Development of Subsurface Brine Disposal Framework in the Northern Appalachian Basin

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Outline

1. Project Overview
2. Background
3. Geological Characterization
4. Class 2 Operational Data
5. Reservoir Performance Analysis
6. Conclusions/Future Work
Project Overview

- Client: RPSEA (2011 Unconventional Resources Program 11122-73)
- Award Date: 4/1/2013
- Period of Performance: 2 years from 4/1/2013 to 9/30/2015
- Contract Type: Cooperative Agreement with cost share
Project Overview

- Objective: Integrate geotechnical and operational data to characterize injection zones and better define injection potential in the region.
Project Overview

Major Project Tasks-

• Data Collection and Review
• Data Analysis and interpretation
• Geocellular Model Development for selected injection zones
• Local-scale simulations
• Source-Sink Analysis Development of Products for Operators
• Survey of Information Sources for Class 2 Brine Disposal
### Background – Study Area

- Study area includes Eastern Kentucky, Ohio, Pennsylvania, and West Virginia.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>KY</th>
<th>OH</th>
<th>PA</th>
<th>WV</th>
<th>NY</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million)</td>
<td>4.4</td>
<td>11.5</td>
<td>12.8</td>
<td>1.9</td>
<td>19.6</td>
<td>EIA (2012)</td>
</tr>
<tr>
<td>Oil Reserves (thousand bbl)</td>
<td>17,000</td>
<td>41,000</td>
<td>24,000</td>
<td>21,000</td>
<td>1,200</td>
<td>EIA (2011); NYSM (2013)</td>
</tr>
<tr>
<td>Gas Reserves (million cu ft)</td>
<td>2,006,000</td>
<td>758,000</td>
<td>26,529,000</td>
<td>10,345,000</td>
<td>253,000</td>
<td>EIA (2011)</td>
</tr>
<tr>
<td>Oil Production (thousand bbl/year)</td>
<td>3,089</td>
<td>4,866</td>
<td>4,349</td>
<td>2,194</td>
<td>364</td>
<td>EIA (2012)</td>
</tr>
<tr>
<td>Dry Gas to Market (million cu ft/year)</td>
<td>124,243</td>
<td>78,858</td>
<td>1,310,592</td>
<td>394,125</td>
<td>31,124</td>
<td>EIA (2011)</td>
</tr>
<tr>
<td>Oil and Gas Wells</td>
<td>165,000</td>
<td>220,000</td>
<td>350,000</td>
<td>170,000</td>
<td>75,000</td>
<td>State Reports (approx.)</td>
</tr>
<tr>
<td>Unconventional Wells</td>
<td>957</td>
<td>601</td>
<td>6,665</td>
<td>2,109</td>
<td>12</td>
<td>State Reports (approx.)</td>
</tr>
<tr>
<td>Rig Count (~Fall 2013)</td>
<td>5</td>
<td>34</td>
<td>57</td>
<td>31</td>
<td>0</td>
<td>State Reports (approx.)</td>
</tr>
<tr>
<td>Oil Consumption (thousand bbl/year)</td>
<td>117,000</td>
<td>219,300</td>
<td>233,100</td>
<td>35,800</td>
<td>238,700</td>
<td>EIA (2011)</td>
</tr>
<tr>
<td>Natural Gas Consumption (million cu ft/year)</td>
<td>222,577</td>
<td>820,485</td>
<td>962,961</td>
<td>115,363</td>
<td>1,216,532</td>
<td>EIA (2011)</td>
</tr>
<tr>
<td>Refining Capacity (thousand bbl/day)</td>
<td>238</td>
<td>528</td>
<td>410</td>
<td>20</td>
<td>0</td>
<td>EIA (2012)</td>
</tr>
<tr>
<td>Total CO₂ Emissions (million metric tons)</td>
<td>150.7</td>
<td>249.1</td>
<td>256.6</td>
<td>98.9</td>
<td>172.8</td>
<td>EIA (2010)</td>
</tr>
</tbody>
</table>
Background – Class 2 UIC Wells

• Class 2 UIC includes both brine disposal wells and EOR wells. This project addresses brine disposal wells only.
Geologic Characterization

- Diverse range of injection zones are present in the N. Appalachian Basin.
- Maps of key zones are being prepared.
Geologic Characterization

- Class 2 brine disposal wells reflect geology, historical development of oil & gas fields in the region.
Geologic Characterization

• Maps were integrated into geologic framework model to illustrate subsurface distribution of key injection zones in the region.

