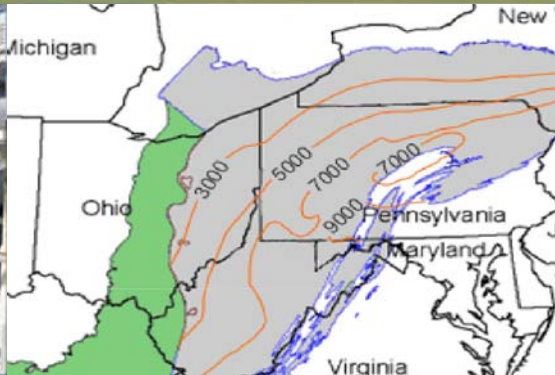
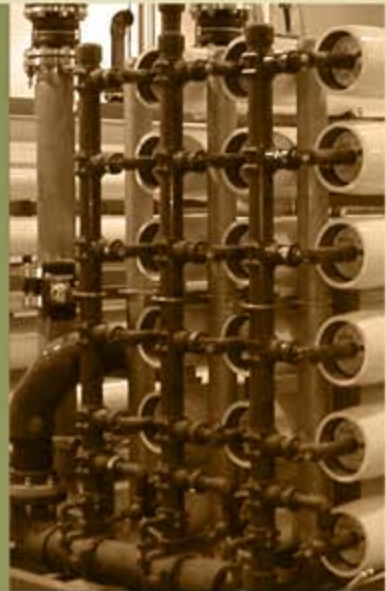


Water Issues Related to Unconventional Oil and Gas Production

Sept 28, 2010

John T Lucey, Jr PE



Flowback Water Volume



- Over 1700 wells drilled in 2009
- If we reach 3000 wells in 2010 and generate 800,000 gallons each well=2.4 billion gallons/yr

Flowback Water Characteristics

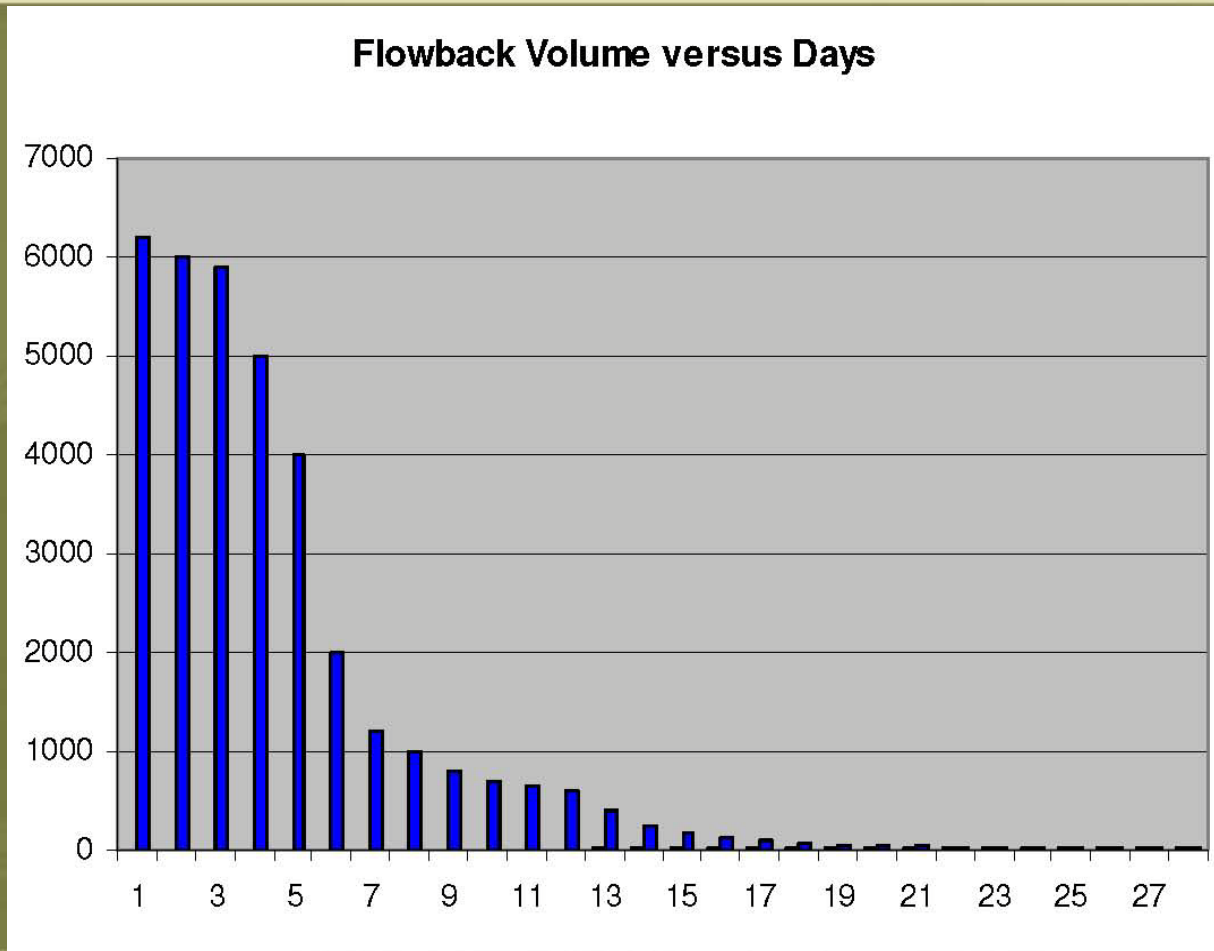
Parameter	units	Barnett Shale	Fayetteville Shale		Marcellus Shale		Marcellus Shale		
		GeoPure	source unidentified		GRI/POGAM Data		GE/SRW Presentation Data		
		IPEC 2007	just after frac	45 days out	5 day	14 day	Day 1	Day 5	Day 14
pH	std units	6.86	8.7	7.4	5.5 to 6.5		6.97	6.42	6.1
TSS	mg/L	4200							
TDS	mg/L	14590	2580	9810	60000	109000	21823	65976	201860
TOC	mg/L					37			
Chloride	mg/L	7830	1170	5780		70000	13600	40600	125300
Sodium	mg/L	4504	1070	4020		32000	6270	17700	47800
Calcium	mg/L	676				10200	1180	4760	23321
Magnesium	mg/L						129	492	2336
Barium	mg/L	936	0.16	5		575	276	1340	248
Strontium	mg/L		5.3	14.5			204	890	2396
Iron	mg/L	173	0.16	179		40	8	21	277

