SWPA-EHP

www.environmentalhealthproject.org

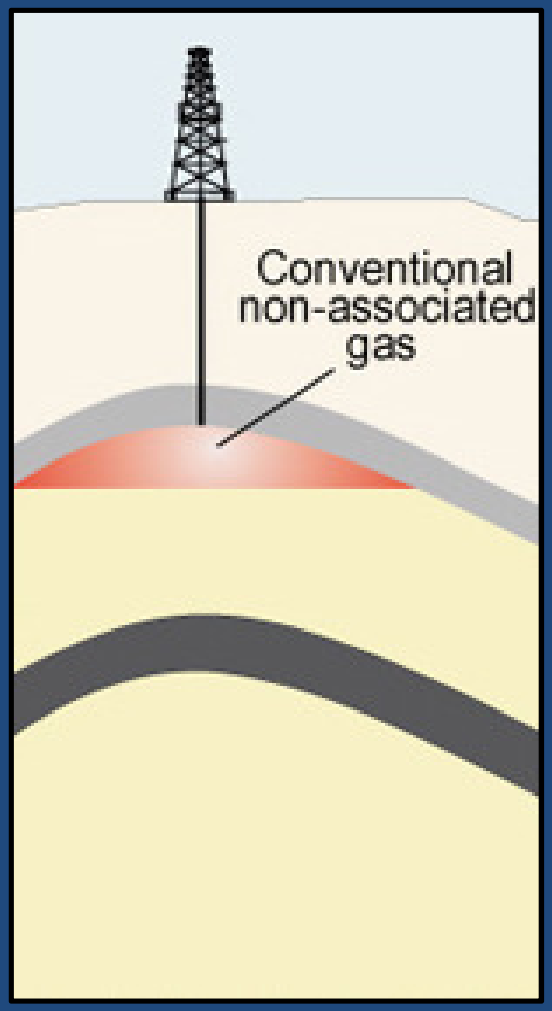
Health Concerns from Unconventional Gas Extraction

Leslie A. Walleigh MD, MPH

7-20-12

Conventional Gas Extraction

- Vertical wells drilled to a defined reservoir of natural gas

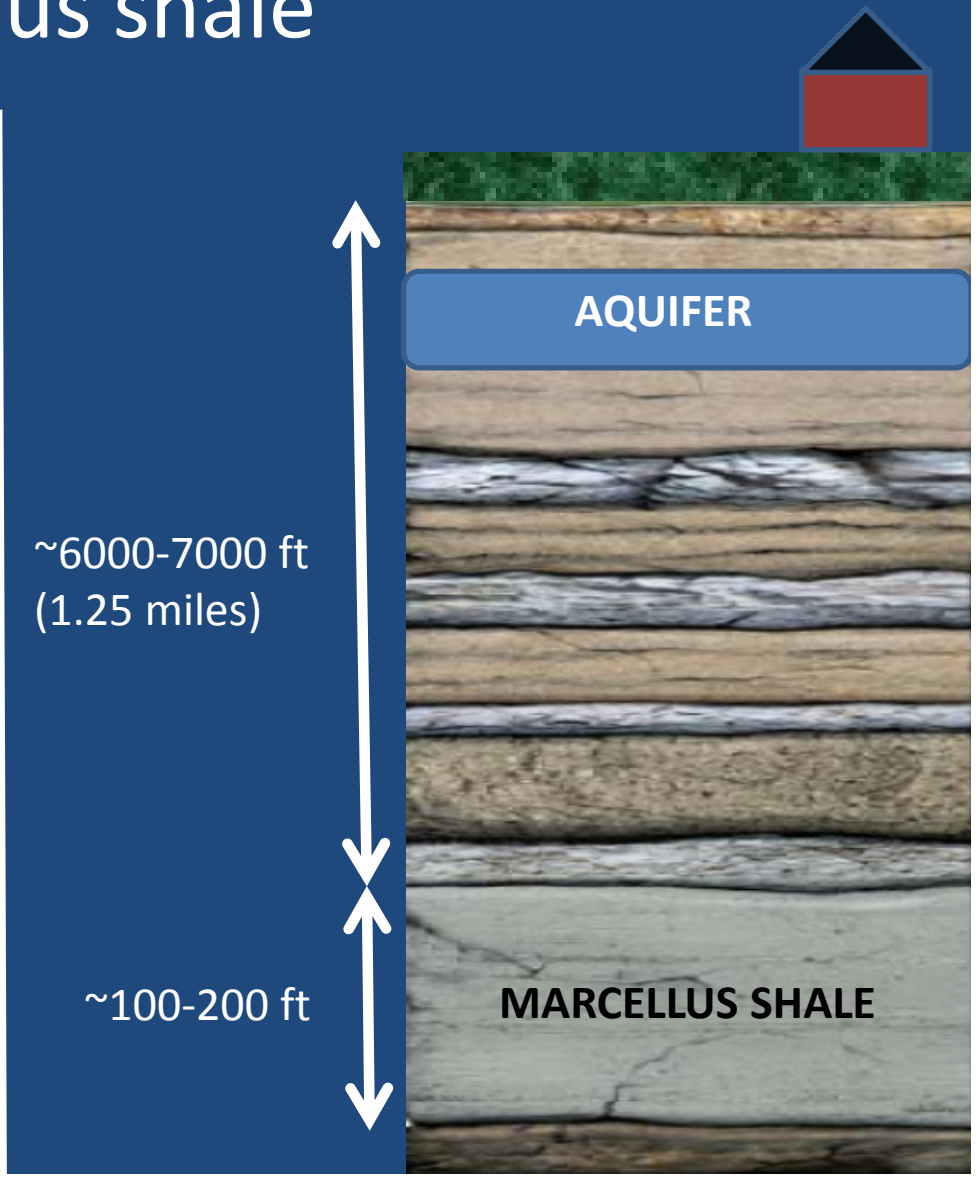


Contents

- Unconventional gas extraction process, difference from conventional gas extraction
- Environmental contamination, human exposures, and health effects from unconventional gas extraction activities
- Social disruption and mental health effects

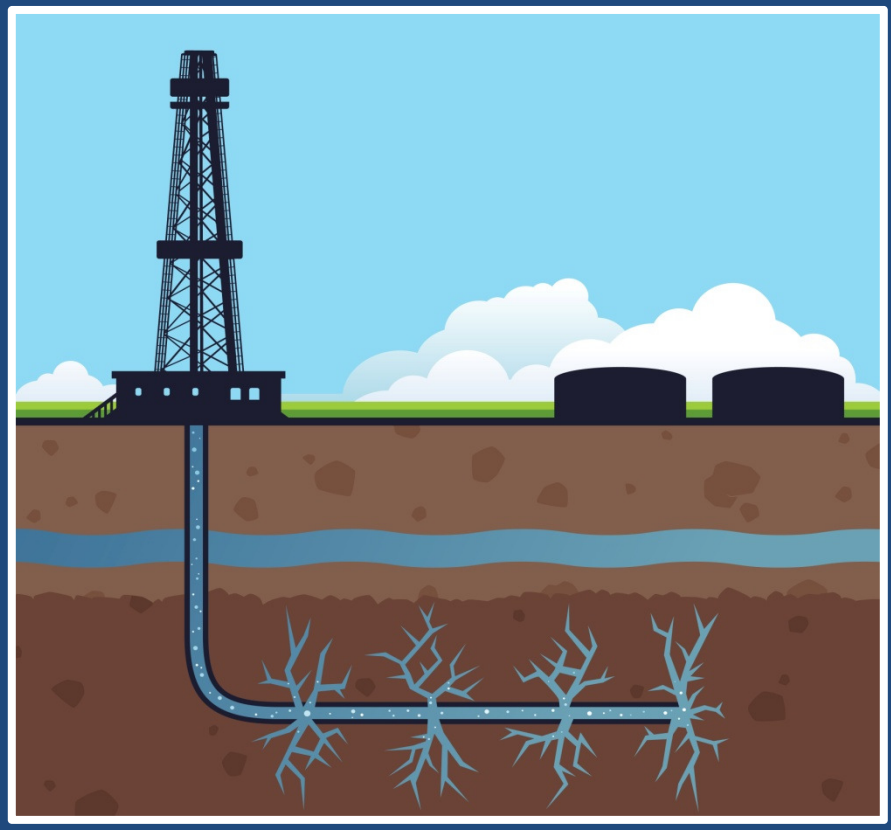
Marcellus shale

- Geologic formation 100-200 feet thick, approximately 6-7,000 feet below the earth's surface.
- Includes miniscule fractures filled with natural gas, which has migrated there over thousands of years.



