Hydraulic Fracturing, Horizontal Wells & Unconventional Oil/Gas Resources

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Southern IL Rural Public Health
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Illinois Hydraulic Fracturing Regulatory Act - P.A. 98-0022

Signed into law June 2013

Rules currently being written with public comments

Covers High Volume Hydraulic Fracturing in Horizontal boreholes
>80,000 gallons of water per stage or
>300,000 gallons of water per well

There are Illinois Oil & Gas regulations since ~1940
Hydraulic Fracturing
In Oil/Gas wells

Is a process performed during a few days in the many decades long life of drilling & production of an oil/gas well.

During the process; water, sand & some chemicals under temporary increased pressures are forced into joints/fractures/voids in formations, opening them up, interconnecting voids and in shales extending joints or fractures.

Following fracturing, pressures are relieved and materials flow from the formation towards the borehole and up the lined borehole to the ground surface.
Mineral Leasing
years

Permits
months

Drilling
wks-mo

Source: Chesapeake Energy Corporation, 2008

Source: DCL Consulting, 2009
Active Drilling Rig in the Barnett Shale Play
Site Restoration 6-12 months

Production 20-30 yrs

Well Plugging & Site Restoration 6-12 months
U.S. Oil & Gas Well History

First gas well – 1821 (NY)

First oil well – 1859 (Penn)

First gas well in Illinois – 1853

First oil wells in Illinois – 1860s
Fracturing
In Oil/Gas wells

Fracturing first used – Nitroglycerin torpedo – 1860s

First hydraulic fracturing experiment – 1947

Commercial operations start – 65 years ago - 1949

Massive hydraulic fracturing ~ 35 years ago - 1970s
Estimated

> 1 million hydraulically fractured vertical wells in U.S.

> 1 million hydraulically fractured sections in horizontal wells in U.S.

> 1.5 million hydraulically fractured sections in horizontal wells outside the U.S.

King, 2012
Horizontal Wells in U.S.

First recorded horizontal oil well – 85 years ago - 1929

Common by 1970s/1980s

~50 thousand in U.S. over past 60 years (2011)

&

Adding 1,000s per year
Hydraulic Fracturing not Unique to Oil & Gas

used for:

Coal Bed Methane recovery
Disposal wells in bedrock
Underground Gas Storage
Water wells
In stiff soil for remediation of contamination
Hard rock underground mining
Geothermal wells for energy production
Granite quarry in North Carolina - 1890s
Background - Illinois Setting
Modified from Barrows and Cluff, 1984
New Albany Shale Oil is deeper than nearly all Illinois oil fields where hydraulic fracturing has occurred over the past 60 years.

Modified from Barrows and Cluff, 1984
Person height = 6 sheets

Local private groundwater resource
~100-200 ft deep

New Albany
5,000 ft deep
&
~200 ft thick

Thickness of one sheet of paper = 1 foot

New Albany
2,500 ft deep
&
~100 ft thick
Thickness of one sheet of paper = 1 foot

Base of “fresh” water where water is 20 X saltier than IL drinking standards limits

depth varies from ~400 to 1,000 ft
Oil production pipe from ground surface into oil resource = a human hair

Thickness of one sheet of paper = 1 foot
New Albany Shale Oil/Gas in the Illinois Basin

First drilling for New Albany gas was in Indiana in 1885

Large number of fields drilled in first half of the 1900s in Illinois & Indiana & Kentucky

Various drilling and fracturing/stimulation techniques tried through the years

Salehi, 2010
New Albany Shale
Sandstone
blue = open space
Vertical Oil/Gas well

Horizontal Oil/Gas well
Surface casing & cement 100 ft. below “fresh water”
Surface casing & cement

Intermediate casing & cement

Production casing & cement
Example of steel casings & production casing
Perforation of casing for production

Shaped charges shoot holes through casing to open it for conventional Oil/Gas production.

