



Water Resource Management for Natural Gas Development

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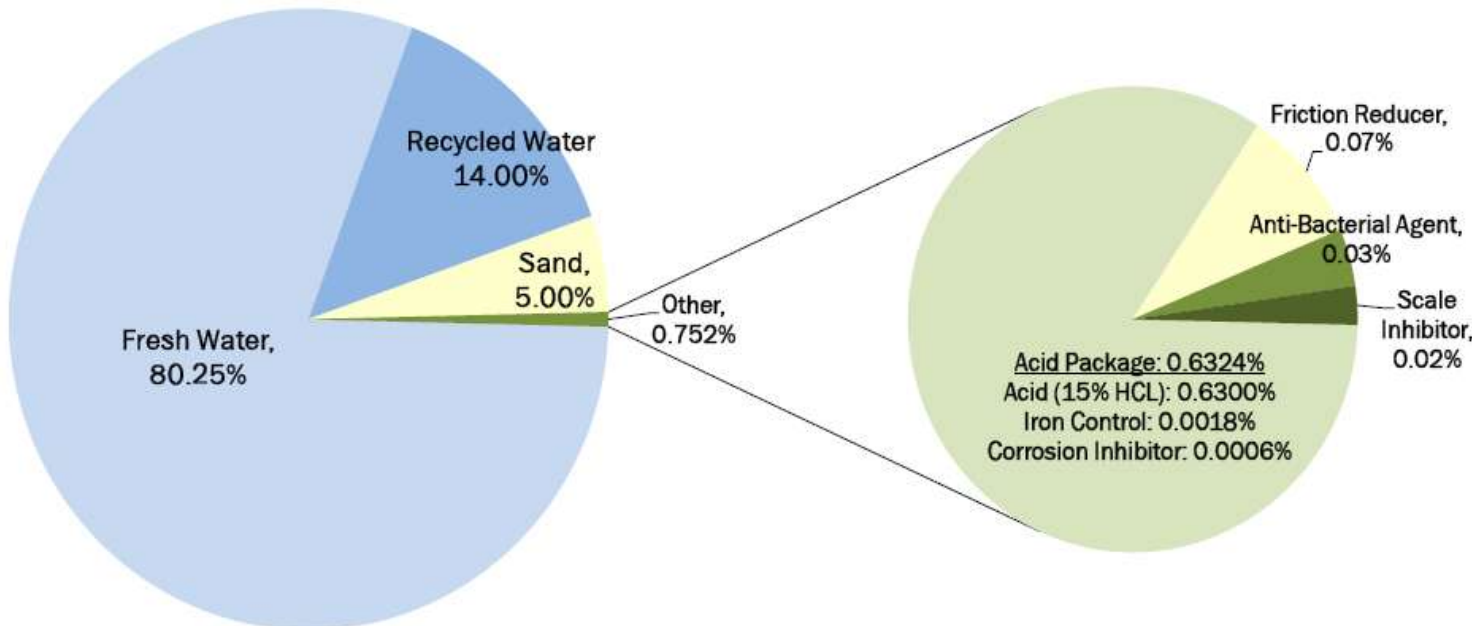
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Shale Gas Development Water Use

