Flowback Management Trends and Strategies

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Chesapeake Bay Scientific and Technical Advisory Committee

Exploring the Environmental Effects of Shale Gas Development in the Chesapeake Bay Watershed

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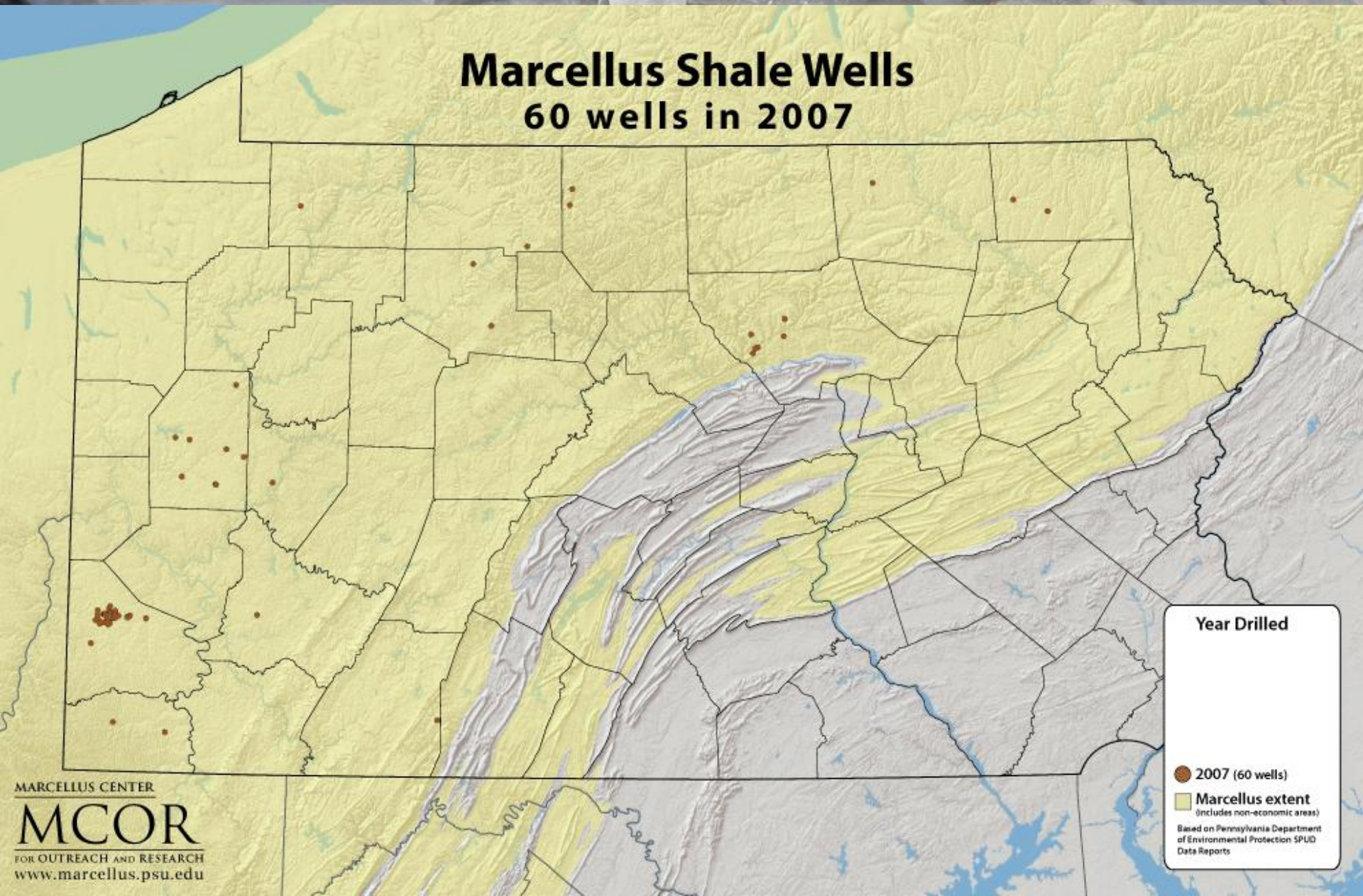
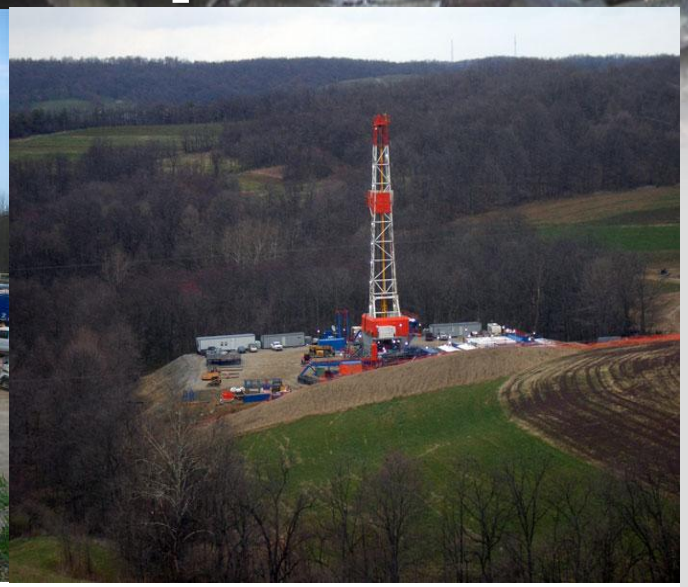
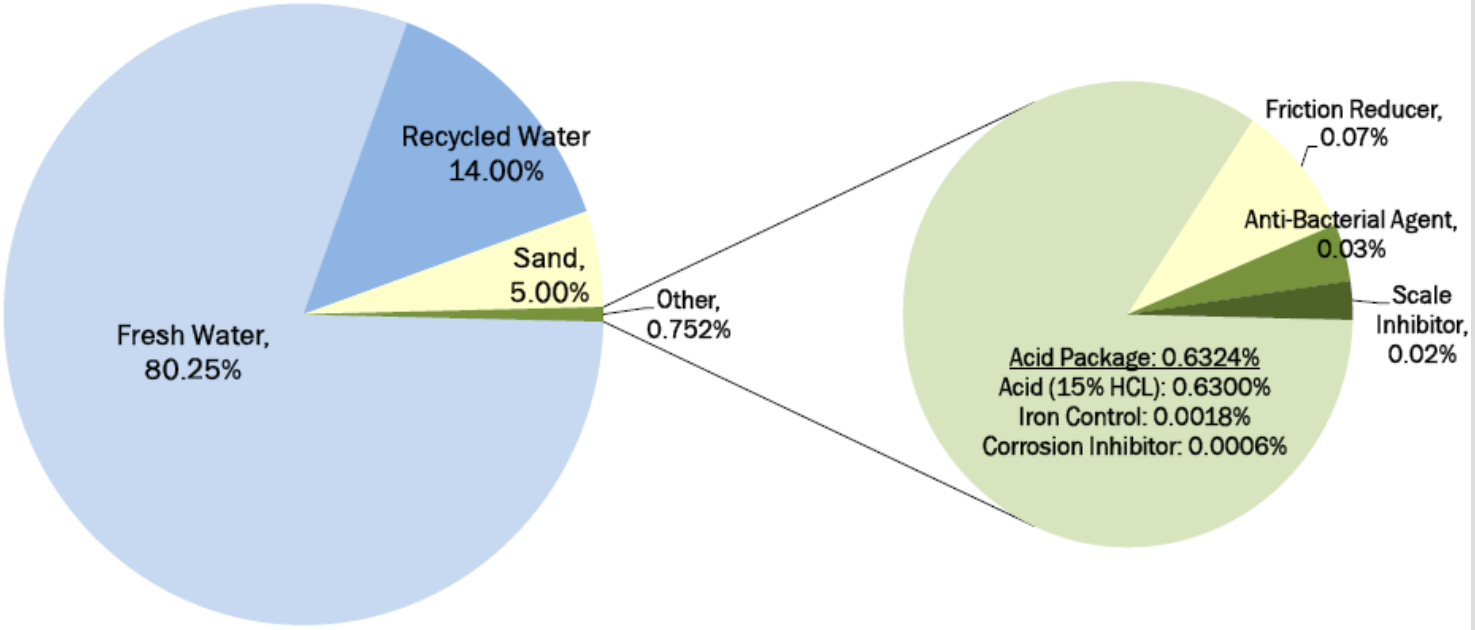
Well Drilling Locations



