatory/NOAA NGDC © 2012

Midstream Surface Impacts on Health/Environment: Impoundments

Photo Courtesy of Bob Donnan

Midstream Surface Impacts: Pipelines and Compressor Stations

Photo Courtesy of Bob Donnan

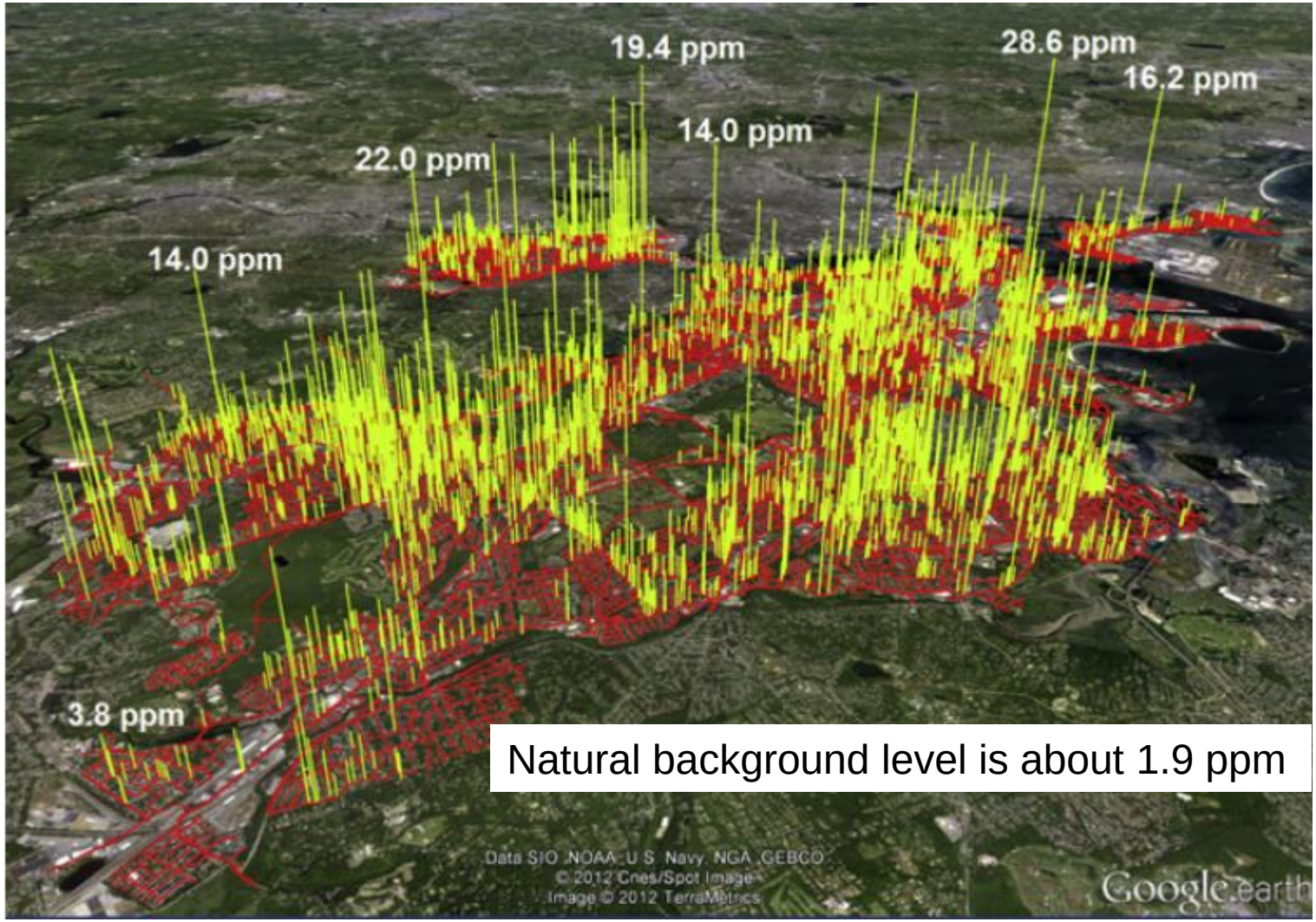
Midstream Impact: Processing Plant Burn-Off, Houston, PA