Conventional Resource = Oil & Gas in limestone or sandstone
If Hydraulically Fractured

Only 10% to 20% of wells

Pressurized water, sand, and chemicals open and connect voids & fractures
Hydraulic Fracturing in vertical wells

- > 20,000 vertical wells hydraulically fractured in Illinois during past 30 yrs.
- > 1 Million vertical wells have been fractured in U.S.
- In Illinois - Average use of low volume fracturing fluids 8,000 to 12,000 gallons of water.
- Recently 1 million gallons used in a vertical well in Indiana – 8 horizons
Over 160,000 oil & reinjection wells drilled in Illinois
Oil fields
Production wells
&
Re-injection wells
121 Fractured
(past 30 yrs)
Horizontal Wells for Shale Oil/Gas

- Natural joints & fractures
- Organic rich layer
Natural Fractures in shale
Perforate casing & start hydraulic fracturing

All horizontal wells are not hydraulically fractured
Pressurized water & sand forced into fractures - opens and extends them

Sand in fractures keeps them open – “props” them open
Side view of horizontal borehole & fracturing
Looking down on network of cracks by horizontal borehole
Hydraulic fracturing performed in separate stages

According to records up to 640,000 gallons used in one horizontal well
Microseismic events show extent of fracturing

10s of thousands of HF microseismically monitored
Micro-seismic monitoring shows extent of fracturing process
New Albany Shale in Kentucky 2010

Salehi, 2010
Figure 48. Map view, stage 2

Figure 49. Lateral side view (orthogonal to lateral), stage 2

Salehi, 2010
Studies & technical literature concerning adaption of horizontal wells and hydraulic fracturing to shale development is extensive from the 35+ years of shale technology development.

550+ technical papers on shale fracturing

3,000+ on all aspects of horizontal wells
Crack = $1500 \times 200$ feet $\times$ $\frac{1}{8}$ inch $\approx 25,000$ gallons

How many cracks intersect a 200 foot stage – length of pipe and use 300,000 gallons of water for the stage?

Only 12
Map view looking down on horizontal borehole
200 foot wide stage fractured

1 stage = 300,000 gallons
7 stages in borehole = 2,100,000 gallons for borehole
Concerns:

Fracturing Fluid

Water Use

Where are Unconventional Resources

Seismicity

Groundwater Contamination
Chemicals The biggest public concerns

What is used is tailored to rock encountered in the borehole

That is why a specific list cannot be produced at time of permit

Whole process of direction of drilling, spacing of perforation holes, length of stage, number of stages are modeled ahead of time using rock properties, in situ stresses, formation water pressure, porosity, joint orientation, joint spacing, etc.

& experience in the area.
Example Hydraulic Fracturing Fluids
[Fayetteville Shale (Arkansas) horizontal well]

- Water & Sand: 99.51%
- Surfactant: 0.085%
- Other: 0.49%
- Friction Reducer: 0.088%
- Acid: 0.123%
- Biocide: 0.001%
- KCl: 0.06%
- Gelling Agent: 0.056%
- Scale Inhibitor: 0.043%
- pH Adjusting Agent: 0.011%
- Breaker: 0.01%
- Crosslinker: 0.007%
- Iron Control: 0.004%
- Corrosion Inhibitor: 0.002%

ALL Consulting 2008
### Example of # of Chemicals Reported

<table>
<thead>
<tr>
<th>Location</th>
<th>Chemicals Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakken (ND)</td>
<td>15 &amp; 2 proprietary</td>
</tr>
<tr>
<td>Eagle (TX)</td>
<td>19 &amp; 1 proprietary</td>
</tr>
<tr>
<td>Fayetteville (AR)</td>
<td>9 &amp; 2 proprietary</td>
</tr>
<tr>
<td>Marcellus-Utica (Penn &amp; Ohio)</td>
<td>12 &amp; 0 proprietary</td>
</tr>
</tbody>
</table>