Shale Gas Development Water Use



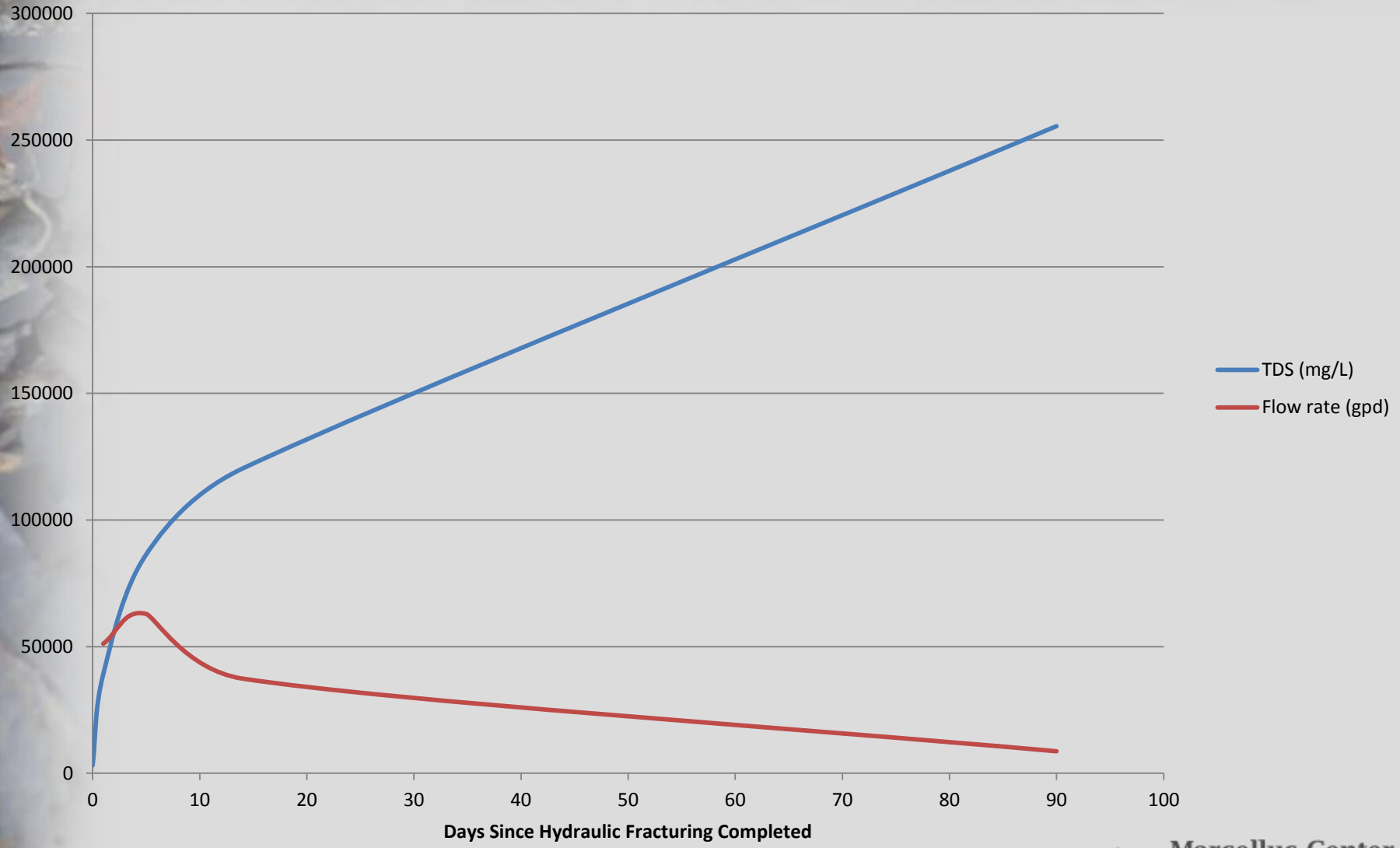


- 80,000 to 100,000 gallons of water used during drilling
- 3 to 7 million gallons of water used during hydraulic fracturing
- Approximately 8-10% of the injected fluids return as flowback water

Source: Chesapeake Energy

Flowback Water Quality Trends

Average Flowback TDS Concentration and Discharge Rate vs. Time



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Flowback Water Management Options

- Direct reuse without treatment (blending)
