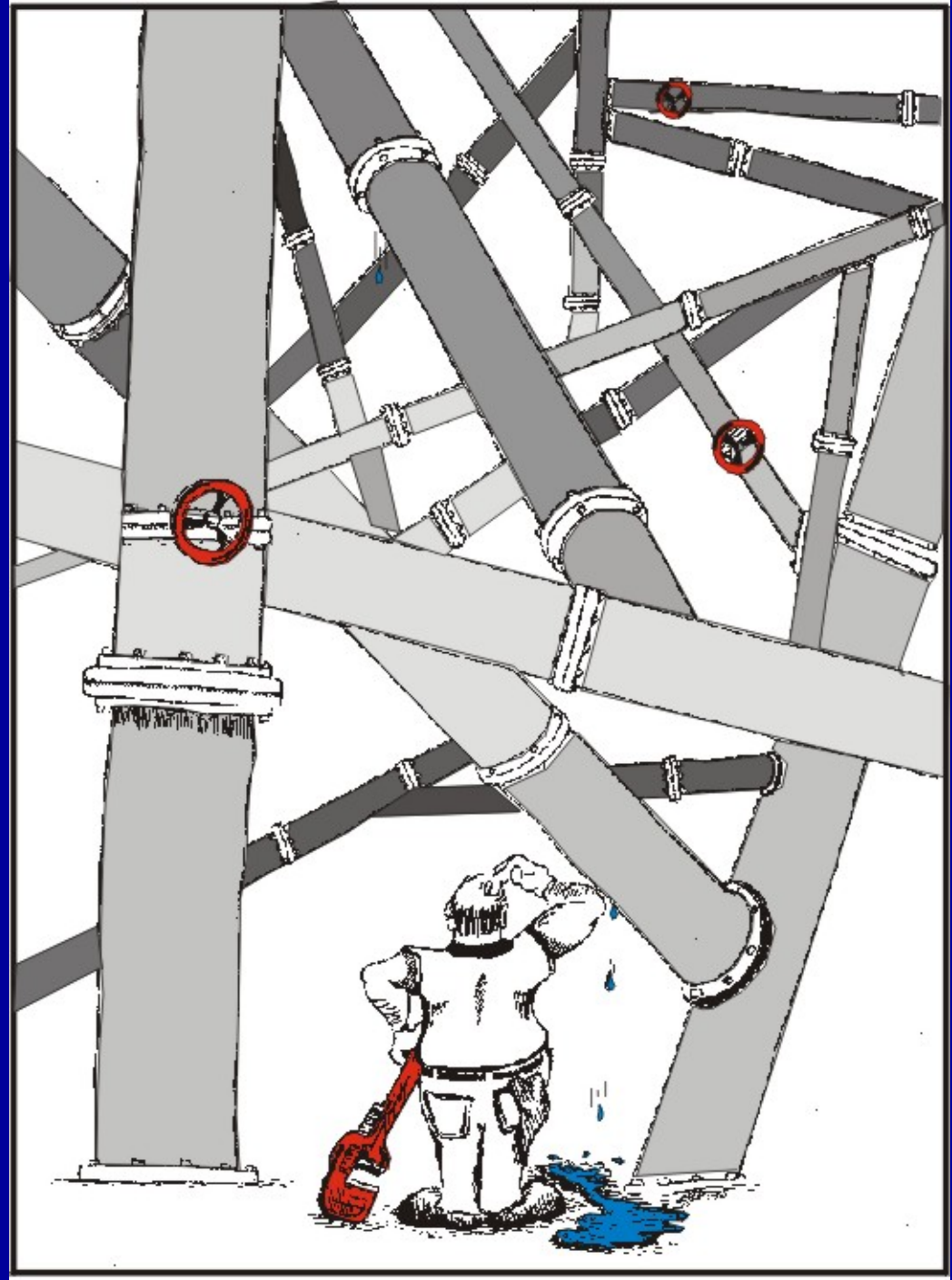
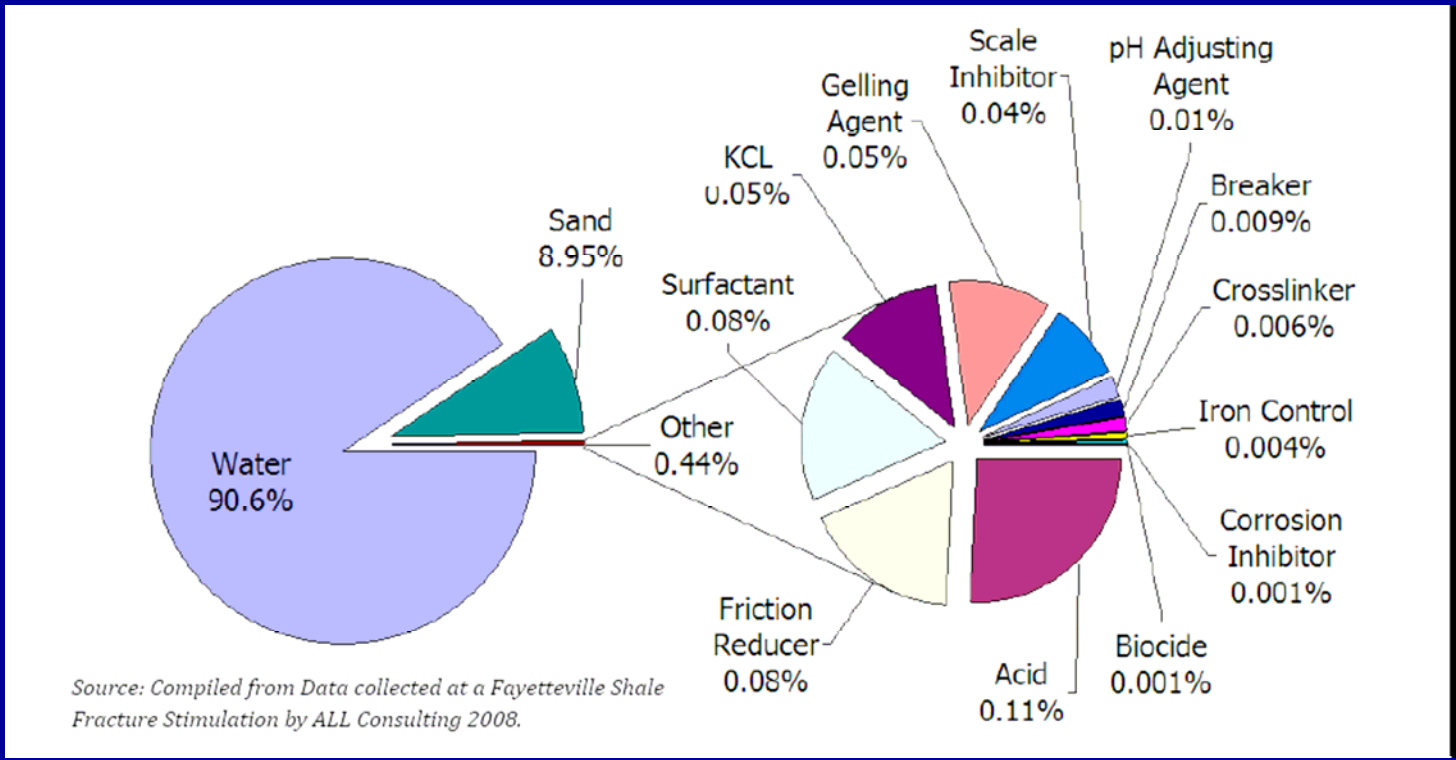
What is the quality of the frack and flowback water?