Hydraulic Fracturing

- Process of injecting fluid into fissures in rock formations, increasing outflow of gas.
- One step in process of unconventional gas extraction.

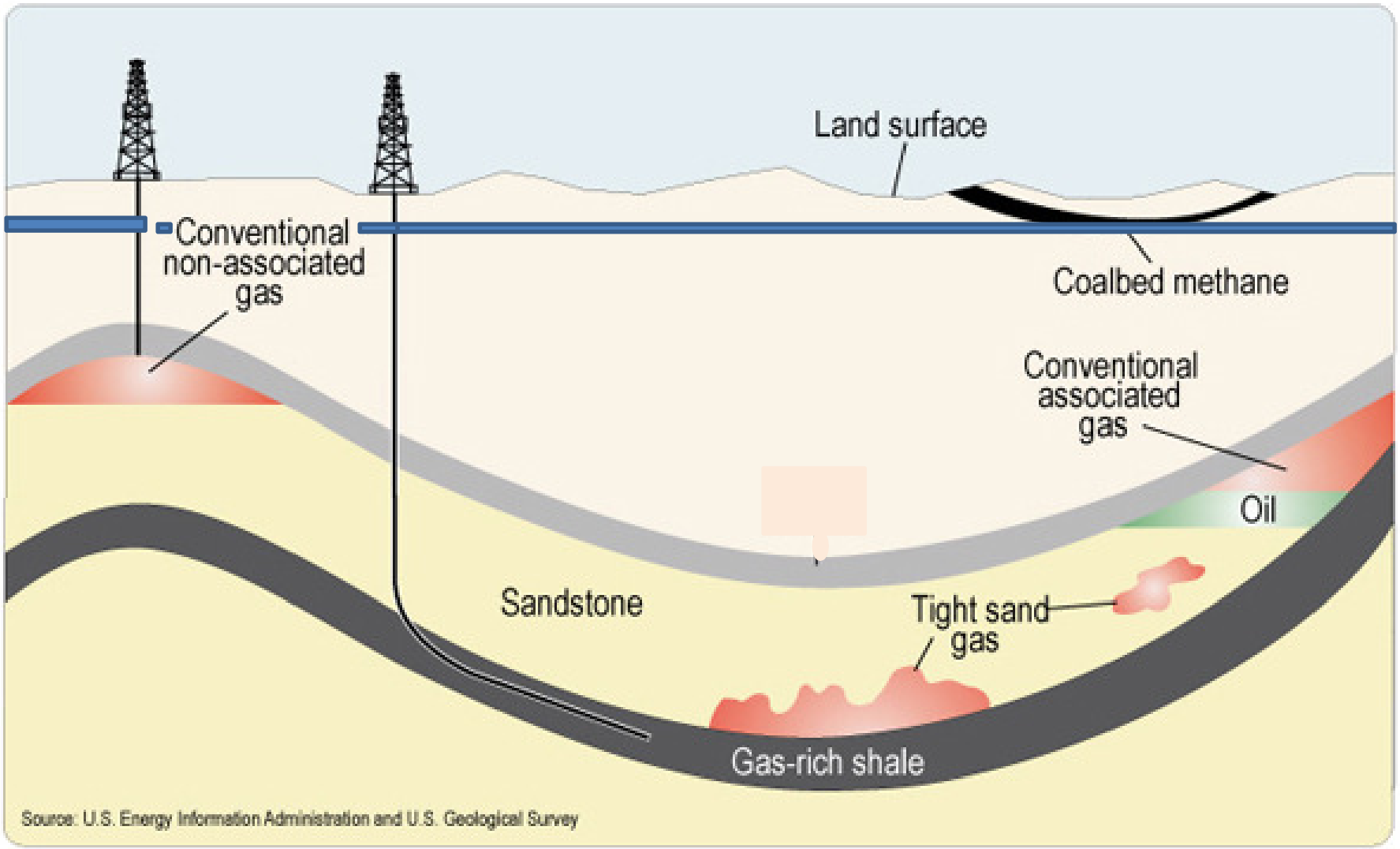


Note: Although hydraulic fracturing has been used previously in conventional gas extraction, the economical production of natural gas from shale required the development of more intensive hydraulic fracturing and other technologies

New techniques required for unconventional gas extraction

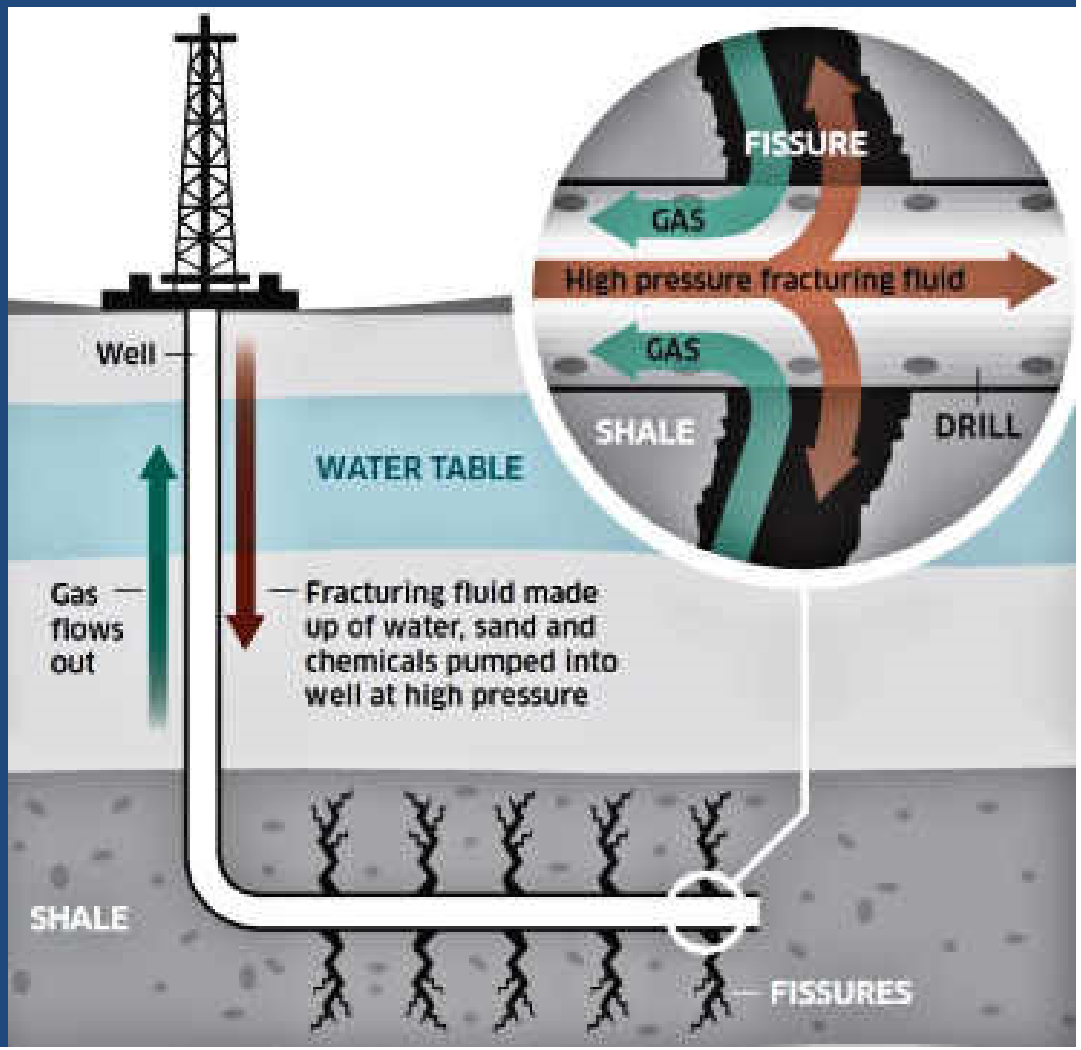
- Directional Drilling (vs. vertical drilling)
- High-fluid volume, high-pressure hydraulic fracturing
- Addition of chemicals ("Slickwater") to reduce friction and increase efficiency of fracturing fluids
- Multi-well sites