  - Blending of flowback w/fresh water for reuse
  - Miminal cost w/some well plugging potential
- On-site treatment and reuse
  - Re-condition water by treatment
  - Moderate cost w/minimal potential for well plugging issues
- Off-site treatment and reuse
  - Same benefit as on-site treatment but with more transport costs
- Off-site treatment and disposal
  - High transportation and disposal costs

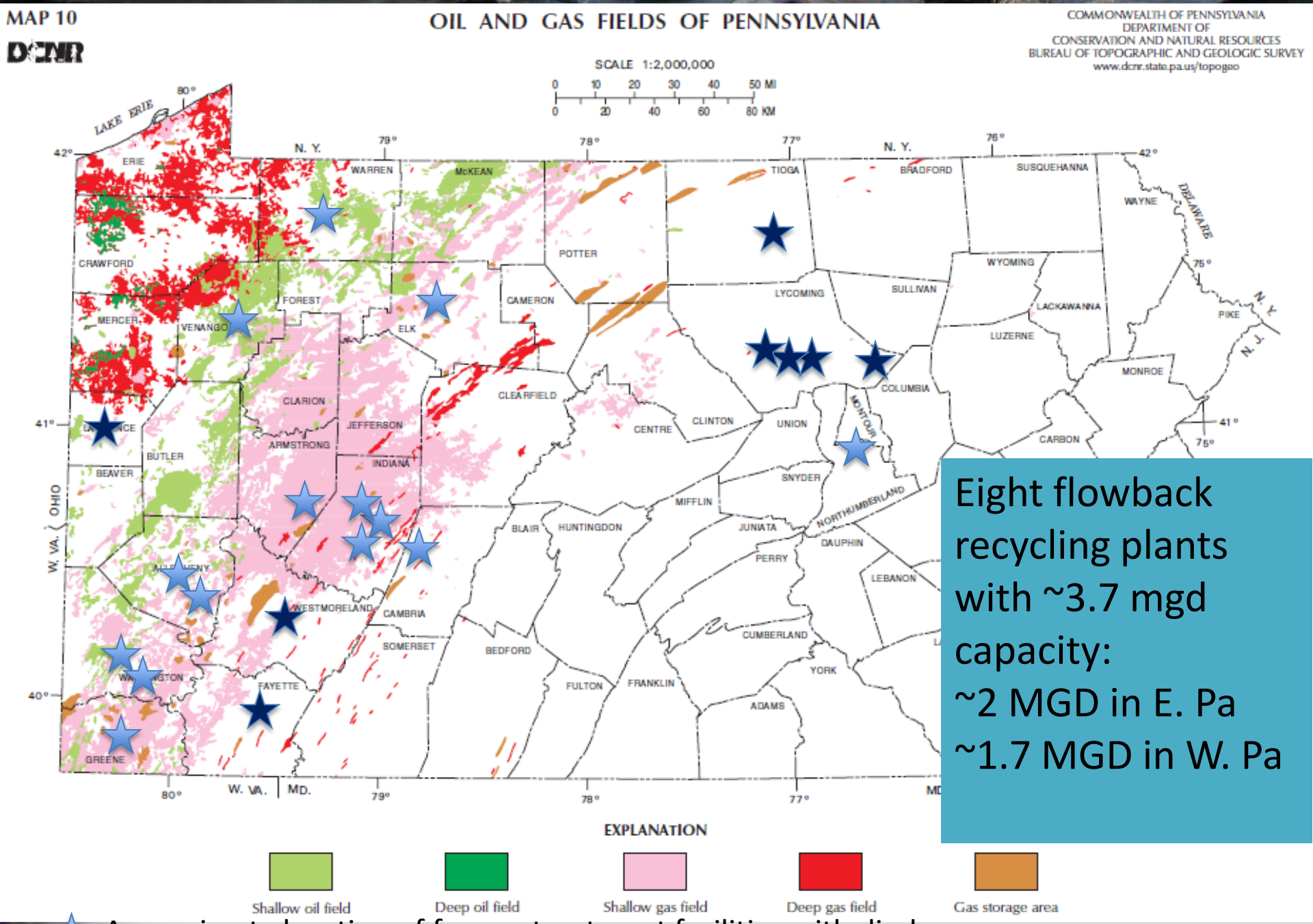
Photo courtesy of TerrAqua Resource Management