Typical Components of Frack Fluid

For a 1.5 million frack job, the 0.5 percent is equivalent to 7,500 gallons of “chemistry”.

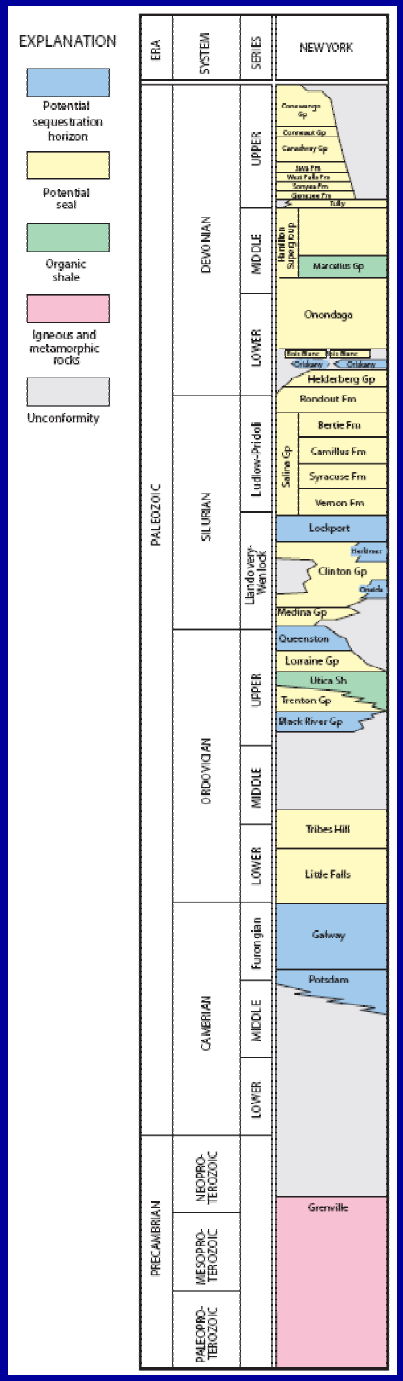


(Arthur, Bohn, Layne, 2008, ALL Consulting)
http://www.all-llc.com/shale/GWPCMarcellusFinal.pdf

What do we do with the flow-back water after the hydrofrac process is complete, and the formation water as gas is produced from the well?

Frack Water Return –
by total volume injected
(1.5 M gal), returned over a
2-week period of time.
(From a well in SW Pennsylvania.)

Constituent	1st Third	2nd Third	Final Third	Units
Bromide	124	479	753	MG/L
Chloride	18,600	80,500	109,000	MG/L
Sulfide, Dissolved	<0.50	29.5	<2.5	MG/L
Solids	34,578	133,620	192,000	MG/L
Temperature	29.3	29.4	25.3	Degrees C
Barium	668	6,100	8,730	MG/L
Iron, Total	23	31.3	71.9	MG/L
Magnesium	69.3	572	890	MG/L
Gross Alpha	1,159	22.41	18,950	pCi/L
Gross Beta	6,500	9.68	7,445	pCi/L
Radium 226	33	2.58	4.67	pCi/L
Radium 228	4.66	1.15	18.41	pCi/L
Manganese, Total	0.73	1.8	2.79	MG/L
Mercury, Total	<0.0002	<0.0002	<0.0002	MG/L
Molybdenum, Total	0.16	0.72	1.08	MG/L
Nickel, Total	0.03	0.07	<0.01	MG/L
Selenium, Total	<0.02	<0.02	<0.02	MG/L
Silver, Total	<0.01	<0.01	<0.01	MG/L
Thallium, Total	<0.02	<0.02	0.1	MG/L
Titanium, Total	0.06	<0.01	<0.01	MG/L
Zinc, Total	0.036	0.028	0.035	MG/L