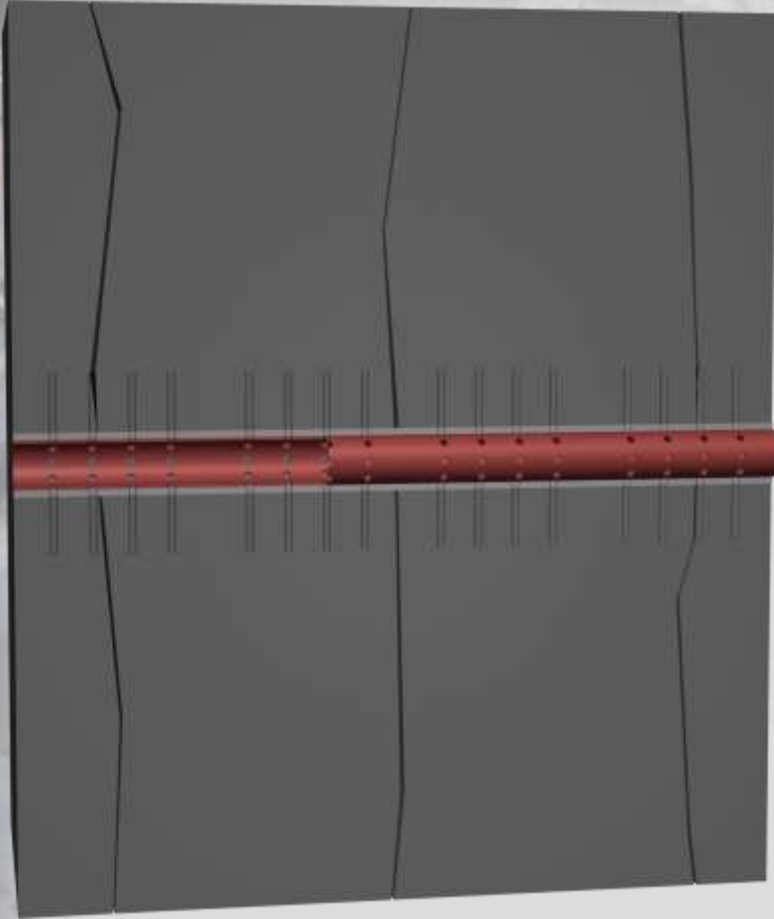


- 80,000 to 100,000 gallons of water used during drilling
- 3 to 7 million gallons of water used during hydraulic fracturing
- Approximately 10% to >50% of the injected fluids return as flowback water

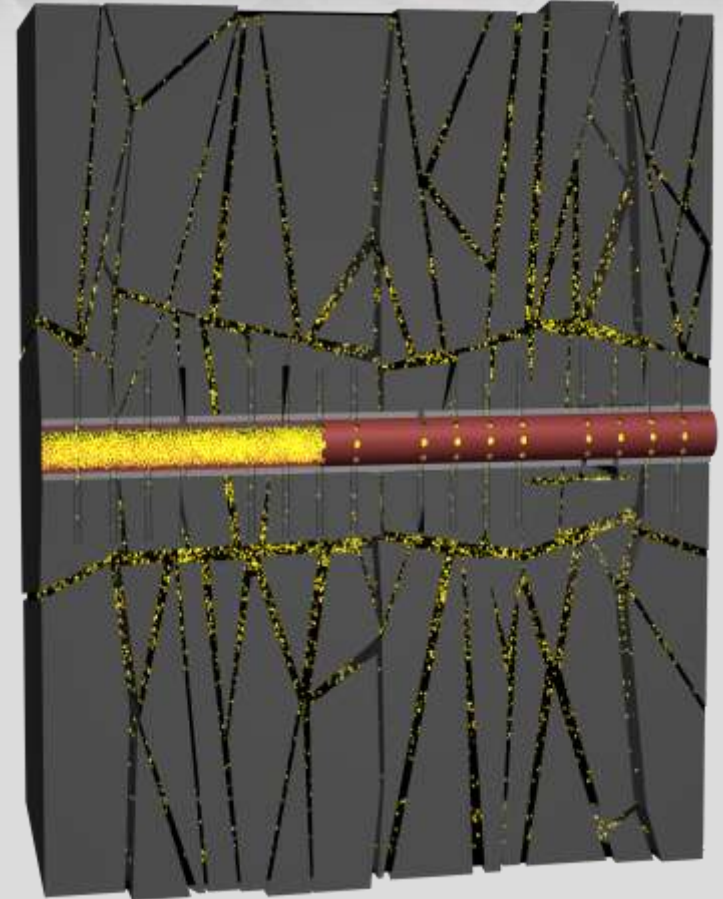


Source: Chesapeake Energy

Pre and Post Hydraulic Fracturing



Every 300-500 feet of casing is perforated to inject fluids into the shale for hydraulic Fracturing.



