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Background

- As of 2013, shale gas 32% of world’s reserves
- Gas as a bridge to more sustainable energy (esp relative to coal) – or too uncertain/risky
- Marcellus largest producing play in US – most development has occurred in PA
- PADEP has public compliance database
  - What has PA experience taught us about risks?
    - Which are most prominent; where and why do they occur
  - How has industry, governments and agencies responded to prevent/mitigate risk?
Water Resource Events Framework

Planned (Deterministic)

- **Surface**
  - WITHDRAWAL
  - WATER TREATMENT

- **Subsurface**

Unplanned (Probabilistic)

- **Surface**
  - SPILLS
  - RUNOFF
  - LEAKS

- **Subsurface**

**Monitoring**

- **Basin-scale**
  (Collective impacts associated with overall pace & scale of development)

- **Local-scale**
  (Specific impacts associated with a reported event)
Total Environmental Violation Trends

• Policy1 (45%) and “Inspector Productivity” main drivers of decreased violation rates

• decreased violation rates w/ higher wells per pad and lower NE drilling

• 2 other policies, seasonality, gas price & operator identity not significant
Specific risks...

- Cementing and Casing
- Solid Waste
- Wetland Impact
- Site Restoration
- Erosion
- Spill

# Violations per 100 Wells Drilled
Spills at the surface:

In PA, violations for spills at the surface most prominent

- Can occur on 5 to 20% wells drilled

- Poor information on impact – exception of handful of “major” events

- Regulations are evolving – e.g. proposed rule change in PA would prohibit “open top” storage of produced water
Stormwater management:

In PA, violations associated with erosion come just behind spills

• Not related to POLICY1, but linked to variables suggesting higher violation rates during exploration (few wells per pad)

• Not much study of this issue

• Similar to problems we typically face with construction/ag and conventional
Conventional comparison

- Cementing and Casing
- Wetland Impact
- Site Restoration
- Erosion
- Spills

# Violations per 100 Wells Drilled vs. Wells Drilled
Conventional comparison

<table>
<thead>
<tr>
<th>Category</th>
<th>Per 100 wells drilled</th>
<th>Per 100 inspections</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CON</td>
<td>UNC</td>
<td>Sig.</td>
</tr>
<tr>
<td>Cementing and casing</td>
<td>2.59</td>
<td>0.42</td>
<td>***</td>
</tr>
<tr>
<td>Solid waste</td>
<td>0.55</td>
<td>1.38</td>
<td>***</td>
</tr>
<tr>
<td>Wetland impact</td>
<td>2.89</td>
<td>1.07</td>
<td>**</td>
</tr>
<tr>
<td>Site restoration</td>
<td>24.75</td>
<td>1.73</td>
<td>***</td>
</tr>
<tr>
<td>Erosion</td>
<td>9.19</td>
<td>7.58</td>
<td></td>
</tr>
<tr>
<td>Spill</td>
<td>12.9</td>
<td>12.17</td>
<td></td>
</tr>
</tbody>
</table>

Note: *, ** and *** indicate significance at 10, 5 and 1 percent levels. The numbers in bold indicate higher number of violations within a particular category.
Caveats, etc

- Environmental risks are likely underestimated by this approach.
- Limited ability to control for the behavior of inspectors and operators.
- Other variables not analyzed here.
- Database not complete!
What can compliance tell us?

- Spills and erosion viol’s most commonly assessed (UNC)
- Regulatory agencies will be challenged with increased activity (exploration to intensification)
- Operator identity and two major policies not significant drivers
- Inspector productivity and shift in regulatory culture (POLICY1) responsible for driving violation rates
- Five of six risk categories showed significant differences between two types of gas development
- Conventional drilling regs good place to start, but need to be re-purposed
A Framework for Assessing Water Resource Impacts from Marcellus Shale Gas Drilling

Planned

Learn More
Introduction to Marcellus Shale
Waste Management
Runoff From Wellheads
Impacts on Water During Drilling
Spills & Leaks at the Surface

Recent Publications
Lessons for NY from EPA
Pavilion Study (link)
Regional, collective impacts on water resources (link)
Testing Drinking Water (link)
Understanding Isotopes (link)
Framework for Assessing Water Resource Impacts (link)

Maps
Marcellus thickness, depth (link)
Marcellus extent in NY (link)
Marcellus in Susquehanna Basin (link)
Marcellus in Delaware Basin (link)
NY and Chesapeake Bay (link)

Bibliography
References for understanding shale gas impacts (link)

Unplanned