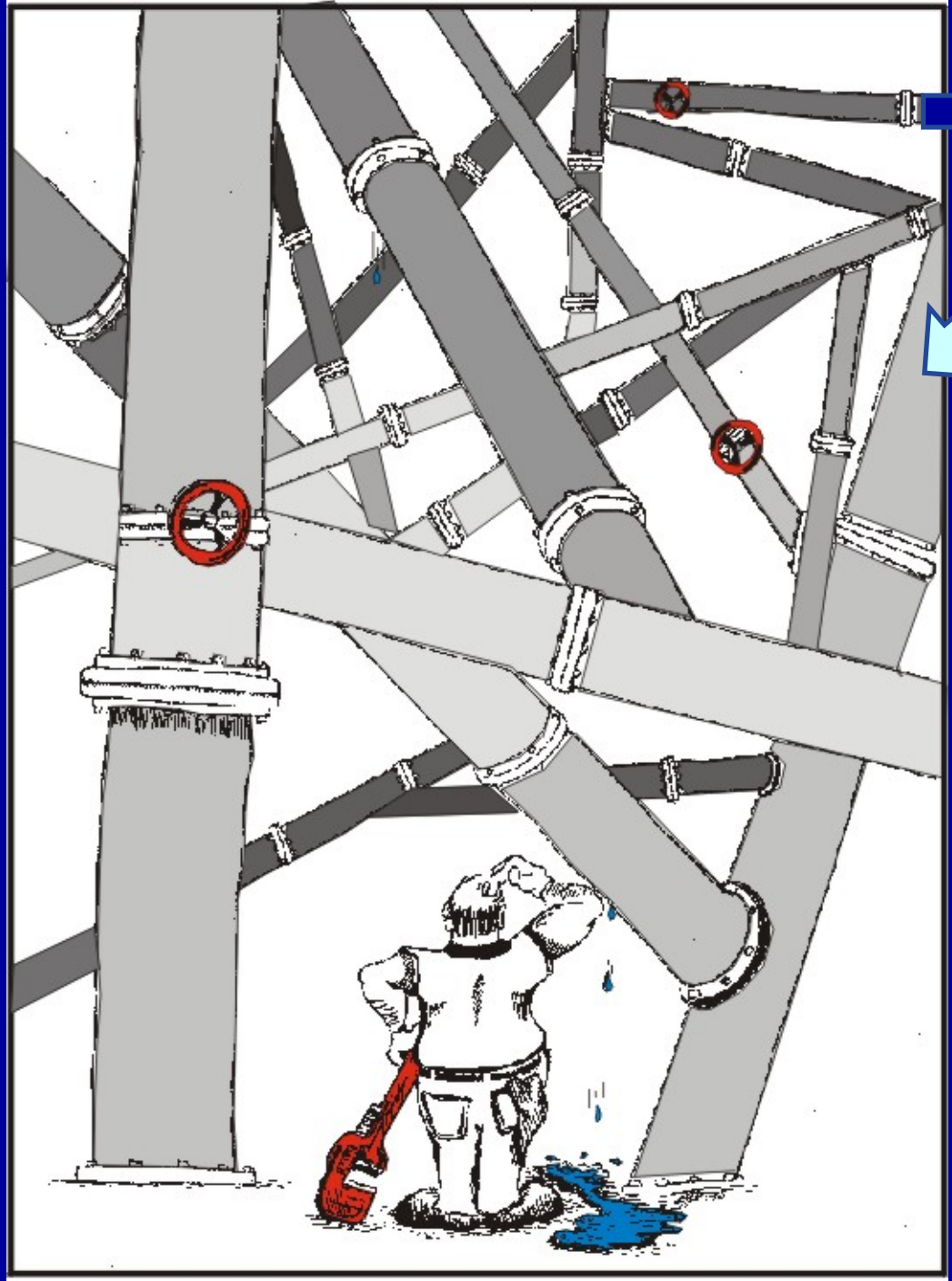


DISPOSAL OF FRACK WATER BY DEEP WELL INJECTION

Trenton-Black River carbonates

Potsdam sandstone

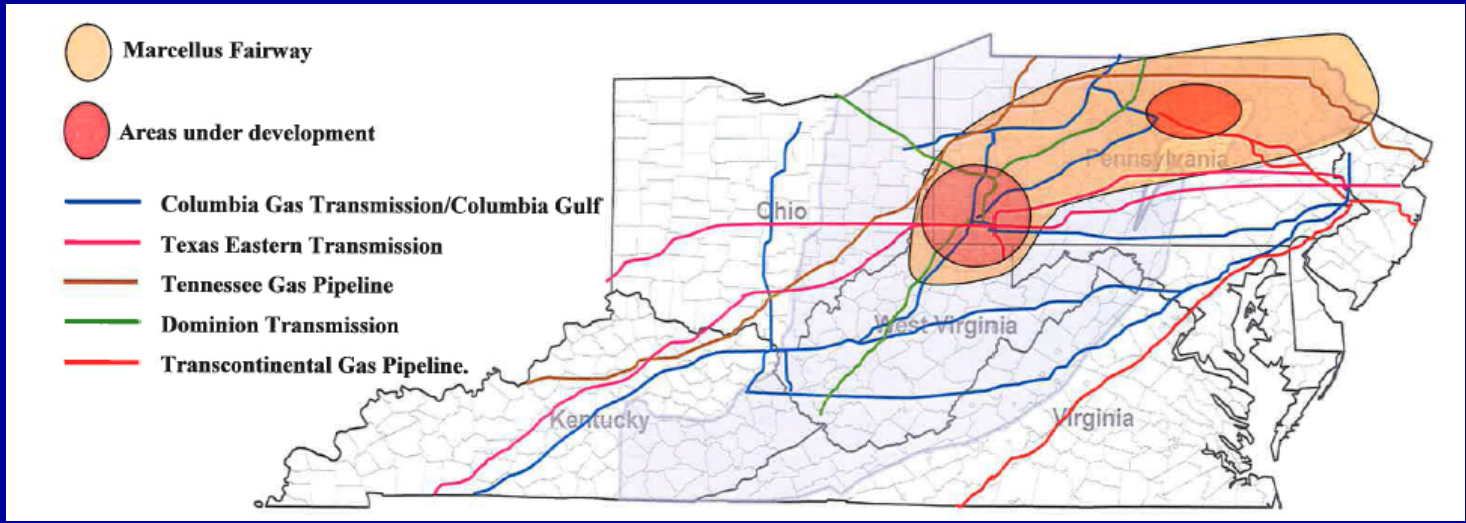
DISPOSAL OF FRAC WATER BY MUNICIPAL WASTEWATER TREATMENT PLANTS AND DISCHARGE TO SURFACE WATER



Proposed “Black box” pretreatment systems to remove ‘constituents of concern’ prior to other treatment and discharge