Approximately 0.5 to 1 million gallons of fluids are injected into each stage.

Water Supply Source Options

- **Municipal Supply vs. Self Supply**
 - Dependent on location, availability, timing
 - Municipal supply access generally quicker but more costly
 - In Pennsylvania, 70% surface intake sources vs. 30% municipal sources
- **Surface water vs. Groundwater**
 - Surface water has been a primary source
 - Groundwater wells may work where sufficient yields can be obtained
 - Some areas of US experiencing significant drought, depleting aquifers
- **Alternative water sources**
 - Abandoned mine drainage
 - Treated wastewater
 - Cooling water
 - Others



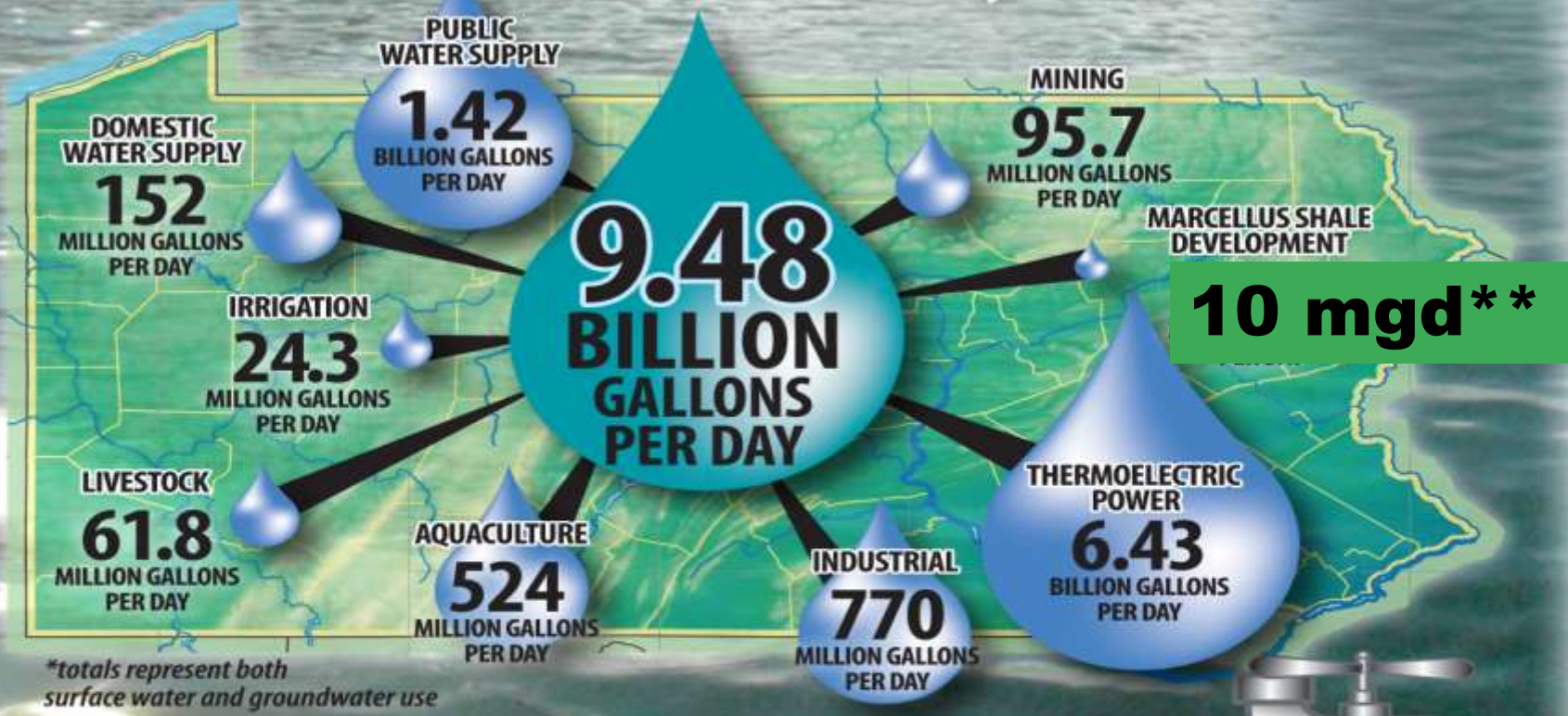
Water Supply Considerations

Number of factors to consider:

- Access to water near the drilling project area
- Proximity to well site: piping vs. trucking
- Availability-seasonal or perennial
- Will pass-by flows be required?
- Water quality
- Permitting complexity
- Other operators on same water body may limit use
- Drilling schedule vs. permitting schedule
- Budget



PA Water Withdrawals by Water Use*



*totals represent both surface water and groundwater use

Sources: J. F. Kenny, N. L. Barber, S. S. Hutson, K. S. Linsey, J. K. Lovelace and M. A. Maupin. 2009. *Estimated use of water in the United States in 2005*. U. S. Geological Survey Circular 1344. 52 p.

Marcellus Shale Gas Development Water Use: June 1, 2008 - May 21, 2010 Susquehanna River Basin Commission basin-wide reported daily use of 0.99 MGD expanded to statewide estimate. Water sources: 29% Public water supplies/71% Surface water withdrawals
 1 MGD daily use in Susq. Basin ÷ wells drilled in Susq. Basin/wells drilled statewide=1 MGD ÷ (765/1428)



Permitting Requirements

Typical approvals necessary from state regulators and agencies prior to drilling:

- 1) Drilling permit
- 2) Water management plan
- 3) Earth disturbance permit
- 4) Encroachment permits (water intakes or crossings)
- 5) River Basin Commission permits:
 - Water withdrawal permit for each intake/source