Directional Drilling



High-fluid volume, high-pressure hydraulic fracturing

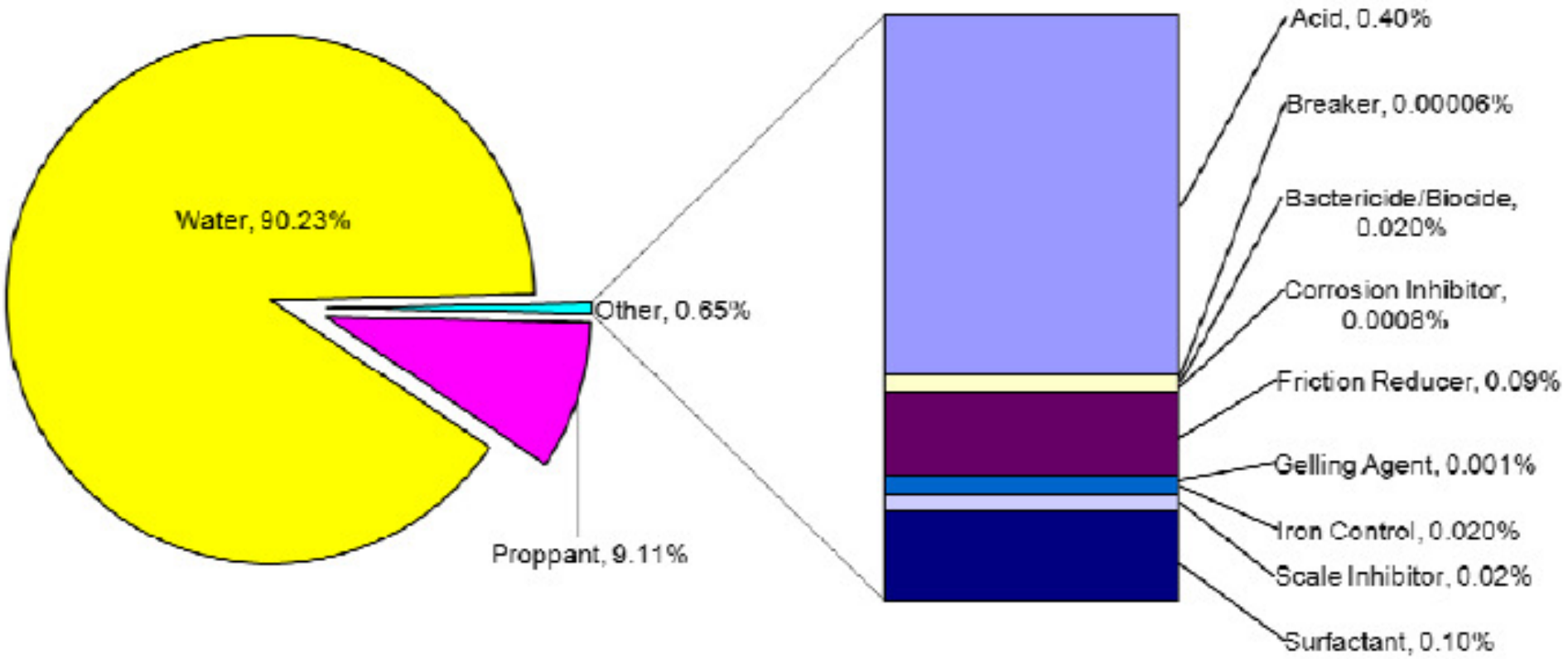
- 4-5,000,000 gallons (vs. 20,000-80,000 gallons) per episode
- 10,000-11,000 psi (vs. 2,000-3,500 psi)



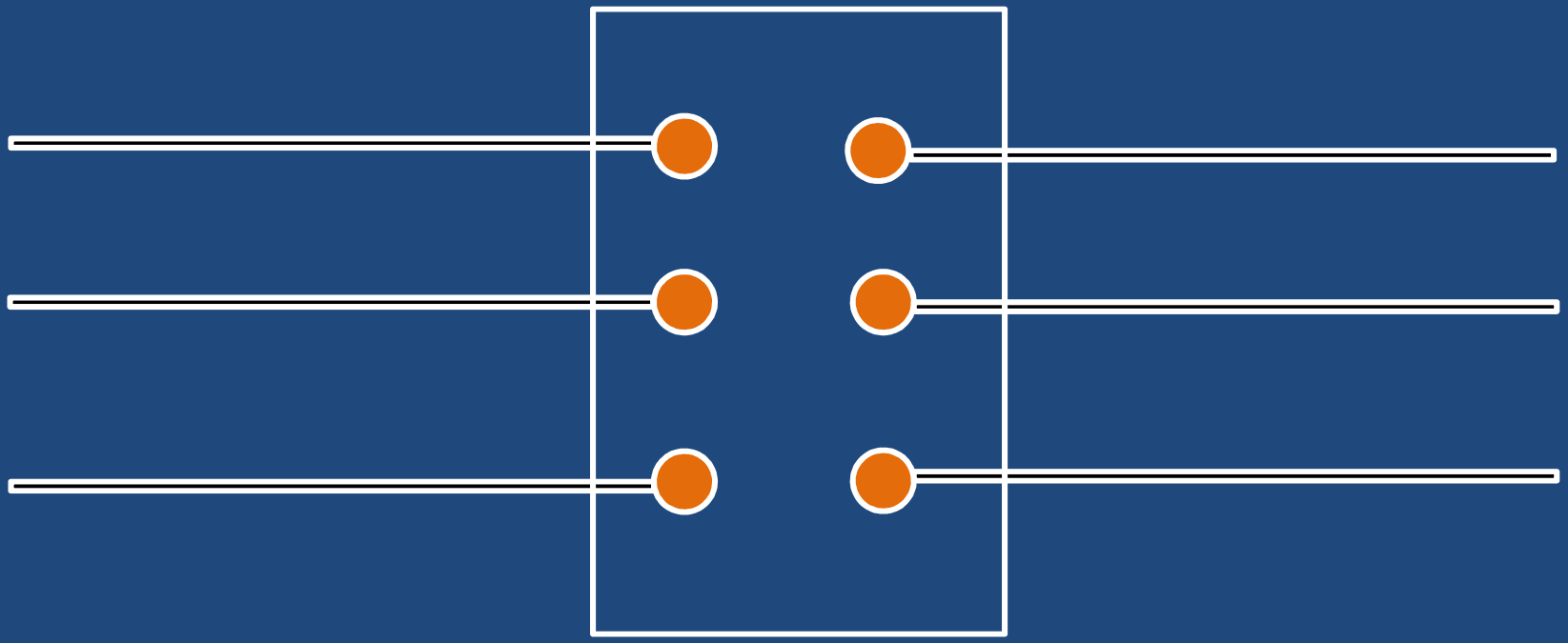
Slickwater

Additive	Purpose	Chemical Example
Proppant	“Props” open fractures	Sand
Solvent	Additive soluble in oil, water, and acid based fluids	Various aromatic hydrocarbons
Surfactant	Reduces fracturing fluid surface tension, aiding recovery	Methanol, ethoxylated alcohol
Acid	Removes cement and drilling mud from casing perforations	HCL
Breaker	Reduces fluid viscosity	Peroxy-disulfates
Biocide	Reduces growth of organisms	Glutaraldehyde
Gelling Agent	Increases fluid viscosity	Guar gum, petroleum distillates
Iron control	Prevents precipitation iron oxides	Citric acid
Scale inhibitor	Prevents precipitation of carbonates and sulfates	Ammonium chloride, ethylene glycol
Buffer	Adjusts pH	Sodium Carbonate, Acetic acid
Clay stabilizer	Prevents migration of clays	Potassium Chloride
Corrosion inhibitor	Reduces rust formation	Methanol
Crosslinker	Increase viscosity	Borate salts
Friction reducer	Minimizes friction of injected fluids	Polyacrylamide, petroleum distillates

