Possible Water Resource Impacts from Marcellus Shale Gas Drilling in the Delaware Basin

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Natural Gas Resources

Most natural gas is currently recovered from conventional oil and gas fields.

“Unconventional” sources of natural gas identified by DOE include coalbed methane, western tight gas sands, and eastern gas shales.

Generally, the more unconventional the resource, the more expensive and difficult it is to obtain.

This talk:

Overview of eastern shale gas resources and previous studies of shale gas

Current interest in the Marcellus Shale: “Moneytalks”

Water-resource implications of Marcellus gas production

Questions and discussion
The Resource Triangle

- Cheap and easy
- Expensive and difficult

Quality of Resource

Quantity of Resource
Eastern Gas Shales

- Devonian-age shales occur in the Appalachian, Michigan and Illinois Basins in the eastern United States.

- Shale is a rock formed from mud deposited in a low water-energy environment.

- Gas has been produced from shale for over a century, but generally slowly and in small quantities.

- U.S. Department of Energy funded the Eastern Gas Shales Project between 1976 and 1981 to investigate the potential of this resource.

- The EGSP recovered 17,000 feet of Devonian Shale drill core.
Eastern Gas Shales Project
Unconventional Gas from Shale

- Shale comes in two types: organic-rich (black) and organic-lean (gray).
- Organic-rich shale contains 1-2% organics by volume.
- Shale porosity is typically around 10%, but permeability is very low.
- In order to produce gas from these rocks, a well bore must contact a large surface area within the formation via hydraulic fracturing. (which will be discussed in more detail later on)
Appalachian Basin Devonian Stratigraphy

DISCUSSION

East-west section shows a westward transition from shelf sandstones (B0 to D2), through slope turbidites (Bralier and Chagrin), to distal and basin, deep water, black and gray shales.

Section based on 27 wells projected from cross section network prepared for the Eastern Gas Shales Project. Facies geometry from cross section network also used to delineate lithologic units. Horizontal datum is approximately the top of the Devonian System.

In the mid-1980's, IGT (now GTI) ran 8 samples of shale through a precision core-testing apparatus.

Seven samples of Ohio Shale, and one sample of Marcellus Shale were analyzed for porosity and permeability using nitrogen and methane under pressures representative of in-situ conditions.
Marcellus Shale

- IGT analyzed ONE sample of Marcellus Shale core from ONE well in West Virginia.
- Porosity was measured with nitrogen gas and also with methane gas.
- Permeability was measured at pore pressures and net confining pressures approximating conditions at the depth of the core.
- We never had any funding to repeat the analyses, or to run any other samples of Marcellus.
Empirical function fit: \( \frac{\text{vol/vol/psi}}{} = (0.224)p^{1/2} \)

Reservoir pressure in WV-6 = 3500 psi

"...the measured initial reservoir pressure of the Marcellus Shale in EGSP Well WV-6 was 3500 psi...(which) results in a potential in-situ gas content of 26.5 scf/ft³ of rock..."

A previously published assessment by DOE of gas potential in Appalachian Basin shales was 0.52 scf/ft³.

Who was excited about this in 1988? Nobody (except me)
Fast Forward 20 years: Gas production from the Marcellus Shale in 2009

Why all the interest now?
How to move down the Resource Triangle

- Make the expensive cheaper: better economics
- Make the difficult easier: better engineering
The wellhead price of natural gas was under $2.00 per 1000 cubic feet (MCF) around 1980. In July 2008, natural gas was selling for almost $11.00 per MCF.
Better Engineering

Horizontal drilling and hydraulic fracturing, developed for the Barnett Shale in Texas have been applied to the Marcellus, greatly increasing gas production from Marcellus wells.
Marcellus Areas of Interest
Marcellus Gas Estimates

- One trillion cubic feet is considered a significant gas field.
- January, 2008: Engelder (Penn State) and Lash (SUNY) estimated 50 TCF recoverable gas from Marcellus Shale.
- November, 2008: Engelder revised Marcellus estimate to 363 TCF
- The Marcellus play has the potential to be the biggest gas field in the United States (Range Resources)
- Could contain enough gas to meet the entire nation’s natural gas supply needs for 14 years.
Future gas demand

- Demand for natural gas as a fuel in the United States is likely to increase.
  - Produced domestically, so it offsets imported oil.
  - Cleanest hydrocarbon-based fuel in terms of emissions ($\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O}$), also has lowest carbon dioxide emission per BTU of any hydrocarbon fuel.
  - CNG can act as a bridge fuel for transportation needs.
  - Vehicles have been running on CNG in western Canada since the 1980’s, and the technology is well-developed.

- Natural gas is difficult to import (cryogenic liquid) – it is most efficiently transmitted through a pipeline.

- A nationwide infrastructure for natural gas is already in place, unlike other energy resources such as ethanol.
Water-Resource Concerns

Marcellus Shale natural gas drilling operations

(Once the well is completed and producing gas, it is not a water-resource concern.)
Hydraulic Fracturing

- Hydraulic fracturing as a production technique for gas and oil has been around since the 1950's.
- A hydraulic fracture increases the surface area of the well bore that is in contact with the formation.
- Hydraulic fractures provide permeable pathways to transport gas to a well.
- Fractures are created by filling the well with fluid and increasing the pressure until the rock strength is exceeded.
- The vertical fracture follows pre-existing planes of weakness.
Hydro-fracturing techniques

- It can require several million gallons of water to fracture a well.
- As the fracture grows, sometimes thousands of feet on either side of the well, additional fluid must be added to maintain the pressure. Up to 4 million gallons per treatment can be used.
Water Sources

- Water for hydraulic fracturing has been taken from streams, lakes and wells.
- The Barnett Shale production in Texas generally uses ground water from the Trinity aquifer.
- A single Barnett Shale well uses approximately 3 million gallons of water. About 2.6 billion gallons (or 8,000 acre-feet) of water were used in 2005 for Barnett Shale frac jobs.
- Hydrofrac water does not have to be finished quality. Virtually any raw water will work.
- Some drillers in PA and NY have been trying to obtain treated wastewater for frac jobs.
- Policies concerning which water sources can be used for hydraulic fracturing vary widely between states, and even within states.
Fracture fluids

The fracture fluid contains proppant, usually sand, designed to keep the fracture open after the pressure is released and the fluid recovered.

Proprietary chemicals called “cross-linked gels” are added to the fracture fluid to increase the viscosity so proppant will be carried into the fracture.

The gels are designed to break down after a short time period, usually hours, to allow the fluid to be recovered from the well.

As much fluid as possible must be recovered to allow the gas to flow.
Disposal concerns

- The recovered fracture fluid must be disposed of:
  - Possible brines, heavy metals, organics from the formation
  - Proprietary chemical mixes and additives

- Potential disposal options:
  - Surface water discharge after treatment
  - Recycling and reusing the fluid
  - Evaporation from a holding tank
  - Re-injection into the ground (done in Texas)

- In Pennsylvania, re-injection has not been allowed so far, but is being considered. Currently, frac fluids are trucked to wastewater disposal facilities.
The Big Questions

- How many Marcellus Shale gas wells could be drilled in the Delaware Basin?
- How much water will be required per well for horizontal drilling and hydraulic fracturing? What are the possible sources of this water?
- What is a sustainable drilling rate that doesn’t strain local water resources?
- What might some of the contaminants be in the recovered hydrofrac fluids? From the proprietary chemicals? From contact with the formation?
- How will the frac fluids be disposed of? Will treatment be required? Monitoring?
- Who pays for regulatory oversight and monitoring?