16 Wells and 274 fracs from one pad using two additives: polyacrylamide friction reducer & dispersant surfactant

ALL Consulting 2012

King, 2012
## Pubs have lists of typical chemicals & how used in fracturing & society

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Function</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyacrylamide</td>
<td>Friction Reducer</td>
<td>Adsorbent baby diapers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drinking water prep.</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Biocide</td>
<td>Medical disinfectant</td>
</tr>
<tr>
<td>Ozone &amp; UV</td>
<td>Alternative Biocide</td>
<td></td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>Crack development</td>
<td>Swimming pools</td>
</tr>
<tr>
<td></td>
<td>not showing up to be great benefit – used less &amp; less</td>
<td></td>
</tr>
<tr>
<td></td>
<td>used up in reactions with rock</td>
<td></td>
</tr>
</tbody>
</table>

If acid used – Corrosion inhibitor used – some toxic. Small amount can be in return water.
Hydraulic fracturing companies are in competition with each other

Moving toward greener chemicals – one has all ingredients entirely from food industry

Moving toward less water

On site treatment of used waters

Several companies are using saline-brackish water
Some shales do Not like fresh water

Use of Brackish non-potable water

Nitrogen fracturing – uses little water

Gasfrac with liquefied petroleum gas gel that is soluble, recoverable, recyclable and reusable
U.S. experience ~2 to 5 million gallons per well

2 million gallons is water used in:

- Pike Co. ~ 1.5 hr
- Rock Island ~ 3 min
- Sangamon ~ 7 min
- Effingham ~ 9 hr
- McLean ~ 3 hr
- White ~ 3 hr

Avg water use in IL per DAY in Millions of gallons

2005 data - Kenny et. al., 2009
Flowback Waters

About 5% to 50% of fracturing fluid flows back out of the well. Many chemicals are consumed or adsorbed by the rock and not returned.

Usually contains dissolved minerals and formation waters which are salty - i.e. brine with trace amounts of heavy metals, small subset of the chemicals and naturally occurring radioactive isotopes – handled under Federal & State regulations.
Management of the flowback waters

Disposed in deep disposal wells – Class II wells

Treated & Used in hydraulic fracturing in other wells

Illinois regulations require storage in tanks at drill site and testing of water before it leaves site

In Penn. - reuse up to 90% in 2012

North Dakota – reuse up to 20% in 2012
Less wastewater with horizontal wells per unit gas

2013 study finds horizontal wells in Marcellus shale in Penn. produce only about 35% of the amount of wastewater per unit gas recovered in comparison to vertical wells.

In other words – a 65% savings per unit of gas extracted.

Lutz et. al., 2013
Concerns:

Fracturing Fluid

Water Use

Where are Unconventional Resources

Seismicity

Groundwater Contamination
Speculative or Uncertain Model at this time

Shaded area - general shale oil window

Orange – shale mature & intense oil generation

Highest maturity area probably gas
New Albany Shale Experiences from Indiana & Kentucky

Some wells are drilled using air drilling technique – not water

No or minimal flow-back water as wells are nitrogen fractured

Volume of produced water is small and is stored in ~2,000 gal tanks

Still need to see what experiences will be in Illinois but early studies (Bergstrom et. al., 1980) show similar concerns with use of water for drilling.

Salehi, 2010
Hydraulic fracturing in
Wayne, Edwards, Hamilton & White Counties
in ~ last 30 years
~ 3,500 oil/gas wells fractured
Using as much as 420,000 to 1,575,000 gallons per well
Oil fields in 4 county area
Carmi, IL
5,200 pop.
Concerns:

Fracturing Fluid

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Seismicity

Groundwater Contamination
Seismic Risk from Hydraulic Fracturing

Hydraulic fracturing produces micro-seismic events of magnitude -1.0 to -4.0

Only detectable by sensitive instruments in deep boreholes.
- Not felt at surface
- Do not cause damage