9/18/11
2:03pm

Photos courtesy of Robert Donnan

Midstream Impact: Processing Plant Burn-Off, Houston, PA

Downstream Methane Leakage from Aging Urban Distribution Pipelines: Boston MA



N.G. Phillips et al. / Environmental Pollution 173 (2013) 1–4

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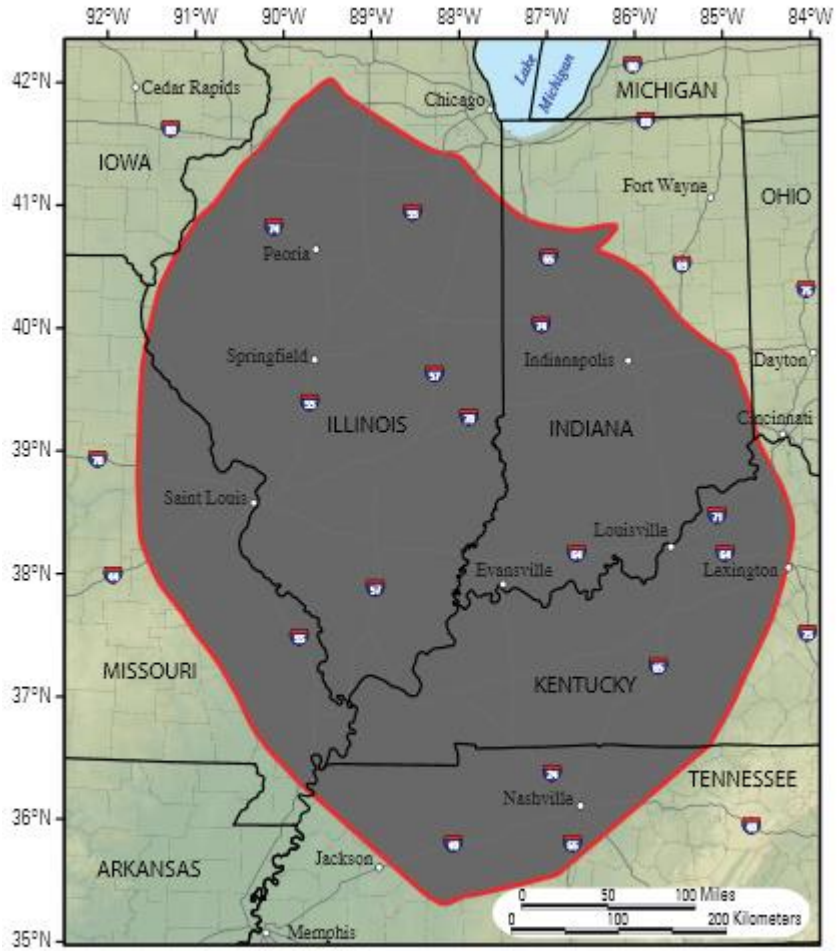