High TDS Treatment Standards

- Any facility that will have a high influent TDS (> 2000 mg/L) will need to install advanced treatment to meet the following effluent discharge limits:
  - TDS-500 mg/L
  - Chlorides-250 mg/L
  - Strontium-10 mg/L
  - Barium-10 mg/L
- These standards adopted in August 2010 per Chapter 95
- Two facilities have thermal technologies to meet this standard, yet most effluent re-used.

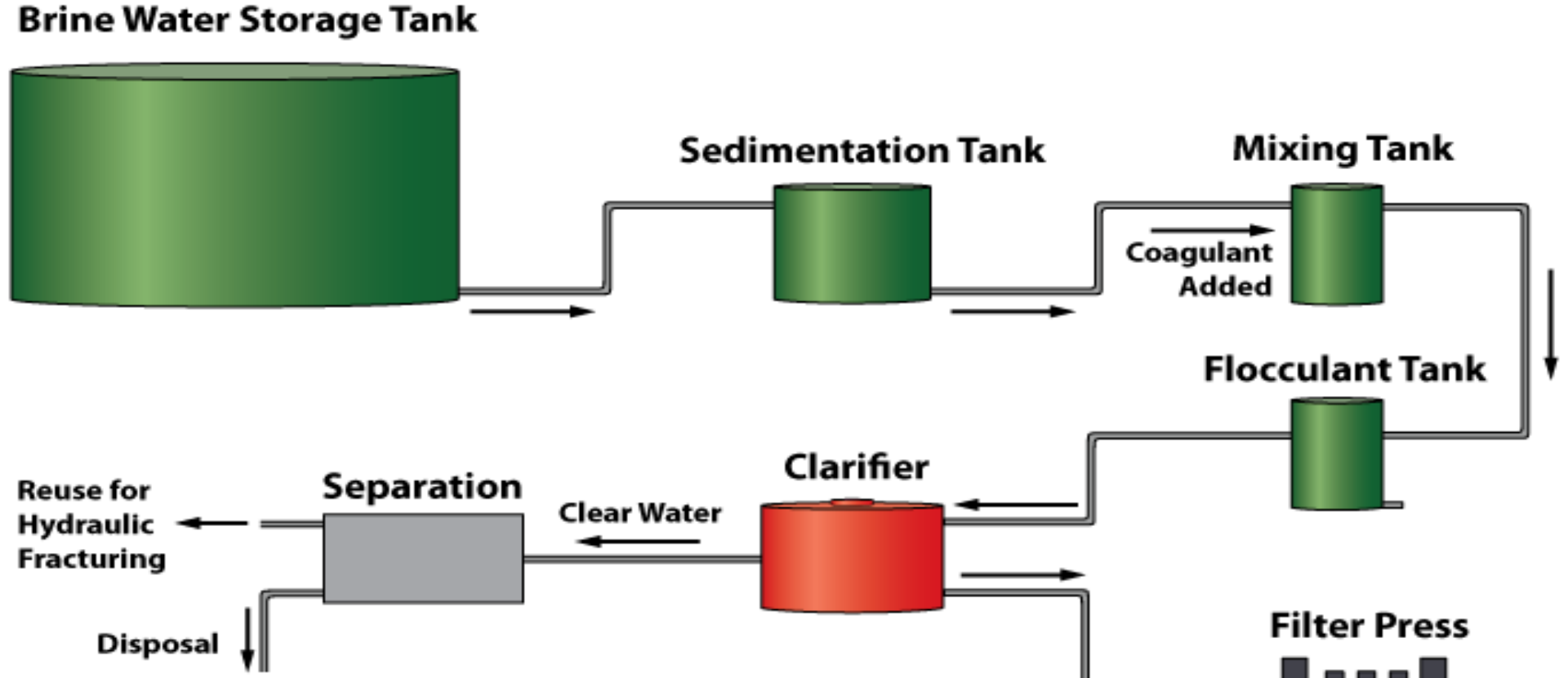
PA's Current Fixed Site Treatment Capacity