Estimated > 1 million hydraulically fractured sections in horizontal wells in U.S. and no felt seismic events
Earthquake Magnitude

~Smallest earthquakes detected in Illinois by seismograph stations

Largest recorded earthquakes in Illinois
Earthquake Magnitude

Hydraulic Fracturing

~ start of being felt

~ start of damage

-4 -3 -2 -1 0 1 2 3 4 5 6
Earthquake Magnitude

Hydraulic Fracturing

~ start of being felt

~ start of damage

1 million times less energy released

31 billion times less energy released
Earthquake Magnitude

Hydraulic Fracturing

-4 -3 -2 -1 0 1 2 3 4 5

~ start of being felt

~ start of damage

One Cherry Bomb

One M80
Earthquake Magnitude

Hydraulic Fracturing

-4 -3 -2 -1 0 1 2 3 4 5 6

~ start of being felt
~ start of damage

Small Apple falling 3 feet & hitting floor
Only TWO felt earthquakes reported in the world attributed to hydraulic fracturing in horizontal wells.

Blackpool, England in April 2011 - Magnitude 2.3 earthquake.

Pressure went out along a bedding plane and intersected an apparently unstable fault which was reactivated by the increase in fluid pressure.
Northeast British Columbia, Canada

One magnitude 3.8 felt by workers

38 events recorded from 2009-2011 (mag 2.2 to 3.8)

Occurred during hydraulic fracturing in wells in fault zone

More than 8,000 high-volume hydraulic fracturing completions in NE BC with no felt seismicity.
Will hydraulic fracturing trigger our natural earthquakes?

Hydraulic fracturing many miles above our natural earthquakes!

Hydraulic fracturing only increases pressures for several hours to part of a day.
Felt Seismicity from hydraulic fracturing in **Vertical Wells**

1979: ~ start of being felt
2011: ~ start of damage
1984-1993: Oklahoma
29 events

(Holland, 2013) (Horner et al., 1994)
Concerns:

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Where are Unconventional Resources

Seismicity

Groundwater Contamination
Dimock, Penn.
USEPA Study

Community concerned about methane in water and possible contamination from gas wells/drilling in area.

USEPA sampled wells & at faucets at 64 homes

Each sample analyzed for 195 constituents

5 wells above the USEPA and Penn. EPA for Primary maximum contamination levels for public water supplies - Coliform (3), Barium (2) & Arsenic (2)

Most considered naturally occurring substances & USEPA worked with individual owners to set up treatment systems at the 5 homes.
Duke University Studies – Penn. & New York

400 water samples – private wells & surface waters

Analyzed for hydrocarbons, isotopes & radionuclide levels

No deep saline brines or fracture fluids found.

Osborn (2011)
Methane Concentrations in Groundwater & Springs

239 sites NY (1999-2011)

Vidic et al., 2013
French explorers in 1626 discovered Native Americans igniting gases that were seeping into and around Lake Erie

Eternal flame
Chestnut Ridge County Park, Western NY State

Etiope, et al., 2013
Areas of Drift Gas in Illinois

Places where you can lite your faucet water on fire

Mike Markham
Fort Lupton, CO
Gas tested 2008
Biogenic – “drift gas”
Pre- and Post-Drilling Testing in Penn.

No difference found for Methane in 47 wells samples within 2,500 feet of gas wells. 1 had increase.

Water chemistry in 233 Rural water wells tested - No influences seen in comparison to pre-existing data. One well elevated in salts below limits & dropped down to original in 10 months.

(Boyer at al., 2011)
127 domestic water wells in two counties

7 samples had high methane but isotope shows biogenic in origin – not from shale gas

Analysis showed chemistry link to the two types of bedrock – not from well drilling.
1987 USEPA reported one water well in West Virginia with gelling agent. Speculated that hydraulic fracturing fluid was forced up several nearby abandoned gas wells in area. This is called a “Frac Hit” or “downhole communications”.