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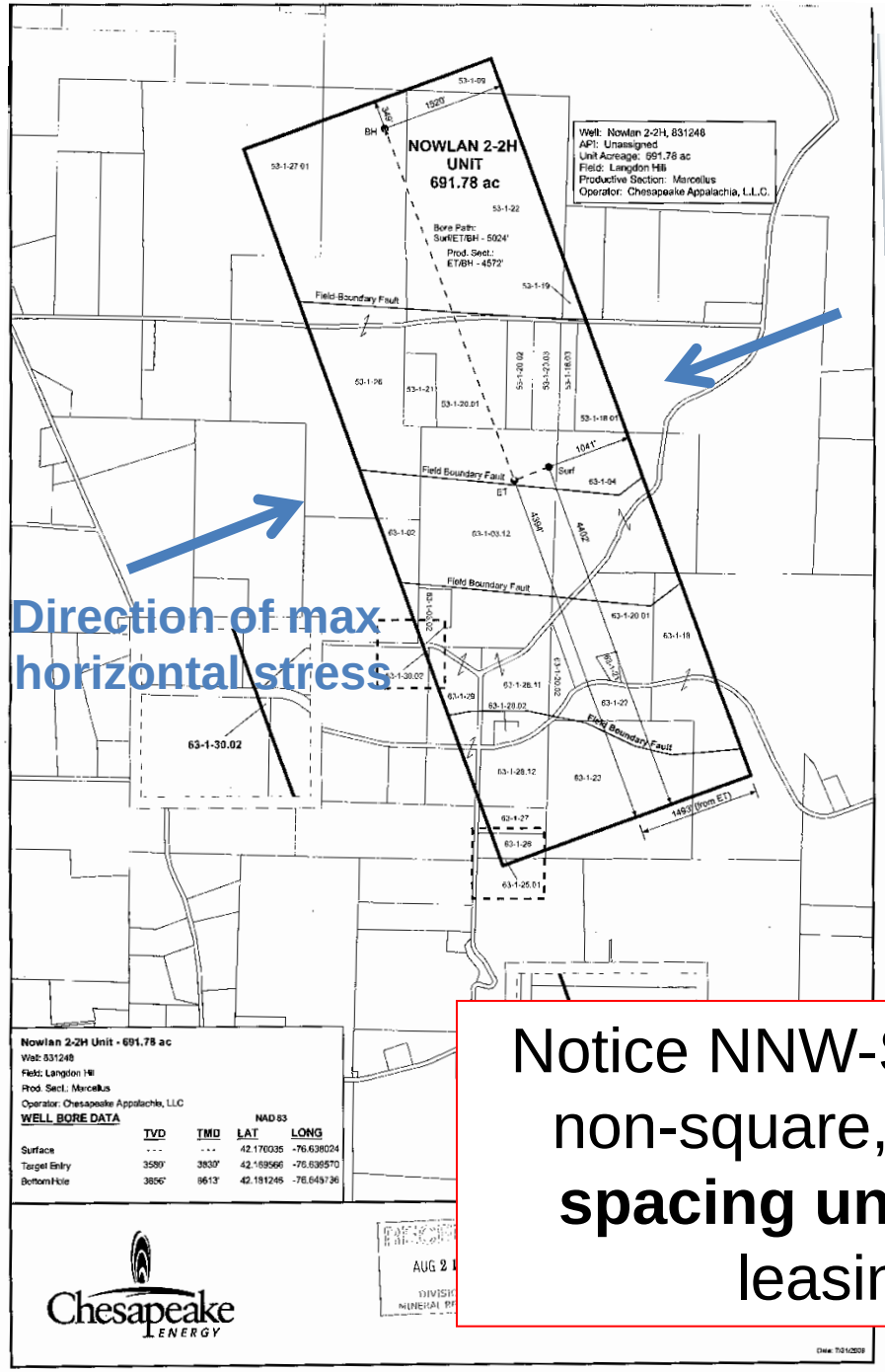
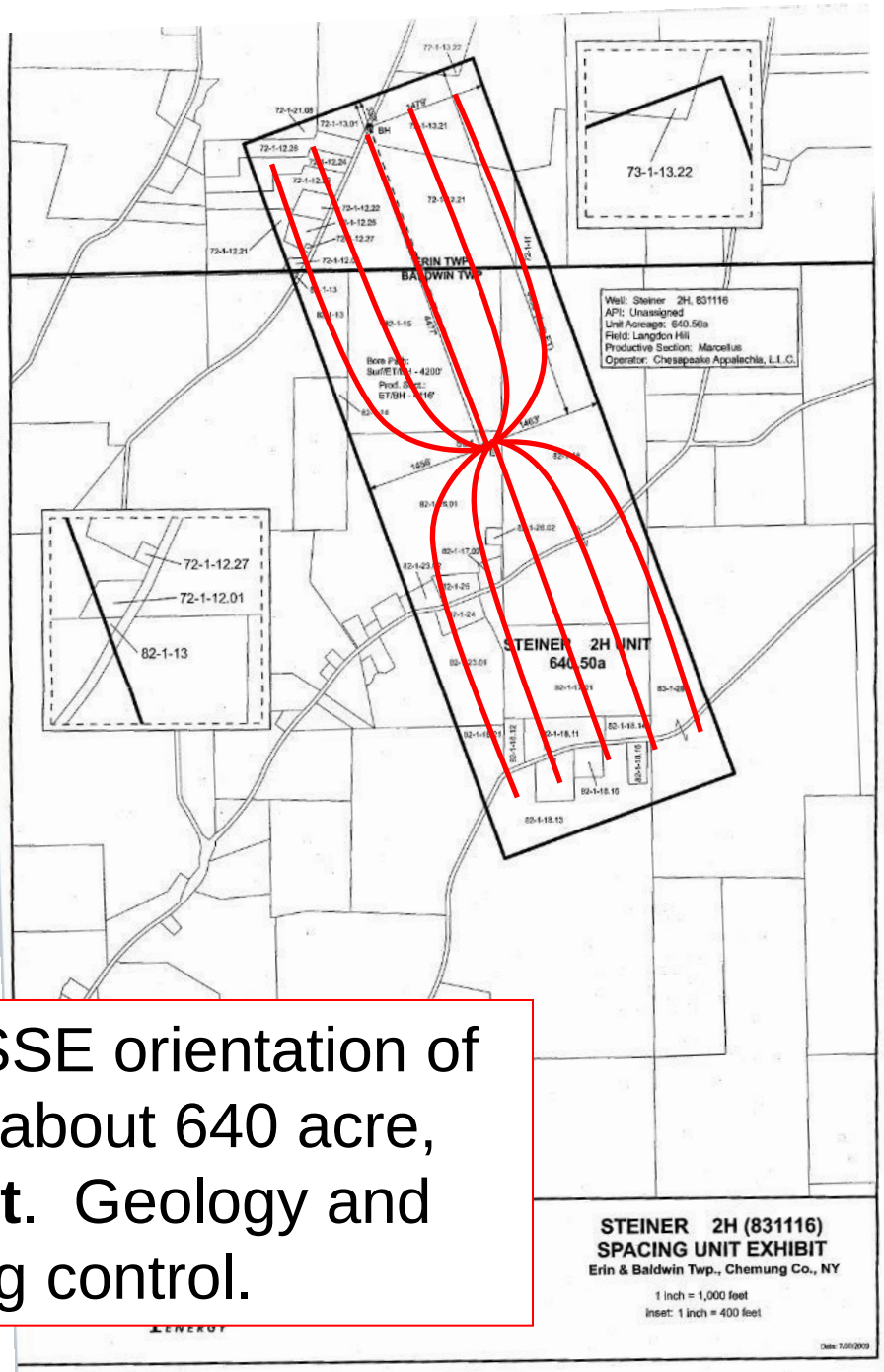
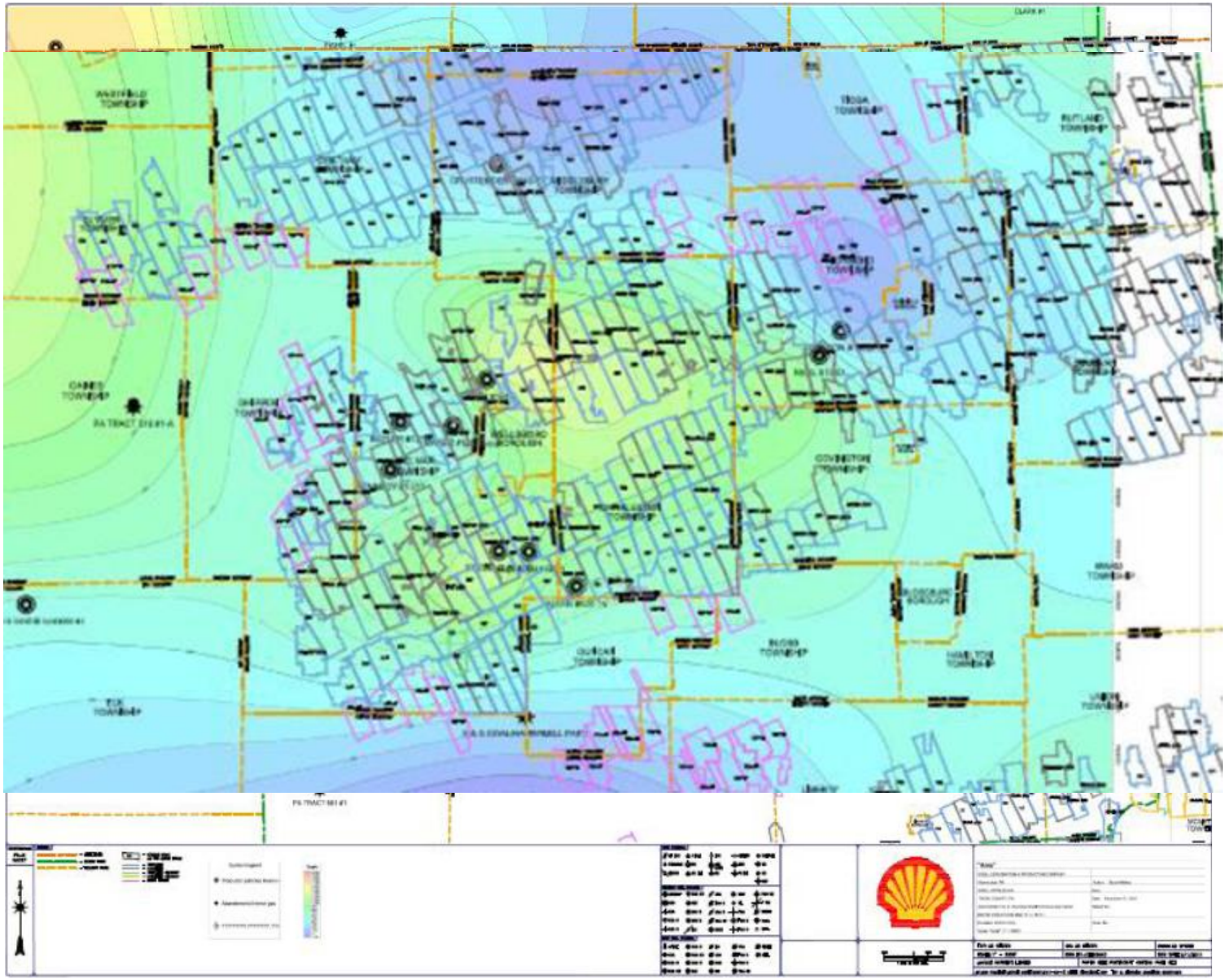




