Wellbore Integrity: Failure Mechanisms, Historical Record, and Rate Analysis

Anthony Ingraffea, PhD, PE
Cornell University
Physicians, Scientists, and Engineers for Healthy Energy (PSE)

Renee Santoro
Physicians, Scientists, and Engineers for Healthy Energy (PSE)

Seth B. Shonkoff, PhD, MPH
Physicians, Scientists, and Engineers for Healthy Energy (PSE)
University of California, Berkeley
Outline of Presentation

• Failure Mechanisms (Covered in Extended Abstract)

• Record
  – Historical Offshore public data
  – Historical Onshore public data
  – Recent: Pennsylvania Marcellus play public data

• Implications for impact on underground sources of drinking water
Industry-Reported Data On Loss of Wellbore Integrity: Offshore Wells

SCP=Sustained Casing Pressure. Also called sustained annular pressure, in one or more of the casing annuli.

- About 5% of wells fail soon
- More fail with age
- Most fail by maturity

\[\text{Wells with SCP by age. Statistics from the United States Mineral Management Service (MMS) show the percentage of wells with SCP for wells in the outer continental shelf (OCS) area of the Gulf of Mexico, grouped by age of the wells. These data do not include wells in state waters or land locations.}\]
Industry-Reported Data On Loss of Wellbore Integrity: Onshore Wells

Watson and Bachu, SPE 106817, 2009.
Industry well integrity outlook

- Industry will drill more wells in next decade than have been drilled in last 100 years
- Global well population is +/- 1.8 million, of which +/- 35% has sustained casing pressure
- Public awareness and concern of zonal isolation requirements is increasing (USA / Australia / Europe)
- Geothermal wells and CO2 sequestration wells are on the increase
- Subsidence is a risk in some depleting reservoirs
  Life cycle extension of aging assets is becoming a pre-requisite of legislators
- Zonal isolation challenges and assurance does need push in technology
- Abandonment of legacy wells is becoming more of a focus
- Industry collaboration is an inevitable pre-requisite on all topics
Outline of Presentation

• Failure Mechanisms (Covered in Extended Abstract)
• Record
  – Historical Offshore public data
  – Historical Onshore public data
  – Recent: Pennsylvania Marcellus play public data
• Implications for Impact on underground sources of drinking water
Recent Operator Performance in the Pennsylvania Marcellus Play: Protocol

• Access Pennsylvania Department of Environmental Protection Violations Database online.

• First Pass: Count wells with violations for “leak” codes; eliminate duplicate wells in database.

• Second Pass: Count wells with leakage noted via inspection but which had not been issued violations.

• Divide total number of wells found leaking per year by number of wells drilled that year.
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>78.73A</td>
<td>Operator shall prevent gas and other fluids from lower formations from entering fresh groundwater.</td>
</tr>
<tr>
<td>78.81D2</td>
<td>Failure to case and cement properly through storage reservoir or storage horizon</td>
</tr>
<tr>
<td>78.83A</td>
<td>Diameter of bore hole not 1 inch greater than casing/casing collar diameter</td>
</tr>
<tr>
<td>78.73B</td>
<td>Excessive casing seat pressure</td>
</tr>
<tr>
<td>78.83</td>
<td>GRNDWTR - Improper casing to protect fresh groundwater</td>
</tr>
<tr>
<td>78.83</td>
<td>COALCSG - Improper coal protective casing and cementing procedures</td>
</tr>
<tr>
<td>78.85</td>
<td>Inadequate, insufficient, and/or improperly installed cement</td>
</tr>
<tr>
<td>78.86</td>
<td>Failure to report defective, insufficient, or improperly cemented casing</td>
</tr>
<tr>
<td>207B</td>
<td>Failure to case and cement to prevent migrations into fresh groundwater</td>
</tr>
</tbody>
</table>
Recent Operator Performance in the Pennsylvania Marcellus Play: Examples of Inspection Comments without Violation

“Stray gas observed. Inspected wellhead only. Purpose of inspection was not to address any open violations on pad.”

“Check on flow back pressure on failed casing, no pressure on 5-1/2x9-5/8 annulus flowing at 3-4 barrels an hour”

“Follow up on plugging of well. Since last inspection have run a CBL and Temp Log in 7" casing. Based on anomalies shown on logs - have perf'd and attempted to squeeze cement to eliminate bubbling at surface. At time of inspection tripping out of hole and will be perforating later today and will see if can establish injection rate and squeeze cement. Bubbling still present in cellar on 9 x 7" annulus. No violations observed at this time...”
## Additional Counts of Wells with Loss of Integrity

<table>
<thead>
<tr>
<th>Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>64 wells with violations, 47 additional wells with loss of integrity noted in Inspection Comments</td>
</tr>
<tr>
<td>2011</td>
<td>97 wells with violations, 45 additional wells with loss of integrity noted in Inspection Comments</td>
</tr>
<tr>
<td>2012</td>
<td>44 wells with violations, 76 additional wells with loss of integrity noted in Inspection Comments</td>
</tr>
</tbody>
</table>
Recent Operator Performance in the Pennsylvania Marcellus Play: Results of Survey

1,609 wells drilled in 2010.
97 well failures.
6% rate of failure.