Illinois regulation has drillers plug nearby old abandoned wells.

Illinois regulations require Pre- and Post-drilling tests of rivers, lakes & groundwater (wells) – First in Nation.
Midwest Experience - Illinois

- Past 30 years records – 20,000 hydraulically fractured wells
- 177 shallower than 500 feet – no groundwater contamination

Hydraulic fracturing New Albany Shale in Wayne County Illinois 1979

Bergstrom et. al., 1980
“Since the late 1940s, an estimated 12,000 gas and oil wells have been drilled in Michigan using hydraulic fracturing, without any reported contamination issues”
Investigation of 5 years (2008-2012) Penn. Oil & Gas complaints
About 1,000 complaints

“The state has never implicated the underground gas extraction process known as hydraulic fracturing, or fracking, in a contamination incident”

Legere, 2013

Investigation of 16 years of Texas complaints
16,000 multi-fractured horizontal wells

No ground water contamination was found in any stage of drilling, well construction, hydraulic fracturing or production operations.

<table>
<thead>
<tr>
<th>State</th>
<th>Study Period</th>
<th># wells Prod.</th>
<th>Cases</th>
<th>Site</th>
<th>Drill</th>
<th>Frac</th>
<th>Prod.</th>
<th>Orphan well</th>
<th>Waste disposal</th>
<th>Plug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texas</td>
<td>16 yrs</td>
<td>250,000</td>
<td>211</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>56</td>
<td>30</td>
<td>75</td>
<td>1</td>
</tr>
</tbody>
</table>

Kell, 2011
Salem Oil Field 1943
Be aware that some findings in other states may not apply to Illinois because of Illinois regulations in place since 1939 or geologic setting.

Pavillion, Wyoming - where fracturing occurred in the same formation as local water resources

Very shallow oil deposits in Northwestern Penn. oil seeps at ground surface – thus first well site with depth of 69 ft.
Many studies over the years on groundwater & fracturing

State Oil and Gas Agency Groundwater Investigations
And Their Role in Advancing Regulatory Reforms
A Two-State Review: Ohio and Texas
Summary

Hydraulic fracturing in oil/gas wells has been practiced since 1947 – a > 60 year track record of use in Oil & Gas wells

Adapting hydraulic fracturing to horizontal shale gas/oil wells began 30+ years ago but expanded use in the last decades.

10s of thousands of vertical wells have been hydraulically fractured in Illinois for Oil & Gas production.

Estimated > 1 million hydraulically fractured sections in horizontal wells in U.S. – no seismic events felt
  – only two felt in world
Many studies performed on possible contamination – best comparison where pre- & post- drilling tests are performed

Hydraulic fracturing is occurring many, many miles above our natural earthquakes located in the crystalline basement

Unconventional resources of shale oil/gas in Illinois is not certain

Horizontal wells & hydraulic fracturing are & can be used for conventional oil/gas resources and other tight formation that are not shale or the New Albany Shale

Other fracturing techniques may be used in the Illinois Shale Oil formation outside of the use of mostly fresh water
Horizontal Drilling - In Shales for unconventional resource

Use 65% less water per unit gas extracted than vertical boreholes

A fraction of the land surface used compared to vertical boreholes
Horizontal wells greatly reduce disturbance of the surface.

4 to 5 acres per drill pad
= 124 to 155 acres disturbed

5 to 10 acres per drill pad
= 10 to 20 acres disturbed

North Dakota Industrial Commission, Department of Mineral Resources
Michigan - Antrim Shale Gas
Gas fired power generation:

- Produces ~50% less CO2 than coal
- CO2 emission in US down to 20 years ago
- Uses 50 to 75% less water than coal fired plants

Grubert, E., and S. Kitasei, 2010
References


References (con’t)


USEPA , 2012 spreadsheet of laboratory results for Dimock, PA.

USEPA , 2012 spreadsheet of laboratory results for Dimock, PA.