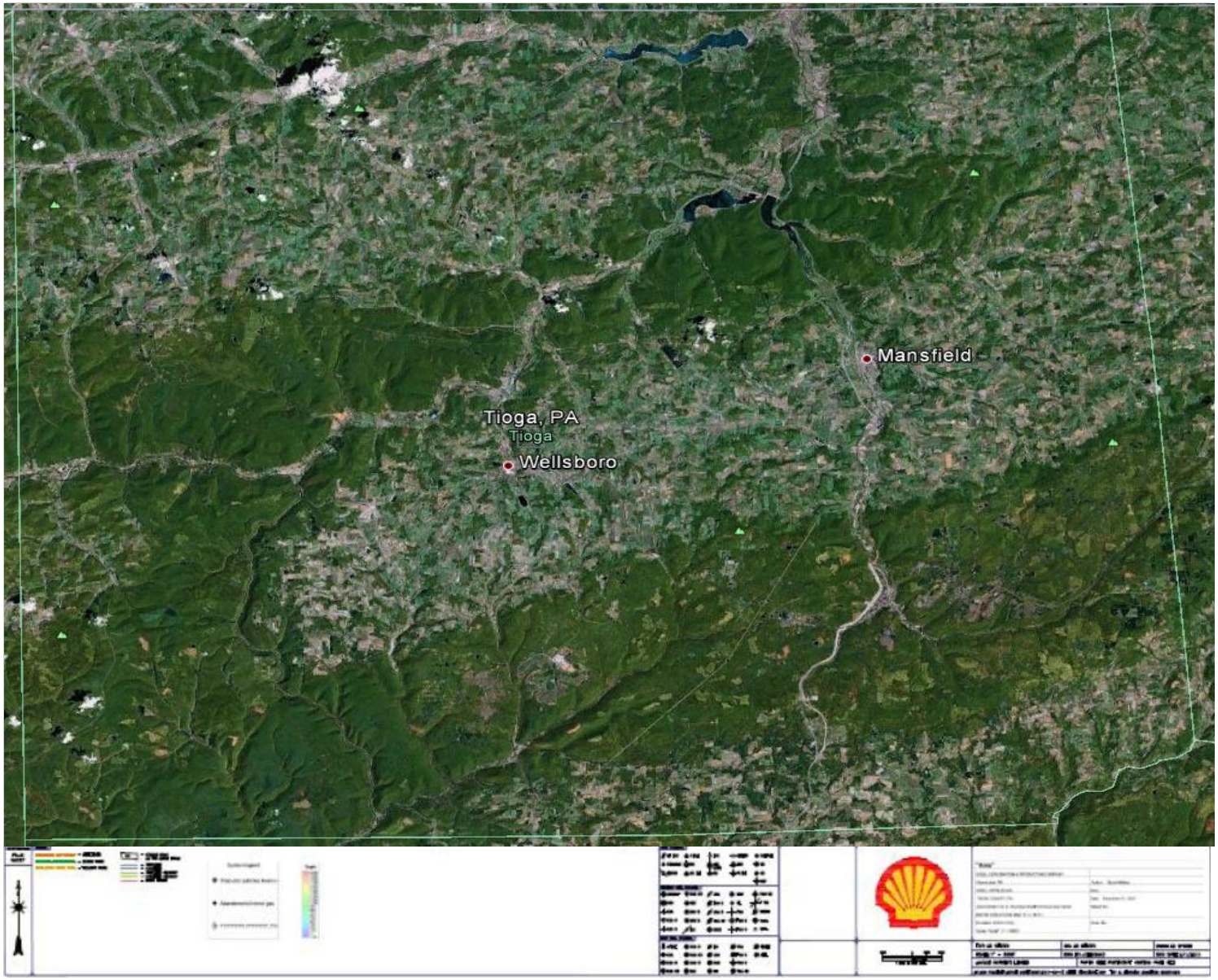
Notice NNW-SSE orientation of non-square, about 640 acre, **spacing unit**. Geology and leasing control.