Slickwater


Water, 90.23%
Other, 0.65%
Proppant, 9.11%
Acid, 0.40%
Breaker, 0.00006%
Bactericide/Biocide, 0.020%
Corrosion Inhibitor, 0.0008%
Friction Reducer, 0.09%
Gelling Agent, 0.001%
Iron Control, 0.020%
Scale Inhibitor, 0.02%
Surfactant, 0.10%

Multi-well Pad

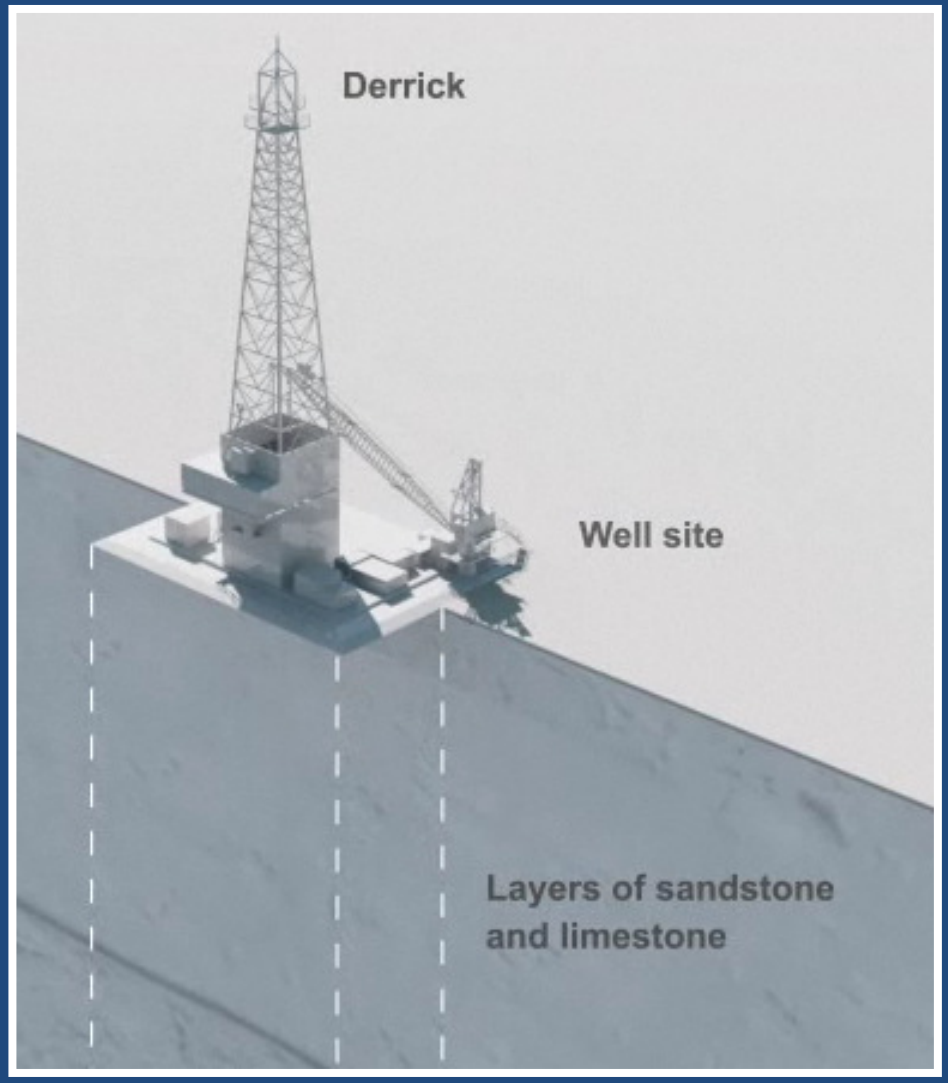


Hydraulic Fracturing Technological Development

Hydraulic Fracturing Technological Milestones [2]	
Early 1900s	Natural gas extracted from shale wells. Vertical wells fractured with foam.
1983	First gas well drilled in Barnett Shale in Texas
1980-1990s	Cross-linked gel fracturing fluids developed and used in vertical wells
1991	First horizontal well drilled in Barnett Shale
1991	Orientation of induced fractures identified
1996	Slickwater fracturing fluids introduced
1996	Microseismic post-fracturing mapping developed
1998	Slickwater refracturing of originally gel-fractured wells
2002	Multi-stage slickwater fracturing of horizontal wells
2003	First hydraulic fracturing of Marcellus Shale[3]
2005	Increased emphasis on improving the recovery factor
2007	Use of multi-well pads and cluster drilling

Source: SGEIS

Unconventional Gas Extraction

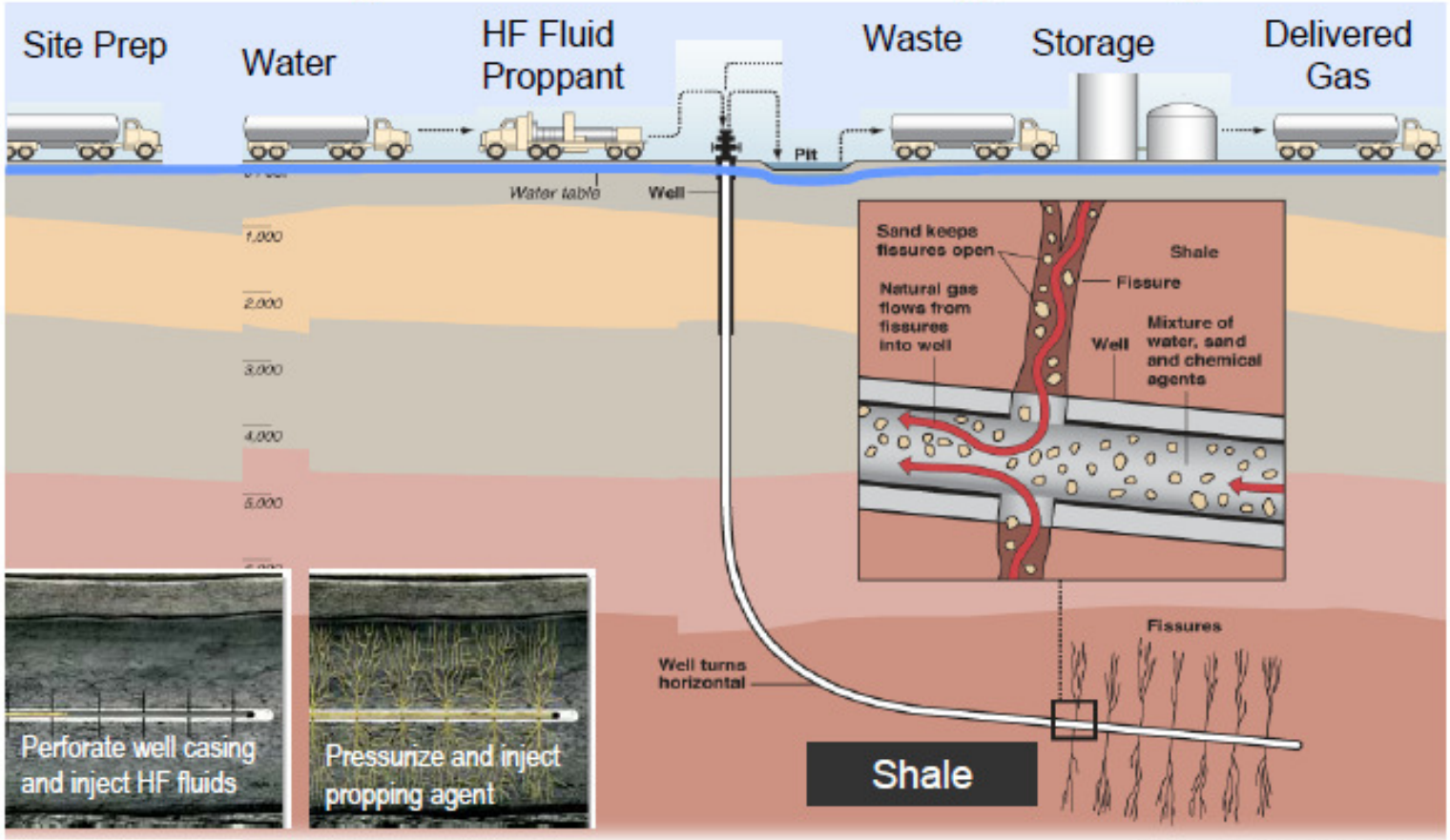


Steps in natural gas extraction

- Seismic testing
- Pad construction
- Drilling
- Hydraulic fracturing
- Waste water management
- Flaring
- Gas production and processing
- Gas transport

EPA United States Environmental Protection Agency

Definition of Hydraulic Fracturing Lifecycle



Adapted from Graphic by Al Granberg

Seismic Testing

- Used to determine geologic characteristics of site before drilling begins.
- Dynamite charges are placed in 20 foot holes. When exploded, seismic equipment measures the shock waves generated.