1,972 wells drilled in 2011.
140 well failures.
7.1% rate of failure.

1,346 wells drilled in 2012
120 well failures.
8.9% rate of failure.

Consistent with previous industry data, and not improving.
Outline of Presentation

• Failure Mechanisms (Covered in Extended Abstract)
• Record
  – Historical Offshore public data
  – Historical Onshore public data
  – Recent: Pennsylvania Marcellus play public data
• Implications for impact on underground sources of drinking water
The Dimock, Pa, “Affected” Area, About 9 Square Miles

2008-2009:
29 pads
63 wells

Typical lateral spacing between pads: <½ mile
Impacted Water Supplies Identified in Pennsylvania Department of Environmental Protection Consent Order, Dimock, PA, 2008-2009: Water Supplies of 13 Families Impacted

Discharge of Natural Gas into the Groundwater

L. Based upon its investigation since January 2009, the Department has determined the following:

1. had caused or allowed the unpermitted discharge of natural gas, a polluting substance, into the groundwater, which constitutes a “water of the Commonwealth,” as that term is defined in 35 P.S. §691.1.

2. As of the date of this Consent Order and Agreement, has taken certain actions approved by the Department to prevent the ongoing, unpermitted discharge of natural gas into the waters of the Commonwealth.
The Bradford County, PA, Affected Areas, 2011

94 pads total
Typical lateral spacing between pads, ¾ mile
### Impacted Water Supplies Identified in Pennsylvania Department of Environmental Protection Consent Order, Bradford County, PA, 2011: Water Supplies of 15 Families Impacted

**EXHIBIT C**

**List of Water Supplies**

**Determination letters pursuant to Section 208(b) of the Oil and Gas Act**

**Sugar Run**

<table>
<thead>
<tr>
<th>Address</th>
<th>Zip Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Run, PA</td>
<td>18846</td>
</tr>
<tr>
<td>Sugar Run, PA</td>
<td>18846</td>
</tr>
<tr>
<td>Sugar Run, PA</td>
<td>18846</td>
</tr>
<tr>
<td>Sugar Run, PA</td>
<td>18846</td>
</tr>
<tr>
<td>Sugar Run, PA</td>
<td>18846</td>
</tr>
<tr>
<td>Gettysburg, PA</td>
<td>17325</td>
</tr>
</tbody>
</table>

**Paradise Rd**

<table>
<thead>
<tr>
<th>Address</th>
<th>Zip Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyalusing, PA</td>
<td>18853</td>
</tr>
<tr>
<td>Wyalusing, PA</td>
<td>18853</td>
</tr>
<tr>
<td>Wyalusing, PA</td>
<td>18853</td>
</tr>
</tbody>
</table>

**Brocktown/Dan Ellis**

<table>
<thead>
<tr>
<th>Address</th>
<th>Zip Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monroeton, PA</td>
<td>18832</td>
</tr>
<tr>
<td>Monroeton, PA</td>
<td>18832</td>
</tr>
<tr>
<td>Monroeton, PA</td>
<td>18832</td>
</tr>
</tbody>
</table>

**Springhill Rd**

<table>
<thead>
<tr>
<th>Address</th>
<th>Zip Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laceyville, PA</td>
<td>18623</td>
</tr>
<tr>
<td>Laceyville, PA</td>
<td>18623</td>
</tr>
</tbody>
</table>

**Vargson**

<table>
<thead>
<tr>
<th>Address</th>
<th>Zip Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granville Summitt, PA</td>
<td>16926</td>
</tr>
</tbody>
</table>
Data collected by PA DEP on methane concentration in private water wells in Susquehanna County, PA. 2433 water supplies were tested:

- 89.5% had concentrations of methane < 0.5 mg/L,
- 95.6% had concentrations of methane < 7.0 mg/L.

Courtesy of Seth Pelepko, PA DEP.
Summary

• Loss of wellbore integrity a well-understood and chronic problem
• Recent experience in PA Marcellus play no exception
• Methane is prevalent in water wells in PA, but at very low levels
• Pressing need for scientific investigation of possible links between leaking gas wells and water well contamination