Flowback Water Characteristics

Table 1
Penn State Water Resources Extension Service
October 2009 Webinar, slide 11

Parameter	units	First 1/3	Second 1/3	Last 1/3
TDS	mg/L	23,978	142,095	245,987
Chloride	mg/L	12,098	64,598	134,065
Barium	mg/L	432	4,786	6,784
Iron	mg/L	12	27	67
Benzene	ug/L	BD	BD	18

Typical Horizontal Well Flowback Curve



Flowback Water Management Options

- Discharge to Merchant Treatment Facility
- Truck to Disposal Wells
- Reuse with no treatment
- Treat and Reuse

Flowback Water Management Options

Discharge to Merchant Treatment Facility

- Limited number of facilities
- Facilities discharge will be limited by TDS and Chloride and other limits
- New facilities require long term commitment of water to keep amortization costs down
- May be best solution if designed as treat and reuse facility

Flowback Water Management Options

Truck to Disposal Wells

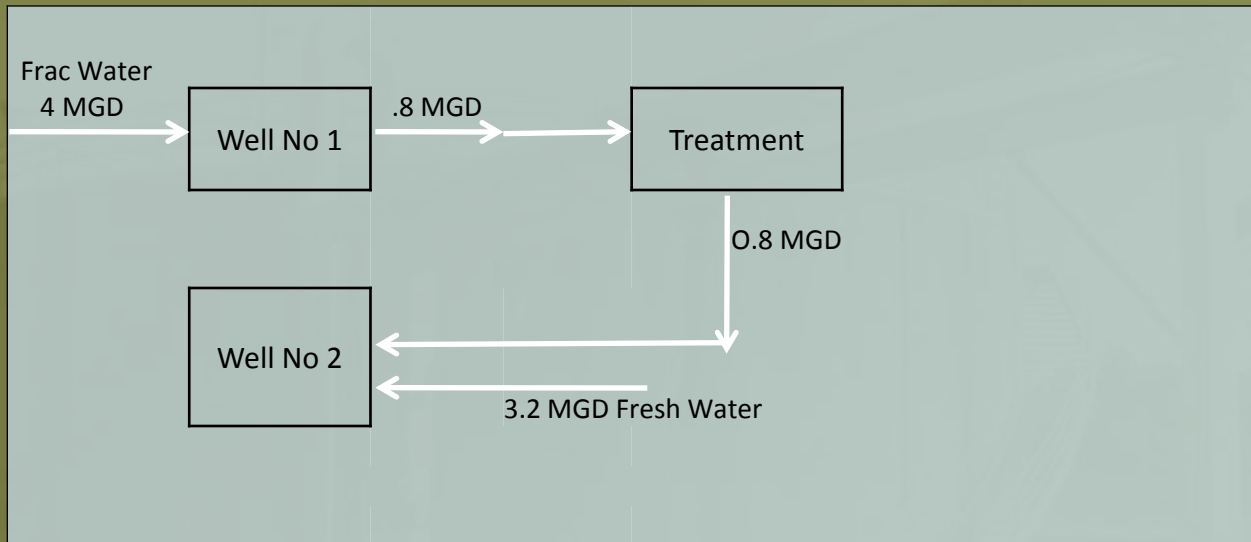
- Very few in PA, just over 40 in OH
- Trucking cost will be about \$1/barrel/hr
- Current wells can handle about 4.5 million barrels/yr
- This is less than 10% of capacity to handle 57 million barrels/yr generated

Flowback Water Management Options

Reuse with no Treatment

- Trucking cost will be about \$1/barrel/hr
- Can increase chemical usage to deal with scalants and other contaminants
- Typically want to remove suspended solids prior to reuse

Typical Treatment and Reuse scheme



Treat and Reuse Options

- Precipitation of Iron
- Precipitation of Barium
- Precipitation of Strontium
- Softening Reactions
- Salt removal



Treat and Reuse Commercial Options

- Mobile treatment systems-many options available
- Modular reuse systems
- Central treatment plants managing water from multiple customers

Mobile Treatment systems

- Effluent is pumped/piped or trucked to next well site
- Mobilization/Demob must be considered
- Precipitation systems, thermal, sludge dewatering etc
- Can be contract operated



Modular Treatment systems

- Utilizes similar technologies as Mobile systems- centrally located to serve several producers
- Adds one additional transport step
- Mobilization/Demob costs are saved
- Gain some economy of scale
- Can be easily automated

Central Treatment systems

- Similar to Mobile and Modular but built to last 20+ years
- Would require long term service contracts
- Would provide optimum economy of scale, lowest operating cost and should provide highest quality