An Industrial-Ideal Pad/Well Buildout Scenario: White County, IL

Clustering of Pads in Tioga County, PA



Clustering of Pads in Tioga County, PA



The Shale Play Life Cycle

- Discovery followed by leasing frenzy.

- Drilling boom follows to meet "held-by-production" lease requirements.

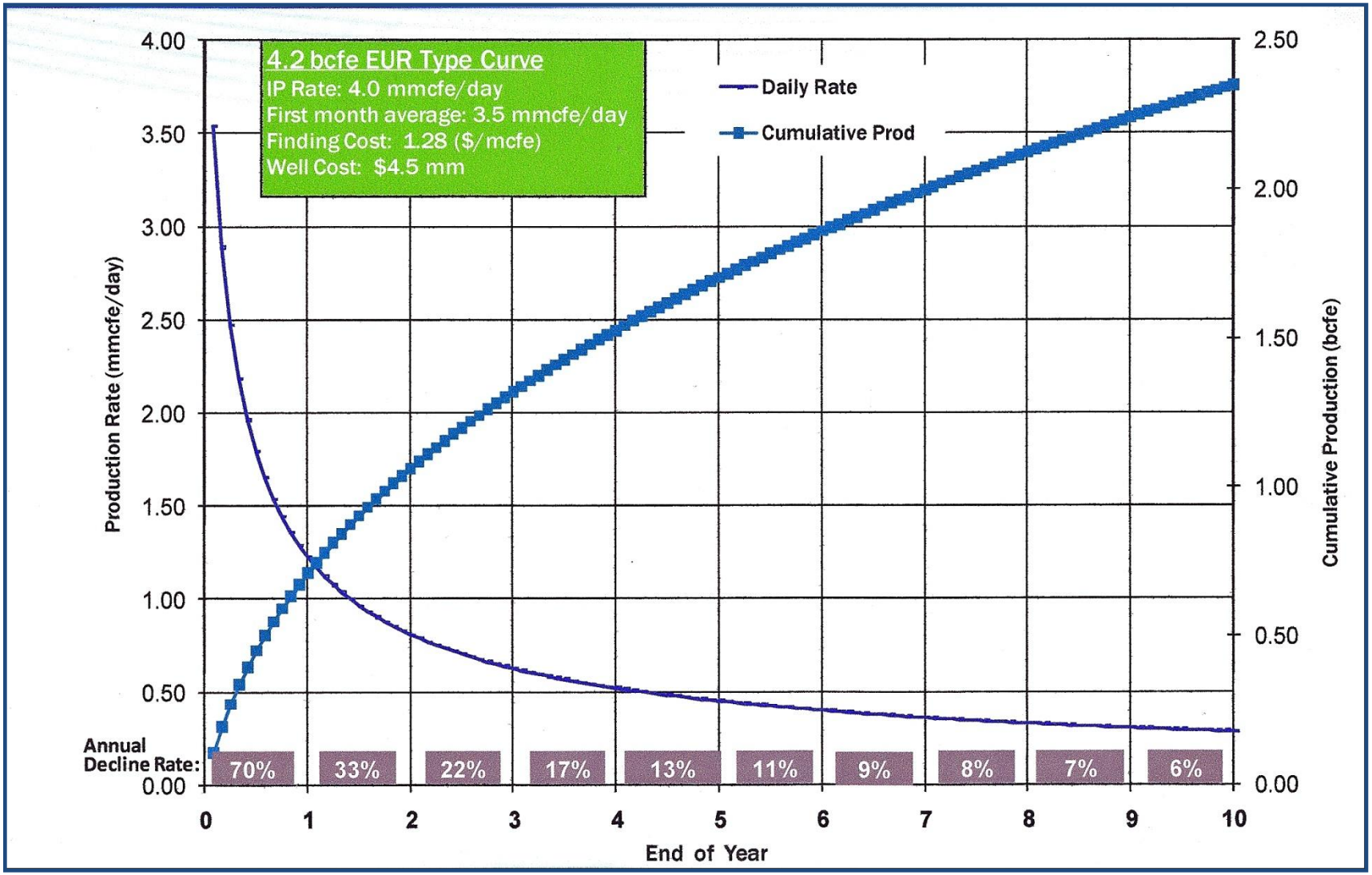
- Sweet spots identified, targeted and drilled off.