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Pad Construction

- 4-6 acres cleared
- Plastic lined pits for drilling waste and water impoundment

Robert Donnan ©2011

Drilling

Hydraulic Fracturing

Flowback fluid

- 3%-80% of hydraulic fracturing fluid returns to surface
- Mixed with
  - salts
  - heavy metals
  - organic chemicals
  - naturally occurring radioactive materials (NORMS)
- Stored onsite or trucked off to processing facilities

Flaring

After a well is drilled and hydraulically fractured, flaring is often used to test initial production of the well.

Gas Processing and Transport

On-site condensate tanks remove some water and impurities

Gas Processing and Transport

Pipelines transport gas to local compressor stations for further purification and compression

Potential Sources of Environmental Contamination and Human Exposures

- Chemical Exposures
  - Air
  - Water
- Non-chemical Exposures
  - Noise
  - Traffic

Potential Sources of Air Contamination and Human Exposures

- Diesel Exhaust
- Flaring
- Fugitive emissions
  - Well head
  - Condensate tanks
  - Compressor stations
- Impoundments

Robert Donnan ©2011

Sources of Air Emissions from Natural Gas Activities

	Fugitive Emissions	Dehydration	Vehicles/ Engines	Flaring	Pits
Particulate Matter		X	X		
Hydrogen Sulfide	X			X	
Ozone	O	O	O		
CO			X	X	
NOx			X	X	
SO2			X	X	
VOCS	X	X	X	X	X
BTEX	X	X	X	X	X
Methane	X	X			X
NORMs	X	X			X

Recognized Health Effects of Air Emissions from Natural Gas Activities

	Pulmonary	Neurologic	Reproductive	Dermal	Hematologic
Particulate Matter	X			X	
Hydrogen Sulfide	X	X		X	
Ozone	O				
CO		X	X		
NOx	X				
SO2	X				
VOCS	X	X	X	X	X
BTEX	X	X	X	X	X
Methane					
NORMs			X	X	X

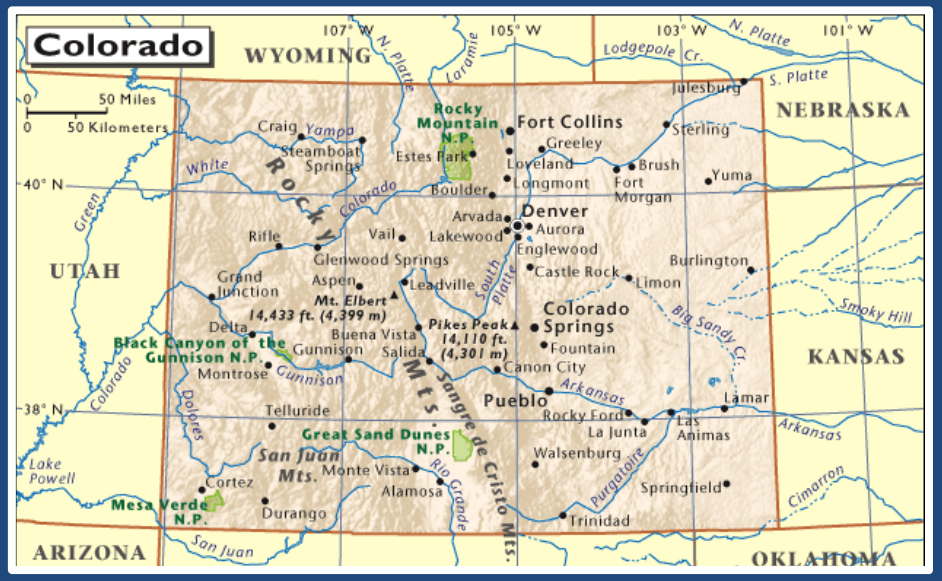
Potential Sources of Air Contamination and Human Exposures

"Human health risk assessment of air emissions from development of unconventional natural gas resources."

Lisa M. Mckenzie, Roxana Z. Witter, Lee S. Newman and John L. Adgate

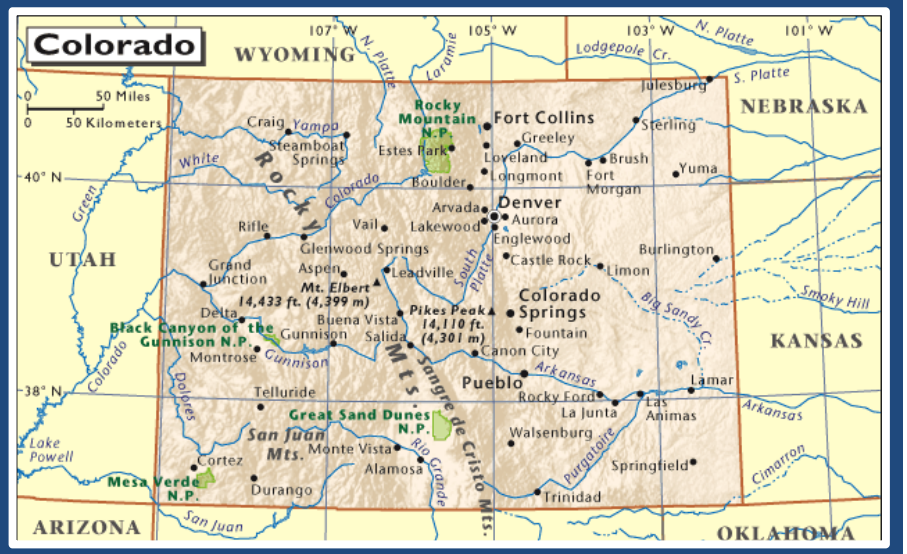
Science of the Total Environment

March 21, 2012



Mckenzie *et al.* Study

- Measured ambient air hydrocarbon emissions
  - 163 measurements from fixed monitoring station
  - 24 samples from perimeter of well pads (130-500 feet from center) undergoing well completion
- Used EPA guidance to estimate non-cancer and cancer risks for residents living > 1/2 mile from wells and residents living ≤ 1/2 mile from wells

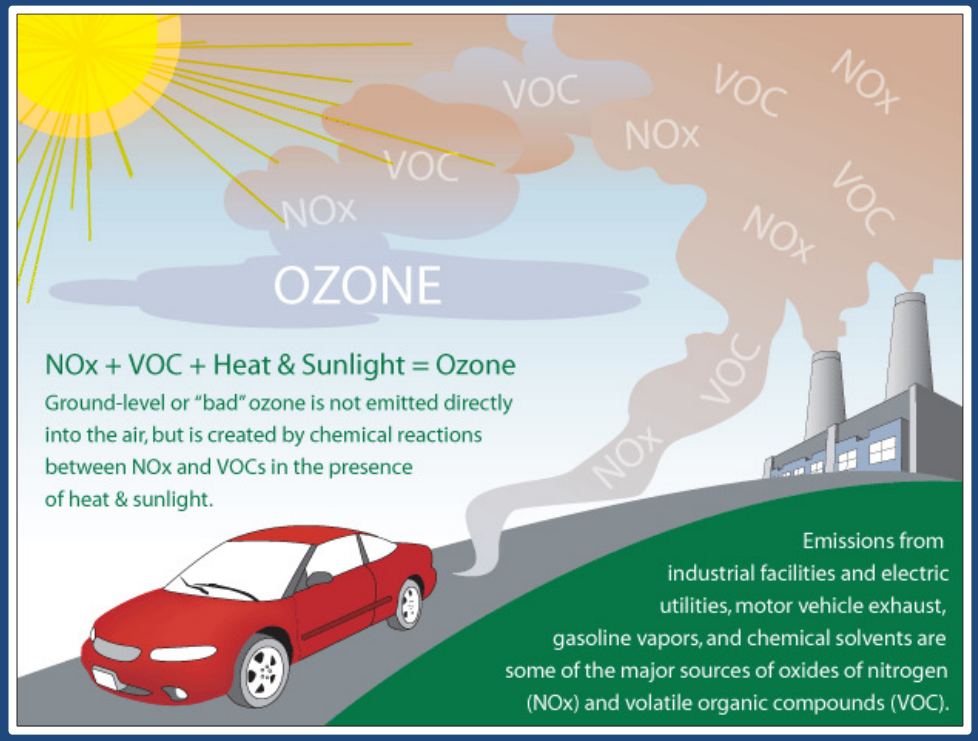


Conclusions from Mckenzie *et al*. Study

- Residents closest to well pads have higher risks for respiratory and neurological effects based on their exposure to air pollutants.
- Residents living close to natural gas well are at higher excess lifetime risk for cancer than residents who live farther from the wells.
- Emissions measured by the fenceline at well completion were statistically higher ($p \leq 0.05$) than emissions at the fixed location station. These pollutants include benzene, toluene, and several alkanes.