- Seven centralized flowback/produced water treatment facilities as of year end 2011 that recycled fluids with eight permitted facilities having total capacity of 3.7 mgd (~88K bbl/day)
  - Six remove scaling agents (~3.3 mgd or 78K bbl/day capacity)
  - Two desalinate water (~400K gpd or 10K bbl/day capacity)
- Approximately 30 flowback water treatment facilities in various stages of permitting or construction



Eight flowback recycling plants with ~3.7 mgd capacity:
~2 MGD in E. Pa
~1.7 MGD in W. Pa

Typical Treatment Scheme for Reuse



-Chemical precipitation can have >99% removal efficiency for potential scaling agents,

-Not generally designed to remove salts,

-Can generate several tons of sludge per 100,000 gallons treated, requiring landfill disposal.

Mobile Flowback Wastewater Treatment and Reuse

- Treatment activities at well site regulated under PaDEP Oil & Gas Regulations (Ch. 78)
- OG-071 permit required for Alternative Waste Treatment anytime there is treatment of waste streams on a well site
- Mobile treatment use increasing due to reduction in:
  - Costs
  - Trucking transport
  - Fresh water use
  - Environmental impact

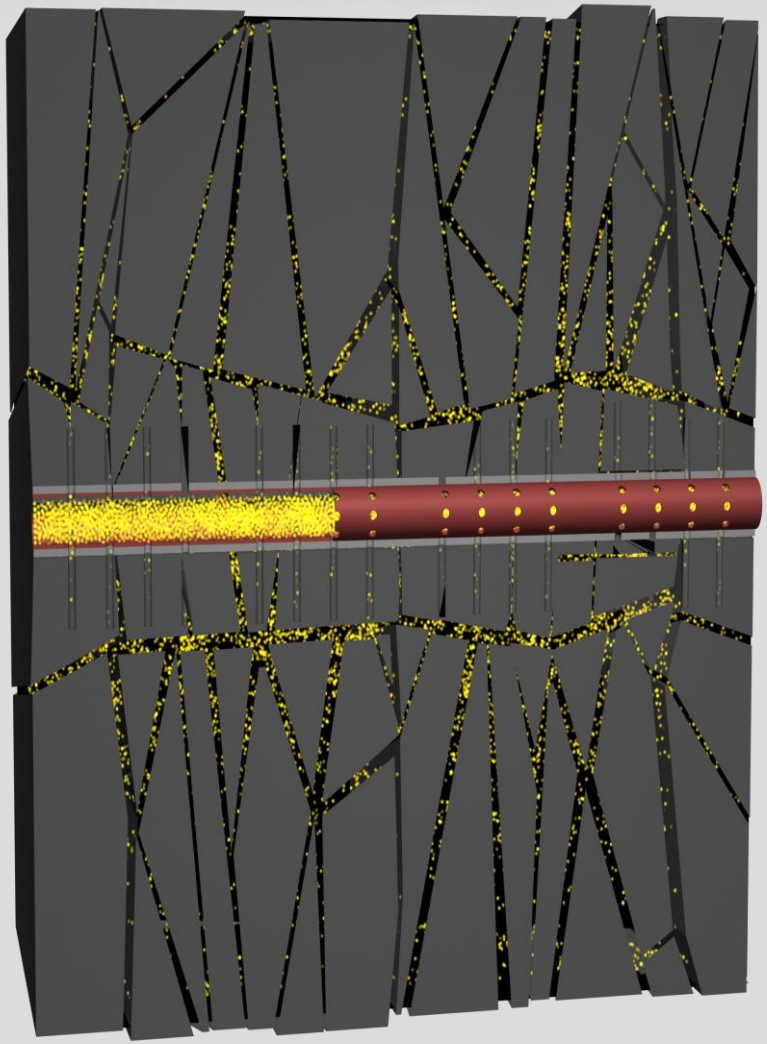
Flowback Treatment Specifications

Example flowback treatment levels for recycling purposes per industry standards:

- Total cations 10 - 2,000 ppm range
  - Acceptable levels range from company to company
  - Primary focus on Ba and Sr, but Ca also a concern
  - Ba, Sr , Fe, Mn, Mg < 10 ppm
  - Ca <1,000 ppm
- Processed water sulfates levels <30 ppm
- TSS <30 ppm
- TDS is variable, >50,000 ppm can be acceptable

Fracturing Fluid Characteristics

- Non-damaging
  - Minimal leak-off
  - High fluid efficiency
  - No scaling
  - Minimal skin effect
- Brine tolerant friction reducer
- Adequate scale and Fe control
- Sufficient viscosity to carry proppant
- Rapid clean-up
- Develop extensive fracture network
- Cost-effective