- Gas production rises rapidly and is maintained for cash-flow despite uneconomic full-cycle costs.

- Sweet spots become saturated and well quality and field production decline.

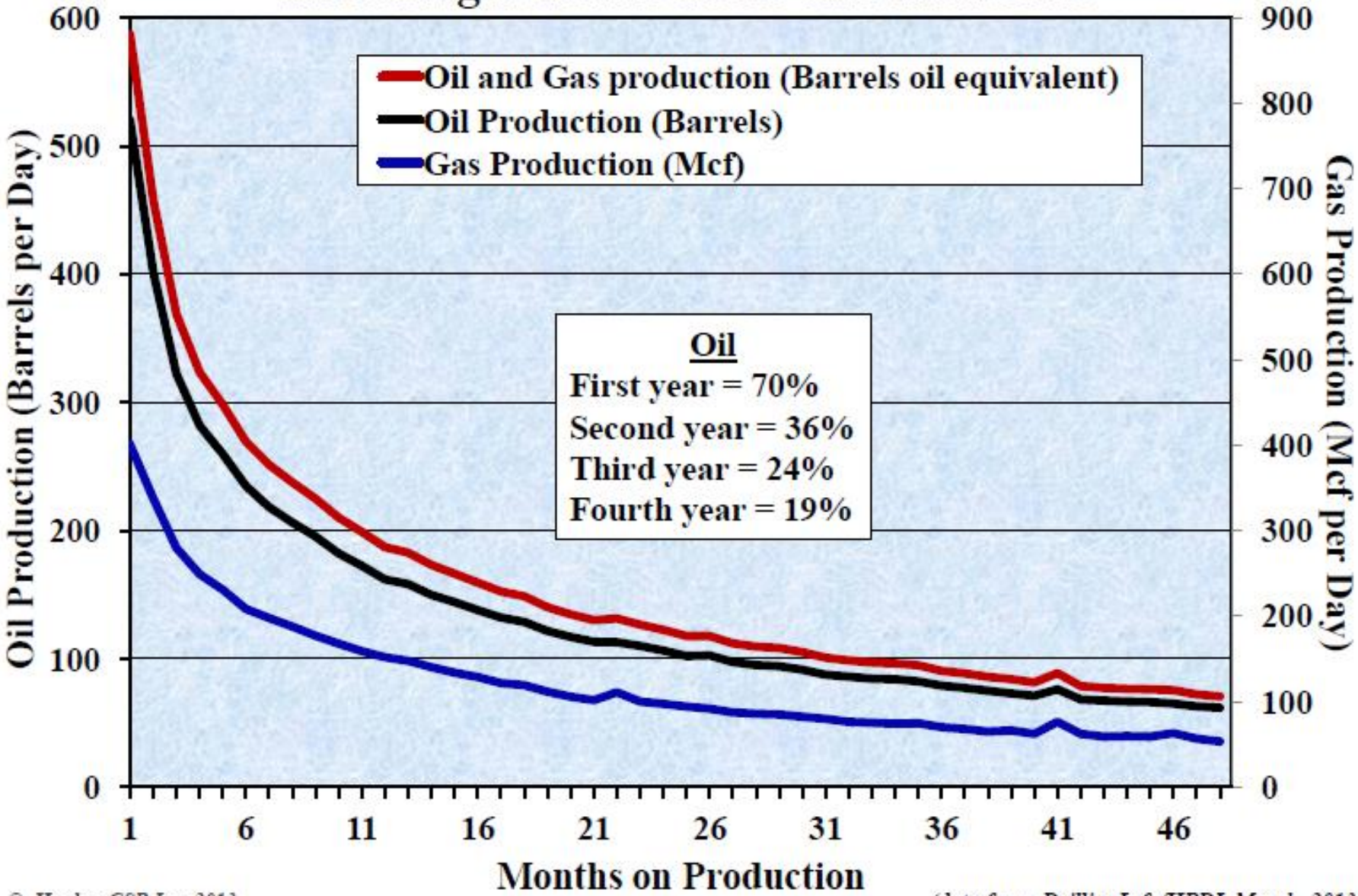
- Plays like the Haynesville become middle aged after just five years.

