31st USAEE/IAEE North American Conference  
Unconventional Gas & Oil Workshop  

Unconventional Gas & Oil  
Environmental & Regulatory Issues  

Robert Kleinberg  
Schlumberger Research  
Cambridge, Massachusetts  

7 November 2012
What’s Old and What’s New

- Horizontal drilling and hydraulic fracturing are not new, but their applications are unprecedented in pace and scale.

- Inputs, surface impacts, and waste generation are multiplied by large factors over previous experience.

- Development is occurring in regions unfamiliar with the oil & gas industry.
Environmental & Regulatory Issues

- Provision of Water
- Fracture Fluids Chemistry
- Disposal of Flowback & Produced Water
- Groundwater Protection
  - Induced Seismicity
  - Fugitive & Vented Methane
- Air Quality
- Surface Disturbance
- Regulatory Approaches
  - Public Acceptance
Surface Disturbance

Kern River, California Oil Field, c. 1930
Modern Horizontal Well Construction & Stimulation

- 16 vertical wells develop 640 acres with approximately 77 ac total disturbance (including proportionate share of roads and utilities)

- 6 to 8 horizontal wells develop 640 acres with approximately 7.4 ac total disturbance – 10 times less acreage disturbed

Lawrence Livermore National Laboratory

Barnett Shale Rig at DFW

Fort Worth Star-Telegram
1 October 2007
Groundwater Protection

5 million gallons of water + 1000 tons of sand for 5000 ft long horizontal well
Microseismic Methods Monitor Fracture Height
Microseismic Methods Monitor Fracture Growth
Fracture Heights Compared to Depth of Drinking Water Aquifers

Fig. 2—Barnett shale measured fracture heights sorted by depth and compared to aquifers.

Fisher & Warpinski, SPE 145949 (2011)
Where the Problems Really Are

http://www.gaslandthemovie.com/

<table>
<thead>
<tr>
<th>Location</th>
<th>Problem</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimock PA</td>
<td>water well explosion; gas in tap water</td>
<td>bad cement job</td>
</tr>
<tr>
<td>Caddo LA</td>
<td>gas escape</td>
<td>bad cement job</td>
</tr>
<tr>
<td>Bainbridge OH</td>
<td>gas explosion</td>
<td>bad cement job</td>
</tr>
<tr>
<td>Dimock PA</td>
<td>polluted creek</td>
<td>surface spill</td>
</tr>
<tr>
<td>Caddo LA</td>
<td>17 dead cattle</td>
<td>surface spill</td>
</tr>
<tr>
<td>Dunkard Creek PA</td>
<td>fish kill</td>
<td>wastewater discharge</td>
</tr>
</tbody>
</table>
Another Bad Cement Job

Deepwater Horizon, 2010
Proper & Improper Cementing

- **Cement**
- **Properly cemented**
- **Poorly cemented**
- **Gas intrusion**
- **Water well**

Oilfield Review, Autumn 2003
## Water Use & Economic Value

**Gas Shale – Corn – Corn Ethanol**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Water Use</th>
<th>Multiplier</th>
<th>Water/mi²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Shale</td>
<td>5x10⁶ gal/well</td>
<td>8 well/mi²</td>
<td>123 acre-ft</td>
</tr>
<tr>
<td>Corn</td>
<td>2 ft</td>
<td>640 acre/mi²</td>
<td>1300 acre-ft</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resource</th>
<th>Product/mi²</th>
<th>Value</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Shale</td>
<td>8 bcf</td>
<td>$29 million</td>
<td>100,000 home-years</td>
</tr>
<tr>
<td>Corn</td>
<td>10^5 bu</td>
<td>$0.8 million</td>
<td>1700 cattle</td>
</tr>
<tr>
<td>Corn Ethanol</td>
<td>3x10^5 gal</td>
<td>$0.8 million</td>
<td>200,000 GGE</td>
</tr>
</tbody>
</table>

Commodity Prices: Associated Press 18 October 2012

- Corn: $7.61/bu
- Natural Gas: $3.59/mcf
### Single-Well Lifecycle Water Costs

<table>
<thead>
<tr>
<th></th>
<th><strong>Barnett</strong></th>
<th></th>
<th><strong>Marcellus</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Disposal Case</strong></td>
<td><strong>Reuse Case</strong></td>
<td><strong>Disposal Case</strong></td>
<td><strong>Reuse Case</strong></td>
</tr>
<tr>
<td>Fresh Water Supply</td>
<td>$25,000</td>
<td>$15,000</td>
<td>$18,000</td>
<td>$13,500</td>
</tr>
<tr>
<td>Fresh Water</td>
<td>30,000</td>
<td>18,000</td>
<td>24,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Treatment</td>
<td>0</td>
<td>50,000</td>
<td>0</td>
<td>30,000</td>
</tr>
<tr>
<td>Reuse Transportation</td>
<td>0</td>
<td>4,000</td>
<td>0</td>
<td>12,000</td>
</tr>
<tr>
<td>Disposal Transportation</td>
<td>40,000</td>
<td>$0</td>
<td>600,000</td>
<td>0</td>
</tr>
<tr>
<td>Disposal</td>
<td>30,000</td>
<td>$0</td>
<td>30,000</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$125,000</td>
<td>$87,000</td>
<td>$672,000</td>
<td>$73,500</td>
</tr>
</tbody>
</table>