Limitations of McKenzie *et al.* Study

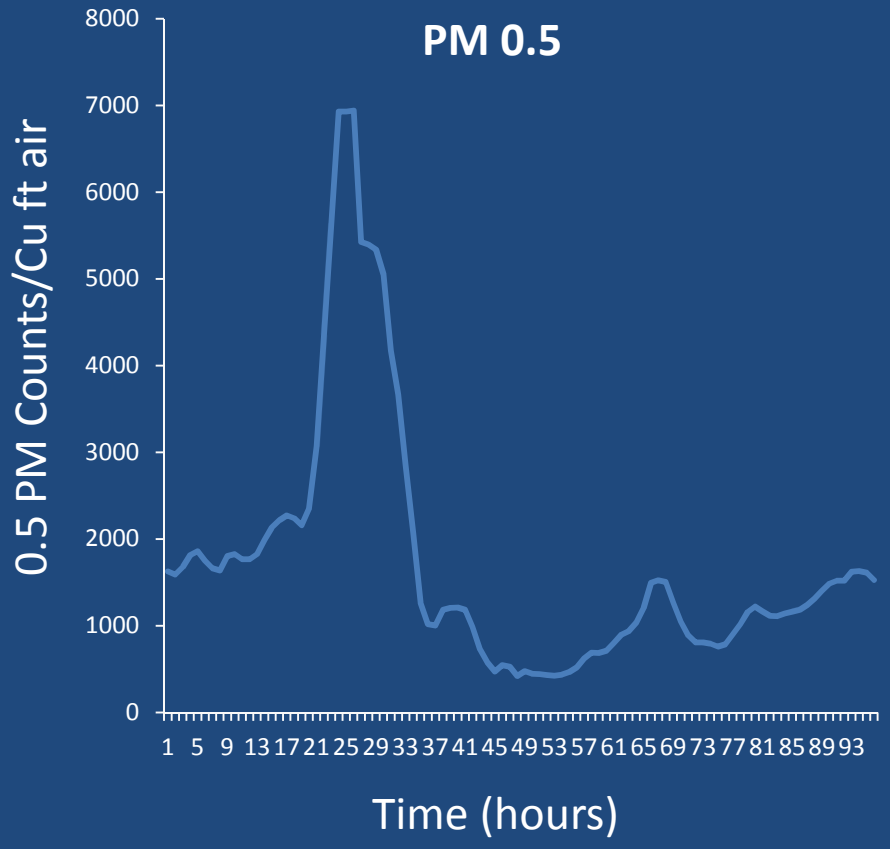
- Did not measure ozone
- Did not measure particulates (PM_{10}, $PM_{2.5}$)
- EPA methods may underestimate health risks of mixed exposures



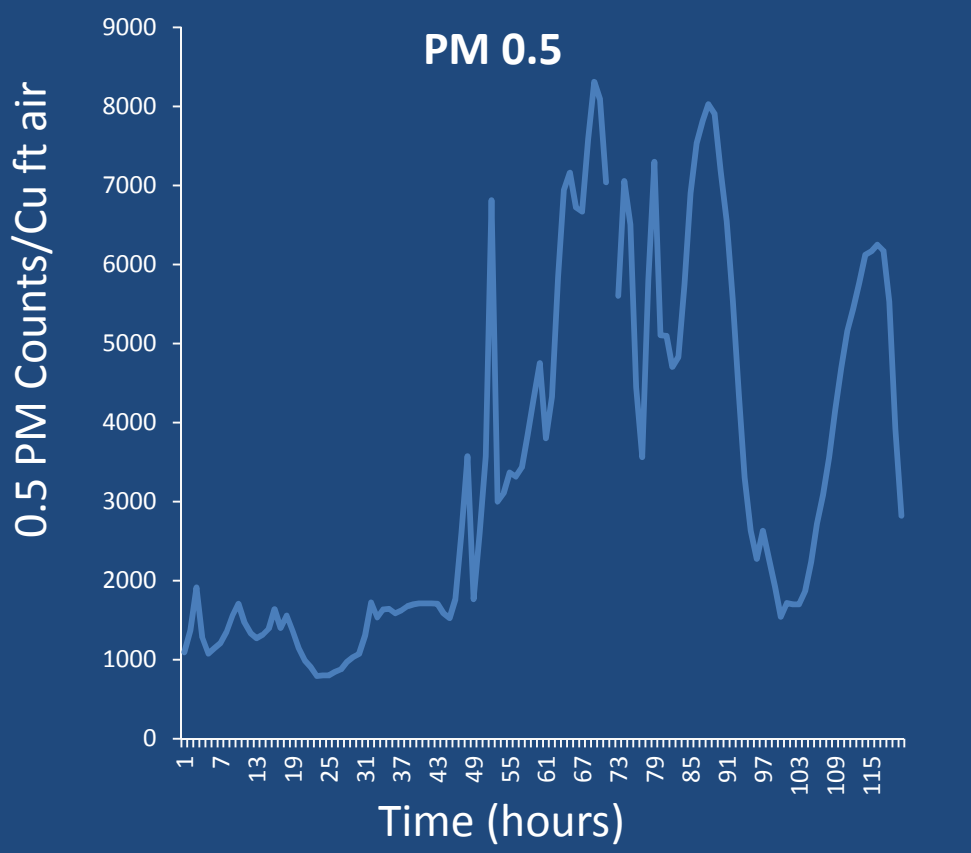
Counts of 0.5 micron particulate matter (PM 0.5) at two homes 1000 ft from compressor station in PA

(Background: 1000-2000 cts/cu ft air)

Home one over 93 hours (4 days)

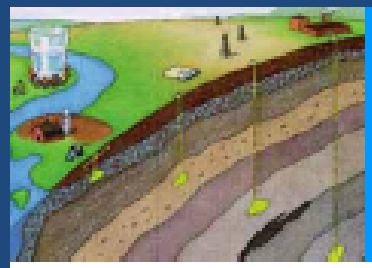


Home two over 115 hours (5 days)



Potential Sources of Water Contamination

- Seismic testing
- Initial drilling through aquifer
- Failures in well casings
- Migration up from fractured rock
- Wastewater storage, transport, or processing
  - Impoundment leak or overflow
  - Pipeline leak
  - Inadequate treatment
- Other on-site or transportation spill or accident



Safe Drinking Water Act: Underground Injection Control Program

- Activities not regulated under Safe Drinking Water Act Provisions for UIC (Sections 1421, 1422, and 1425)
  - Oil and gas *production* activities
  - Hydraulic fracturing (except use of diesel) per 2005 Energy Policy Act
  - Natural gas storage
- States may choose to regulate these activities
- Surface water discharges are regulated under the Clean Water Act (CWA)

EPA United States Environmental Protection Agency

Potential Sources of Environmental Contamination and Human Exposures

"Water Pollution Risk Associated with Natural Gas Extraction from the Marcellus Shale."

Daniel J. Rozell and Sheldon J. Reaven, Risk Analysis , 2011

Using probability analysis, assessed risk of water contamination from Marcellus Shale drilling. Determined that there was substantial potential risk primarily related to wastewater management.