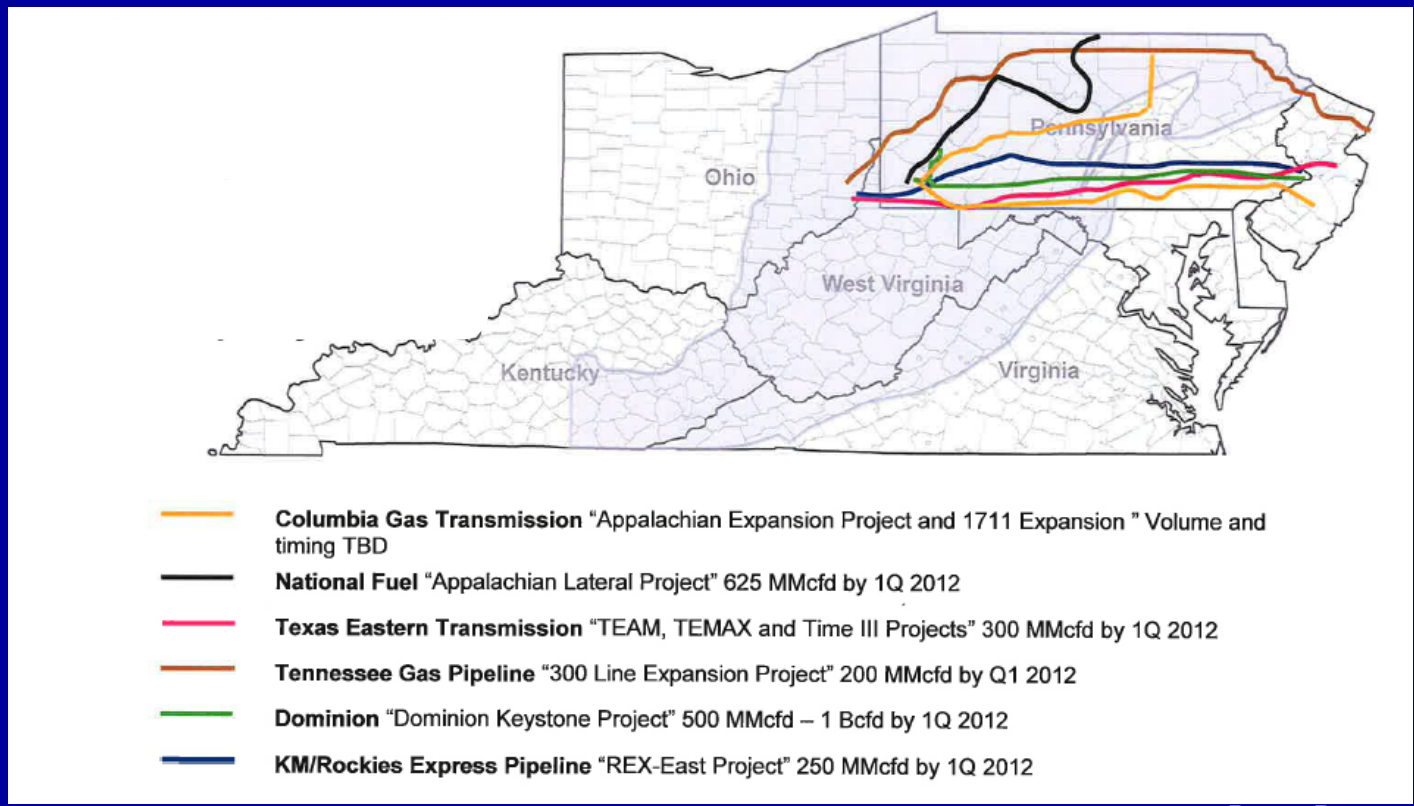
Pipeline infrastructure and land disturbance

Existing Major Pipelines



Potential new pipelines in Pennsylvania

These are only the major transmission pipelines, not the gathering or intermediate pipelines



Range Resources, 2009

Regional Water-Resource Concerns

- What are the regional characteristics of black shale bedrock formations throughout the Marcellus, Utica, and other potential gas-bearing units?
  - Geologic nature – thickness of units, fracture tendencies, faults, etc.?
  - Geochemical nature – how variable are the mineral and water-quality characteristics?
  - Radiochemical nature – what radioisotopes are present and are they mobile, or made-mobile during drilling and fracking?
- Where is the fresh water / brackish water interface within regional groundwater aquifer systems (Unconsolidated and bedrock aquifers)
- What is the regional water-quality of streams where flowback/ formation waters may be treated and discharged?
- Development of Wellhead-to-Market pipeline systems – how will the layout of pipeline gathering systems be established to protect ecosystem habitats as well as land and water resources?

Water-Resource Concerns with Gas Production Processes

- Protection of Surface -and Ground-water Resources during entire process –
  - Drill pad construction, storm-water runoff, chemical storage and handling
  - Drilling of well – cuttings and fluid handling
  - Hydro-fracturing process
  - Transportation of water/fluids to and away from site

- Source of water for drilling, hydro-fracturing – millions of gallons per well

- Containment of drill cuttings and water – multiple wells per drilling site

- Containment of return hydro-frack fluids (flowback) and formation water
  - 2 different types of water-quality concerns

- Disposal of frack fluids and formation water – consideration of zero discharge (treatment and recycling of water)

- Other fluids for fracturing (Liquefied gases – nitrogen, carbon dioxide)

- Site restoration and long-term maintenance
- Closure of well(s)

Questions?