Slutz er al., SPE 157532 (2012)
State Review of Oil & Natural Gas Environmental Regulations
http://www.strongerinc.org/

State Reviews
The Process
Past Reviews »
Upcoming Reviews
Rules of Participation

Past Reviews
STRONGER has successfully reviewed 22 state regulatory programs, representing over 94% of domestic onshore oil and gas production. Ten of these states have volunteered for at least one follow-up review, with the results indicating that 76% of recommendations from the initial review had been successfully implemented.
Please see our overview of the state review process for more information.

To view individual state reviews, please select from the highlighted states below. States interested in volunteering for review are encouraged to contact STRONGER.

Severance Tax Rates (c/mcf)

Resources for the Future
http://common-resources.org/2012/revised-maps-of-shale-gas-regulation/
Are States Paying Attention?

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvania</td>
<td>85</td>
<td>22,670</td>
<td>270</td>
<td>$6.9 million</td>
</tr>
<tr>
<td>New Mexico</td>
<td>12</td>
<td>27,000</td>
<td>2250</td>
<td>$14,000</td>
</tr>
<tr>
<td>New York</td>
<td>14</td>
<td>no data</td>
<td>no data</td>
<td>$40,000</td>
</tr>
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</table>

*Breaking All the Rules, The Crisis in Oil & Gas Regulatory Enforcement*

Earthworks Oil & Gas Accountability Project, September 2012
Is the Environment Being Protected?

The University of Texas Law School attempted to collect data on complaints and enforcements for fifteen states for the years 2008-2011. A partial list of the problems they encountered:

- Enforcement data is collected, recorded and organized differently in each state. In New York every well file must be examined individually to determine the extent of regulatory enforcement.

- There is no uniformity of data formats, nor even how to request data.

- Some states provided full data sets, others provided partial data, some provided none.

- Some states fail to preserve certain complaints about shale gas development, and the public is unable to determine which complaints were not preserved.

Fact-Based Regulation for Environmental Protection in Shale Gas Development
University of Texas Energy Institute, February 2012
Costs of Regulation

POTENTIAL ECONOMIC AND ENERGY SUPPLY IMPACTS OF PROPOSALS TO MODIFY FEDERAL ENVIRONMENTAL LAWS APPLICABLE TO THE U.S. OIL AND GAS EXPLORATION AND PRODUCTION INDUSTRY

Prepared for:
U.S. Department of Energy Office of Fossil Energy

Prepared by:
Advanced Resources International, Incorporated

January 2009
Cost of Remediating Water Pollution

<table>
<thead>
<tr>
<th>Locale</th>
<th>Problem</th>
<th>Response</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rouseville PA</td>
<td>petroleum</td>
<td>replace supply</td>
<td>$300k</td>
</tr>
<tr>
<td>Atlanta MI</td>
<td>VOCs</td>
<td>replace supply</td>
<td>$500k</td>
</tr>
<tr>
<td>Montgomery Co. MD</td>
<td>solvents</td>
<td>county water</td>
<td>$3M + $45k/yr</td>
</tr>
<tr>
<td>Orange Co. CA</td>
<td>VOCs etc</td>
<td>multiple</td>
<td>$54M</td>
</tr>
</tbody>
</table>

Community costs only.

Does not include state, federal, and private industry funding.

Does not include costs to individuals including lost wages, medical expenses, reduced property values, higher water bills, etc.

Summary

Technical Improvements are Mitigating Environmental Impacts

- Multi-well drilling pads reduce surface disturbance and truck traffic.
- Water purification services and better additives allow reuse of flowback water.
- Better understanding of induced seismicity is leading to engineering controls.

Is the Environmental Record Improving?

- Although often loathe to admit it, industry has become sensitized by bad publicity that accompanies safety and environmental incidents.
- Industry consolidation has led to the re-entry of risk-averse international oil companies (IOCs) into the US land gas market.
- Is the number and severity of incidents involving safety or environmental protection trending up or down? This information is difficult to compile due to lack of uniformity of state-by-state data collection.

Public Perception of Gas Shale Production Operations

- Though there is agreement among politicians that cheap and abundant natural gas is desirable, is public opinion vulnerable to the next film about fracking?
Coming Soon
In theaters January 11.

Promised Land (2012)
- Drama - 11 January 2013 (USA)

Your rating: -/10
( awaiting 5 votes)
Reviews: write review

A salesman for a natural gas company experiences life-changing events after arriving in a small town, where his corporation wants to tap into the available resources.

Director: Gus Van Sant
Writers: John Krasinski (screenplay), Matt Damon (screenplay), and 1 more credit »
Stars: Matt Damon, Frances McDormand and John Krasinski
See full cast and crew
Robert L. Kleinberg, Ph.D.

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