 - Consumptive use permit for each well pad

Each state has unique permitting and withdrawal guidelines, which may differ from watershed to watershed within the state, example:

Pennsylvania and New York has two major river basin commissions, Susquehanna and Delaware, no drilling in Delaware Basin or in New York because of different regulations.

Water Transport



Piping vs. Trucking

- Road damage can be an issue on smaller roads
- Piping not always practical
- Trucking costs are significant
- Trucking accidents occur
- Traffic is a concern
- Piping generally more cost effective over long term



Water Storage

Storage options:

- Centralized impoundment
- Single pad-dedicated impoundment
- Frac tanks

Storage options based on ultimate scale of operations (long term vs. short term)



Emerging Water Management Trends

- **Use of alternative water sources**
 - **Groundwater supply wells closer to drilling**
 - **Municipal wastewater use (3 plants in permitting process in PA)**
 - **Acid mine drainage**
- **Flowback recycling**
 - **Estimated >70% of flowback is being recycled in PA**
- **On-site treatment technologies**
 - **Evaporation**
 - **Filtration**
 - **Chemical precipitation**
- **Closed loop drilling and fluids storage**
- **Lined well pads to minimize releases**
- **Temporary above-ground impoundments**
- **GPS tracking services of water hauling trucks**
- **Regulatory monitoring down stream from discharges**
- **Testing of private water supplies prior to drilling to ensure no impacts**

Temporary Impoundments



Can store ~ 1 million gallons in reusable above ground impoundments with less disturbance

Vertical Storage Tanks



Vertical tanks provide more storage on size with less footprint, translating into smaller wells pads



Lined Well Pads



Potential for soil or groundwater contamination is minimized with lined well pads.

Closed Loop Drilling Systems



Potential for spills or releases is minimized with closed loop drilling systems.

Thank you!

Questions?



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