Key Data for Estimation of Well Productivity and Economics: PA



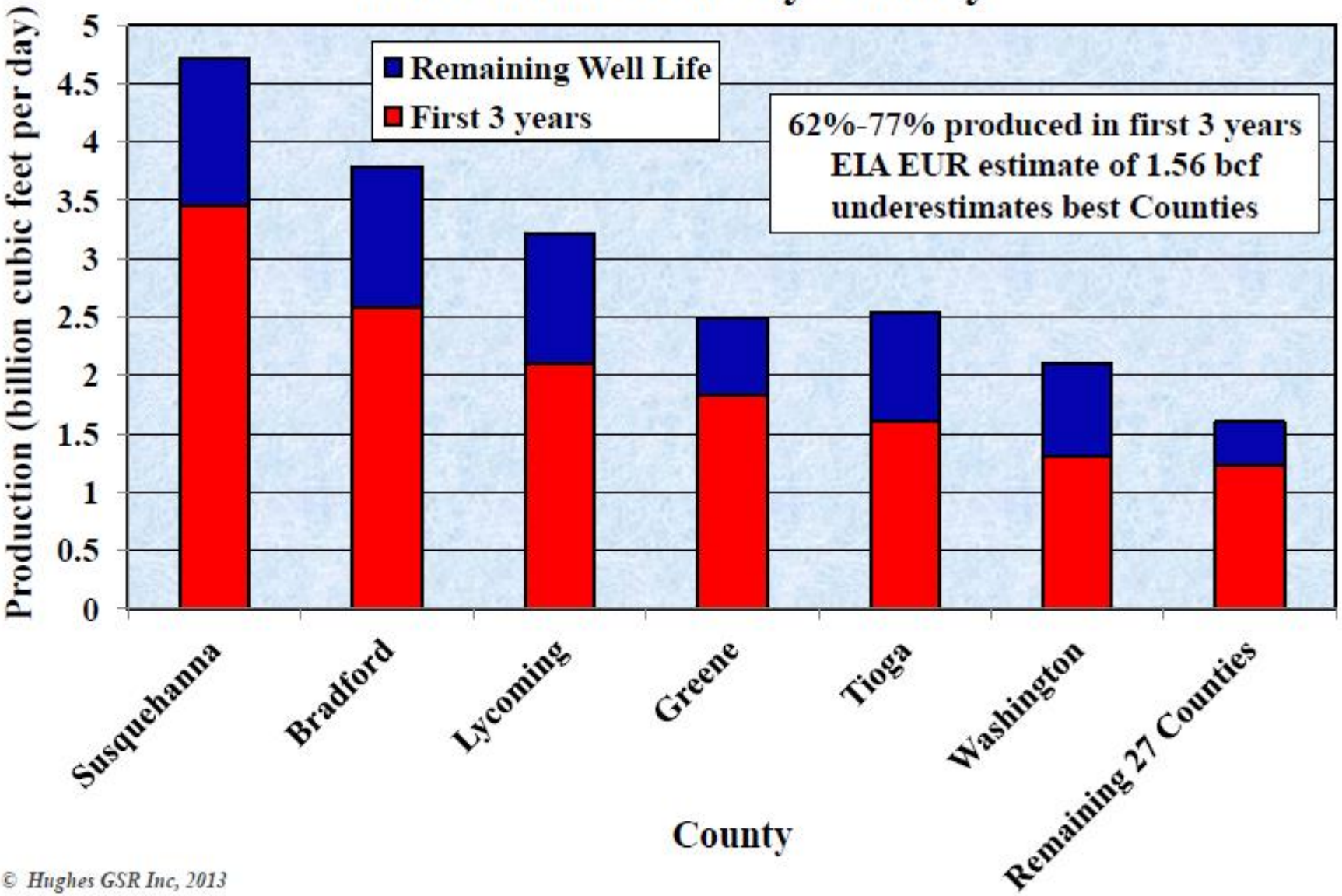
From: Chesapeake Energy (CHK) published *pro forma* data