Robert Donnan ©2011

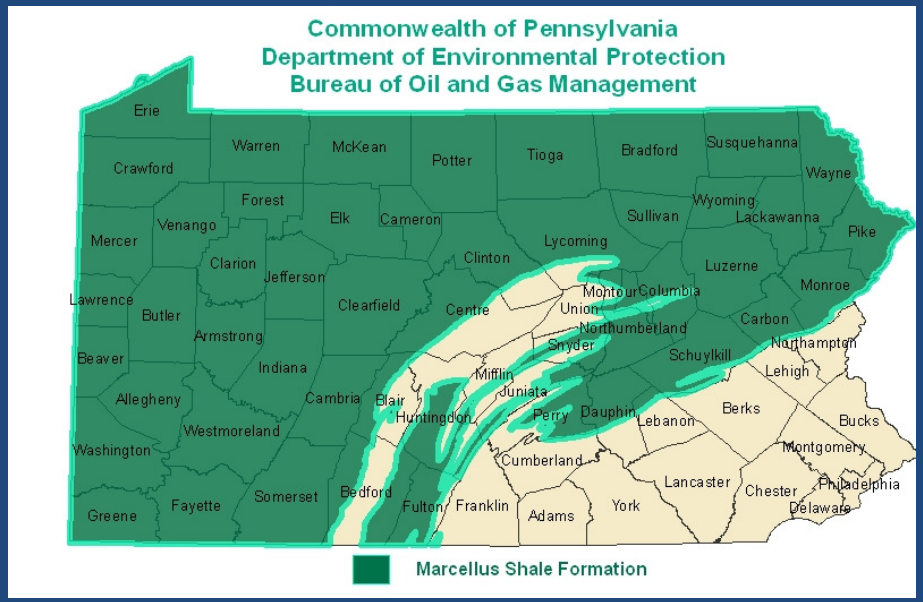
Potential Sources of Environmental Contamination and Human Exposures

"Methane contaminated drinking water accompanying gas-well drilling and hydraulic fracturing."

Osborn, SG *et al.*

Proc Natl Acad Sci USA, 2011

Found higher levels of methane in private wells in proximity to gas drilling activities



Potential Sources of Environmental Contamination and Human Exposures

- Pavillion, Wyoming - EPA 2012
  - 2010 ATSDR issued a Health Consultation for Pavillion, Wyoming after finding contamination of private wells drawing from shallow waters within the aquifer.
  - EPA's subsequent sampling found contamination of wells drawing both from shallow and deep areas within the aquifer.

Potential Sources of Environmental Contamination and Human Exposures

- Pavillion, Wyoming - EPA 2012
  - Shallow sources of contamination were thought to be related to leakage from surface pits used for storage and disposal of drilling wastes and produced and flowback water.
  - Deeper sources were thought to be related to gas production, which would include drilling and hydraulic fracturing, as well as actual gas production

Potential Sources of Environmental Contamination and Human Exposures

- Pavillion, Wyoming - EPA 2012

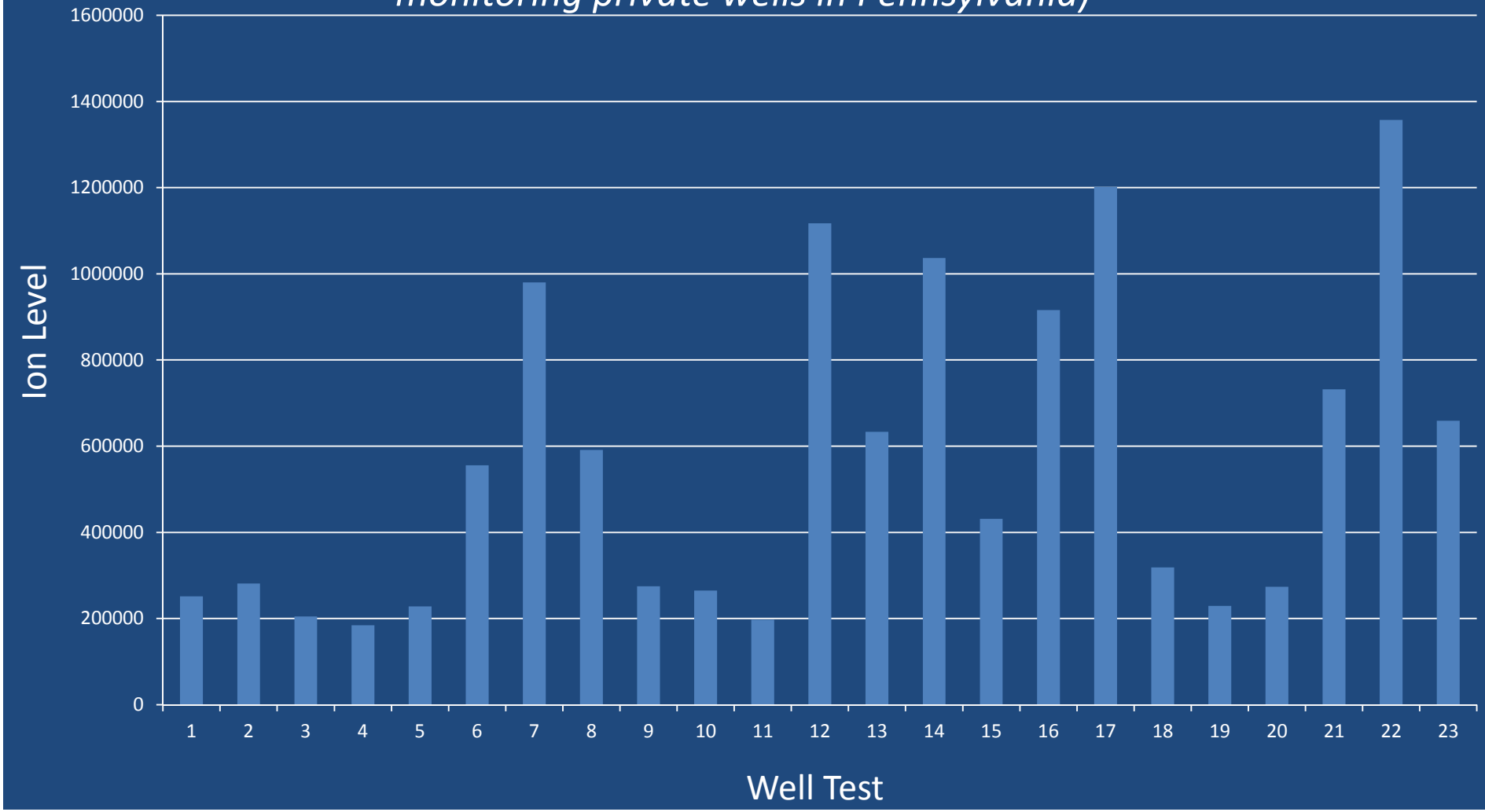
"In summary……inorganic and organic compounds associated with hydraulic fracturing have contaminated the aquifer at or below the depths used for domestic water supply in the Pavillion area. …..gas production activities have likely enhanced the migration of natural gas in the aquifer and the migration of gas to domestic wells in the area."

Organic compounds frequently found in 23 Drinking Water wells near a natural gas extraction site in Wyoming

- 1,3 dimethyl adamantane
- adamantane
- methane
- tph as gasoline
- tph as total petroleum hydrocarbons
- 2 chlorophenol
- bist 2ethyl hexal phthalate
- butylbenzophthalate
- caprolactam
- phenol
- tph as diesel

Levels of salt ions (Na,CL,Ca,Ba) reported in Wyoming 20 drinking water wells near gas extraction sites.