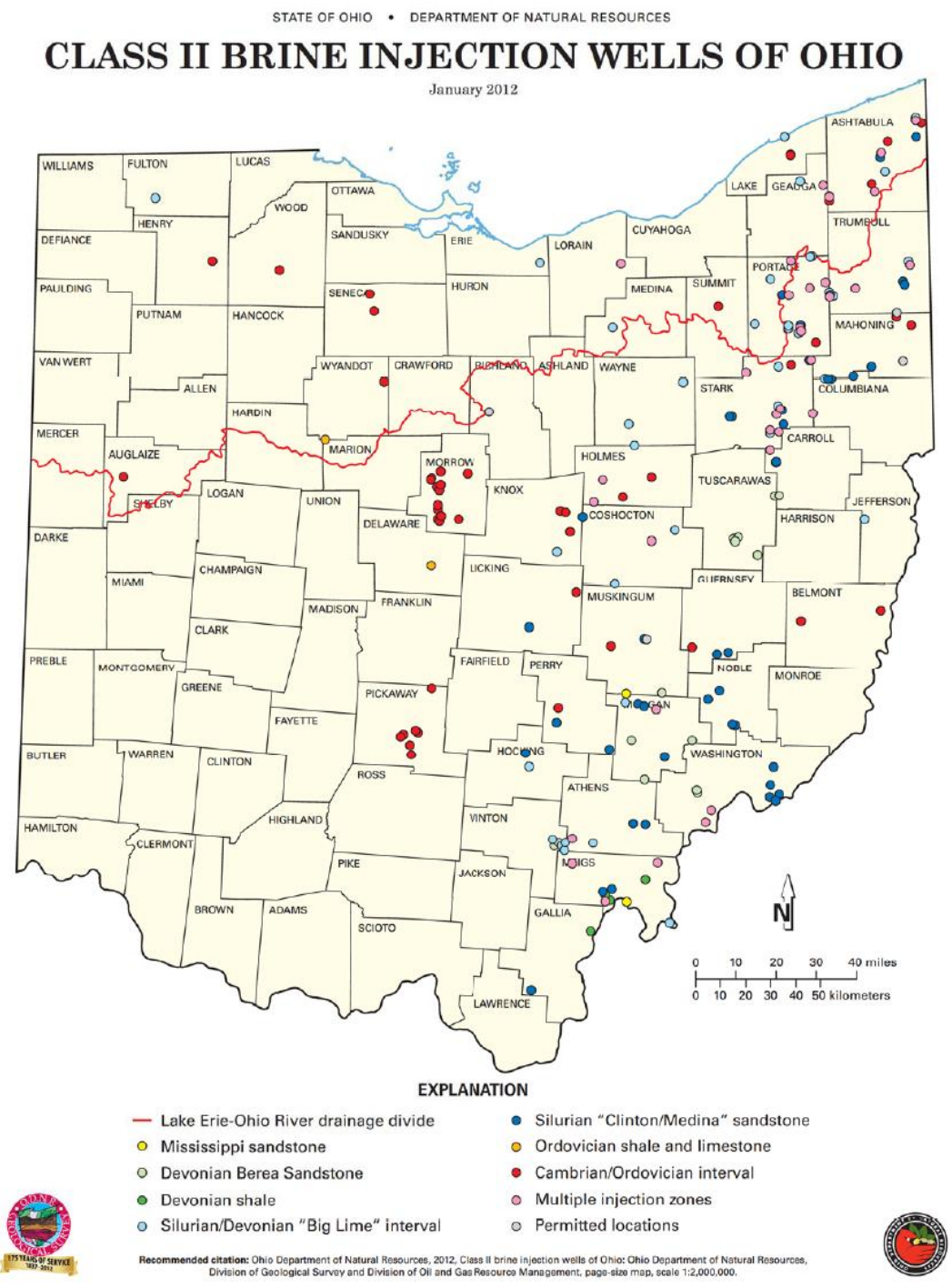
Underground Injection Wells in PA

- Currently 8 injection wells in PA (only 3 commercial facilities)
- Limited injection capacity (~5000 bpd/210,000 gpd)
- Relatively little use for Marcellus flowback disposal
- Difficult to find suitable target injection reservoirs in PA
- EPA has primacy for UIC permit
- Two UICs recently approved in Warren Co.

Fluids Management Trends for 2011

2011 Totals		
Generated fluids (bbls)	18,222,521	%
Reused fluids (bbls)	13,292,870	~73%
Disposed (bbls)	4,929,651	~27%

	1st Half 2011	2nd Half 2011	% increase
Number of wells w/fluid waste	1,875	2,603	39%
Generated fluids (bbls)	8,097,067	10,125,454	25%
Reused fluids (bbls)	5,462,328	7,830,542	43%
Recycled at fixed plant (bbls)	975,025	1,766,490	81%
Recycled in field (bbls)	4,487,303	6,064,052	35%
Disposed fluids (bbls)	2,634,739	2,294,912	-13%
Injected fluids (bbls)	761,601	1,981,580	160%
Flowback recycling (%)	67%	77%	15%
Fixed plant recycling (%)	18%	23%	26%
Field recycling (%)	82%	77%	-6%
UIC disposal (%)	9%	20%	108%



Ohio UIC Well Stats	
Year	MM BBLS injected
2005	6
2006	6.1
2007	6.1
2008	6.9
2009	7.1
2010	8.2
2011	12.2

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Waste Management Trends

- Flowback water reuse is increasing
  - ~77% industry-wide, was ~10% just a couple years ago.
- Little to no discharge of treated flowback/produced water to surface water
- Field recycling and fixed site treatment being utilized increasingly
  - Field recycling ~40,000 bpd in 2011
  - Fixed treatment plant use ~10,500 bpd in 2011
- Additional centralized treatment facilities in various stages of permitting/construction
- Beneficial reuse of sludges and solids for landfill cover is occurring at some facilities
- UIC disposal well use increasing in OH
  - Was ~5% a year ago, now ~20%
- UIC well sites being pursued in PA

The End

Hopefully that *clarified* everything!

Photo courtesy of TerrAqua Resource Management