• Regional model has limitations.
Geologic Characterization

• Systematic review of available geophysical logs was completed to evaluate injection zone properties. The initial log data set included 688 Raster Tiff Images and 26 digital Las files.

• Gross and net thickness, average porosity, and porosity-feet estimates for each injection zone were calculated.
Geotechnical Testing

• Testing rock cores from state libraries for injection formations and caprocks for hydraulic/geomechanical properties.
  – Triaxial compressive test for acoustical velocities,
  – Acoustic velocities at hydrostatic conditions,
  – Static and dynamic Young’s modulus,
  – Poisson’s ratio,
  – Fracture toughness,
  – Bulk modulus, and
  – Shear modulus.
Class 2 Operational Data

- Class 2 UIC brine disposal monthly operational data was compiled from Western Kentucky, Ohio, Pennsylvania, and West Virginia UIC programs.
- Data was evaluated with statistics, graphs, and maps based injection formations, depths, locations.
- We looked at 2008-2012 time period and 2012.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Count &gt;0</td>
<td>218</td>
<td>218</td>
<td>174</td>
</tr>
<tr>
<td>Max</td>
<td>766,596</td>
<td>120,976</td>
<td>2,384</td>
</tr>
<tr>
<td>Mean</td>
<td>80,620</td>
<td>7,061</td>
<td>628</td>
</tr>
<tr>
<td>Median</td>
<td>32,015</td>
<td>2,668</td>
<td>543</td>
</tr>
<tr>
<td>STD</td>
<td>122,317</td>
<td>12,293</td>
<td>480</td>
</tr>
</tbody>
</table>
Class 2 Operational Data

- Demand for brine disposal in relation to unconventional wells in the study area (E. KY, OH, PA, WV).
Class 2 Operational Data

- Summary of Class 2 Brine Disposal Total Injection Volume in 2012 by Deepest Injection Formation.
- Data may reflect well activity more than injection capacity/performance.
Class 2 Operational Data

- Summary of Class 2 Brine Disposal Total Injection Volume in 2012 by Deepest Injection Formation.
- Data may reflect well activity more than injection capacity/performance.

![Diagram showing injection data by formation and 2012 average injection rate and wellhead injection pressure.]
Operational Data

- Summary of Class 2 Brine Disposal Total Injection Volume in 2012 by depth.
Operational Data

- Wellhead pressure and flow data are being collected from several Class 2 brine disposal injection wells in the study area.
- Data are being analyzed for reservoir properties, which will provide better understanding of injection zones in the region.
Reservoir Performance Analysis

- Results of the geological analysis and operational data were evaluated for indicators of reservoir performance.
- More detailed ‘relative injectivity index’ analysis was completed for monthly operational data for indicators of reservoir performance.

![Graph showing Average Monthly Injection vs Porosity-Ft](image)

- **Formation**
  - CLINTON
  - LOCKPORT
Reservoir Performance Analysis

- ‘Relative injectivity index’ analysis provided more qualitative indicator of reservoir performance for 24 wells.
- Data may reflect other well conditions, scale, well workovers, injection activity, and other factors.

**Example- ‘Clinton’-Medina Injection Well**

**Example- Mount Simon Injection Well**
Conclusion/Future Work

• Data was analyzed on brine disposal wells, geological conditions of injection zones, subsurface hydrologic conditions, geotechnical rock core test data, and operational data from injection wells for the Northern Appalachian Basin.

• There are a wide variety of injection zones used for Class 2 brine disposal in the Northern Appalachian Basin.

• It is challenging to absorb/analyze/evaluate all the information.

• The regional framework depicts the general setting for Class 2 brine disposal wells in the region.

• Operational data provides typical range of parameters (monthly injection rates, injection pressures) for brine injection wells in the region based on injection formation, which will be useful for operators.

• However, sometimes data merely reflects well activity.
Conclusion/Future Work

• A systematic analysis of 688 raster and 180 digital geophysical logs was completed for Class 2 Brine Disposal wells in the study area.

• Some of the carbonate units need multiple suites of logs for reservoir evaluation since thin zones of irregular porosity constitute the majority of the injection intervals.

• Integrating geologic data with operational data proved challenging, and many wells only provided indicators of reservoir performance.

• Results from the data integration and analysis task will be used to develop site-specific geocellular models, complete reservoir simulations of the injection process, and assess source-sink capacities.