Bakken/Three Forks Horizontal Well Type Decline Curves including North Dakota and Montana



(data from DrillingInfo/HPDI, March, 2013)

Estimated Ultimate Recovery for Pennsylvania Marcellus Horizontal Wells By County



Annual Capex Required to Offset Overall Annual Decline by Shale Play

Field	Rank	Number of Wells needed annually to offset decline	Approximate Well Cost (million $US)	Annual Well Cost to Offset Decline (million $US)
Haynesville	1	774	9.0	6966
Barnett	2	1507	3.5	5275
Marcellus	3	561	4.5	2525
Fayetteville	4	707	2.8	1980
Eagle Ford	5	945	8.0	7558
Woodford	6	222	8.0	1776
Granite Wash	7	239	6.0	1434
Bakken	8	699	10.0	6990
Niobrara	9	1111	4.0	4444
Antrim	10	~400	0.5	200
Bossier	11	21	9.0	189
Bone Spring	12	206	3.7	762
Austin Chalk	13	127	7.0	889
Permian Delaware Midland	14	122	6.9	842
Total		**7641**		**41829**

(well cost data from various sources and is approximate)

Prognosis for Future Production based on Latest Rig Count

Field	Rank	Number of Wells needed annually to offset decline	Wells Added for most recent Year	October 2012 Rig Count	Prognosis
Haynesville	1	774	810	20	Decline
Barnett	2	1507	1112	42	Decline
Marcellus	3	561	1244	110	Growth
Fayetteville	4	707	679	15	Decline
Eagle Ford	5	945	1983	274	Growth
Woodford	6	222	170	61	Decline
Granite Wash	7	239	205	N/A	Decline
Bakken	8	699	1500	186	Growth
Niobrara	9	1111	1178	~60	Flat

“There is no time to waste….”

“Natural gas is a delaying tactic…There is no time to waste… We have to decide whether we are in the business of delaying bad outcomes or whether we are in the business of preventing bad outcomes.”

Ken Caldiera, Senior Scientist
Department of Global Ecology,
Carnegie Institution, Stanford, CA
April 15, 2012

We Own the Wind, the Sun, the Water: Their Fuel Cost is Zero.

Wind, water and solar energy will provide a stable, renewable source of electric power not subject to the same fuel supply limitations as fossil fuels and nuclear power. Due to the eventual depletion of coal, oil, natural gas, and uranium resources, their prices will continue to rise.

We Own the Wind, the Sun, the Water: They Make Us Energy Secure and Independent

Where Can You Find Reliable Information?

http://www.psehealthyenergy.org/

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EARTHWORKS' Oil & Gas Accountability Project works with tribal, urban and rural communities to protect their homes and the environment from the devastating impacts of oil and gas development. Learn more.

HOT ISSUES

New Mexico showdowns over common sense drilling protections: drilling rules under attack in court and legislature

Feb 22 -- The battle over New Mexico's landmark Pit Rule -- the nation's most protective measure to safeguard citizens, water and land from hazardous oil and gas drilling wastes -- is building to a showdown in the courthouse and the Roundhouse (NM's Capitol).

In December District Judge Barbara Vigil heard arguments from the New Mexico Oil and Gas Association, which is seeking to overturn the Pit Rule in its entirety. Tomorrow (2/23) she will hear

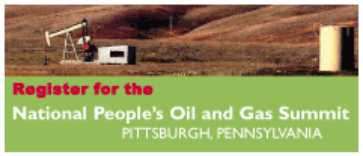
http://www.earthworksaction.org/oil_and_gas.cfm

Rule.

More info:

- Read our press release.
- The Albuquerque Journal's recent story gives some political context to the showdown.
- newmexicocommonsense.org provides fact sheets that explain why New Mexico's pit rule is, in fact, common sense. And why industry's arguments against it are bunk.
- Background on what the New Mexico pit rule is.

On November 19th and 20th, the 2010 National People's Oil & Gas Summit was held in Pittsburgh, Pennsylvania, the heart of the Marcellus Shale natural gas drilling boom.



The Summit was a huge success with more than 250 citizens from 26 states and Canada joining together to share information, stories, and strategies.

Click here to view the agenda and download copies of presentations and materials from the 2010 National People's Oil & Gas Summit. (Video clips from the Summit will be available

COMMUNITY VOICES

Buffalo, WY

"Reaching an Agreement: Luck of the Draw" provides an account of Pete Dube's efforts to achieve a Surface Use Agreement with a company. Even with that agreement, he struggled to get the company to deal with methane gas that started seeping into his stock well soon after the company drilled a CBM well on a neighbor's property.

PUBLICATIONS

Joint letter to House

estate amendment. Vote "yes" on passage HR 3534

Oil and Gas Pollution Fact Sheet

Contaminants associated with the various stages of oil and gas development

Our Drinking Water at Risk

What EPA and the Oil and Gas Industry Don't Want Us to Know About Hydraulic Fracturing. (Full Report)

Oil and Gas at Your Door? (2005 Edition)

A landowner's guide to oil and gas development.