(The these results are comparable to conductivity values recommended for monitoring private wells in Pennsylvania)

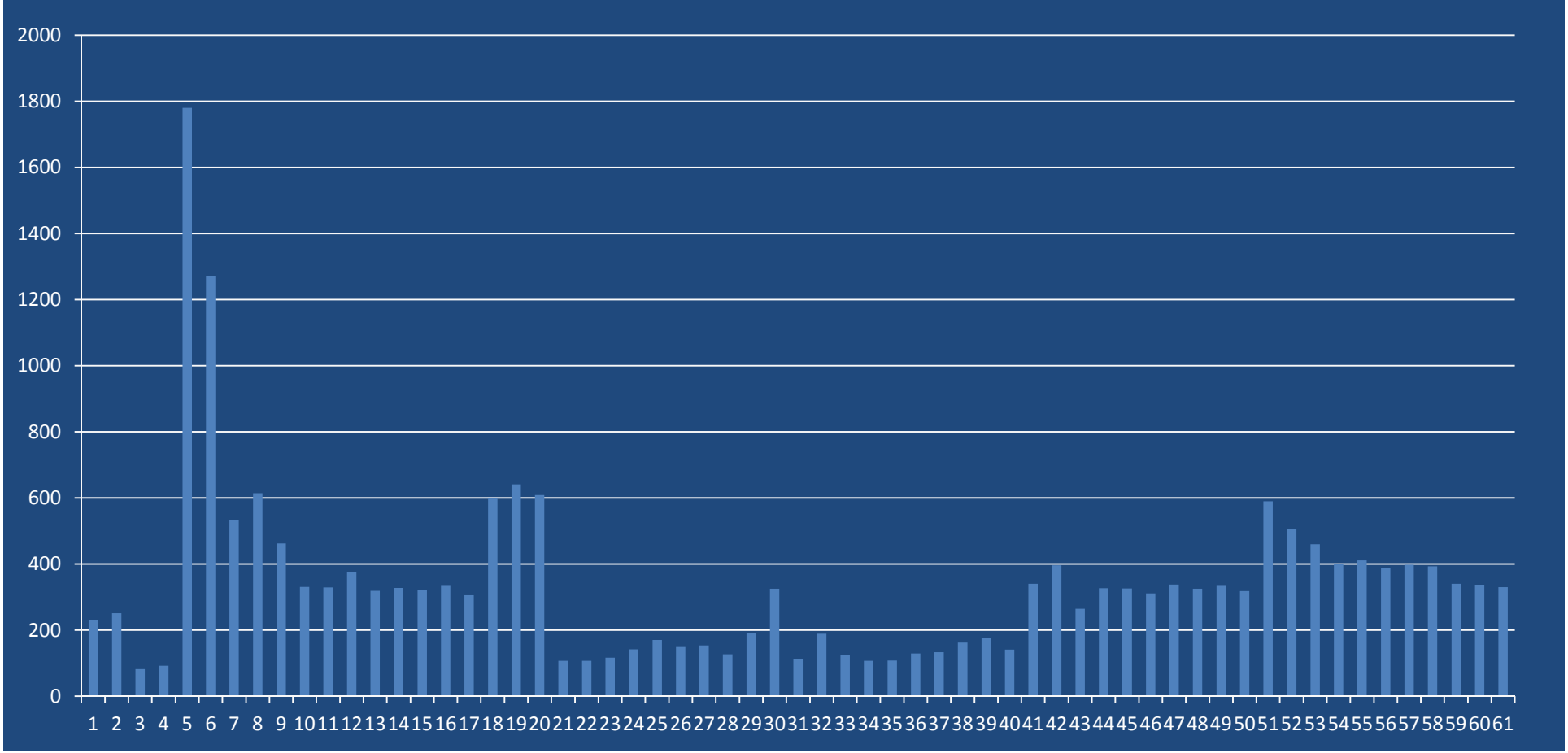


Potential Sources of Environmental Contamination and Human Exposures

- Pavillion, Wyoming - EPA 2012
  - EPA's extrapolation to hydraulic fracturing used in the Marcellus Shale
    - Contamination from surface sources more likely
    - Contamination from deeper sources less likely

Conductance reports from 13 Pennsylvania Drinking Water Wells in regions with active natural gas extraction.

(Typical water is <500)



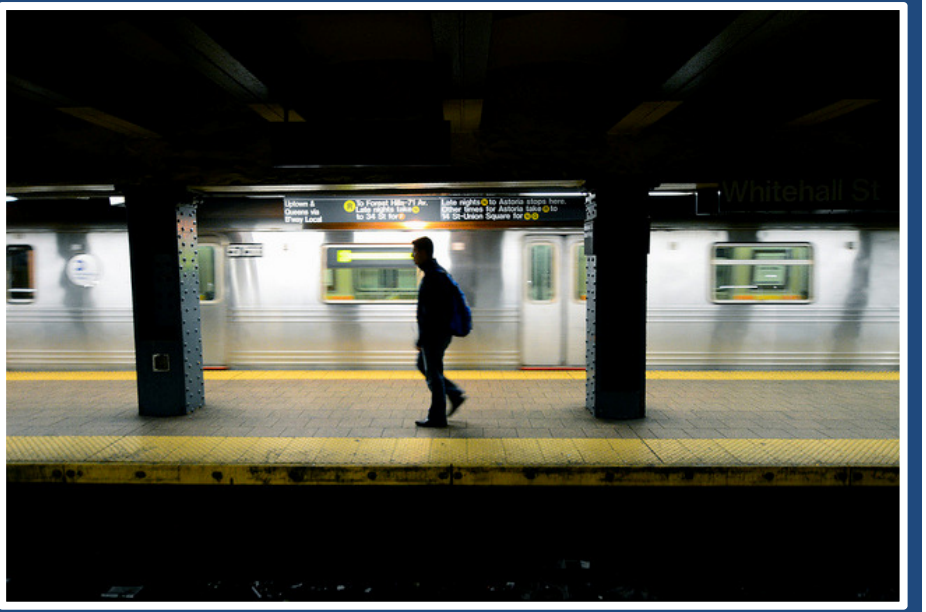
Potential Non-chemical Sources of Human Exposures

- Noise
- Traffic

Noise

- Decibel levels of indoor activities

Decibels	Activity
100	Subway passing
90	Shouted conversation, food blender
80	Garbage disposal
70	Vacuum cleaner
60	Dishwasher
50	Normal conversation
40	Quiet office
30	
20	Whisper



Noise

- Estimated Construction Noise Levels at Various Distances for Well Pad Preparation

Construction Equipment	Quantity	Usage Factor %	Lmax SPL @ 50 Feet (dBA)	Distance in Feet/SPL (dBA)					
				50 (adj.)	250	500	1,000	1,500	2,000
Excavator	1	40	81	77	63	57	51	47	45
Bulldozer	1	40	82	78	64	58	52	48	46
Water truck	1	40	76	72	58	52	46	42	40
Dump truck	2	40	76	75	61	55	49	45	43
Pickup truck	2	40	75	74	60	54	48	44	42
Chain saw	2	20	84	80	66	60	54	50	48
_	**Composite Noise Level**			**84**	**70**	**64**	**58**	**55**	**52**

Source: Revised Draft SGEIS 2011

Noise

- Estimated Construction Noise Levels at Various Distances for Rotary Air Well Drilling

Construction Equipment	Quantity	Sound Power Level (dBA)	Distance in Feet/SPL[1] (dBA)					
			50 (adj.)	250	500	1,000	1,500	2,000
Drill rig drive engine	1	105	71	57	51	45	41	38
Compressors	4	105	77	63	57	51	47	45
Hurricane booster	3	81	51	37	31	25	22	19
Compressor exhaust	1	85	51	37	31	25	21	18
Composite Noise Level			**79**	**64**	**58**	**52**	**48**	**45**

Source: Revised Draft SGEIS 2011

Noise

Estimated Construction Noise Levels at Various Distances for High-Volume Hydraulic Fracturing

Construction Equipment	Quantity	SPL[1] (dBA)	Distance (feet)	Quantity Adjusted Sound Level	Distance in Feet/SPL[1] (dBA)					
					50	250	500	1000	1500	2000
Pumper truck	20	110	3	123	99	85	79	73	69	67
Pumper truck	20	115	3	128	104	90	84	78	74	72

Source: Revised Draft SGEIS 2011

Noise

Assumed Construction and Development Times

Operation	Estimated Duration (days)
Access roads	3 - 7
Site preparation/well pad	7 - 14
Well drilling	28 - 35
Hydraulic fracturing single well	2 - 5

Source: Revised Draft SGEIS 2011

Health Effects of Noise

- Noise induced hearing loss (worker)
- Sleep disturbance
- Increased blood pressure
- Decreased task performance
- Annoyance
- Irritability

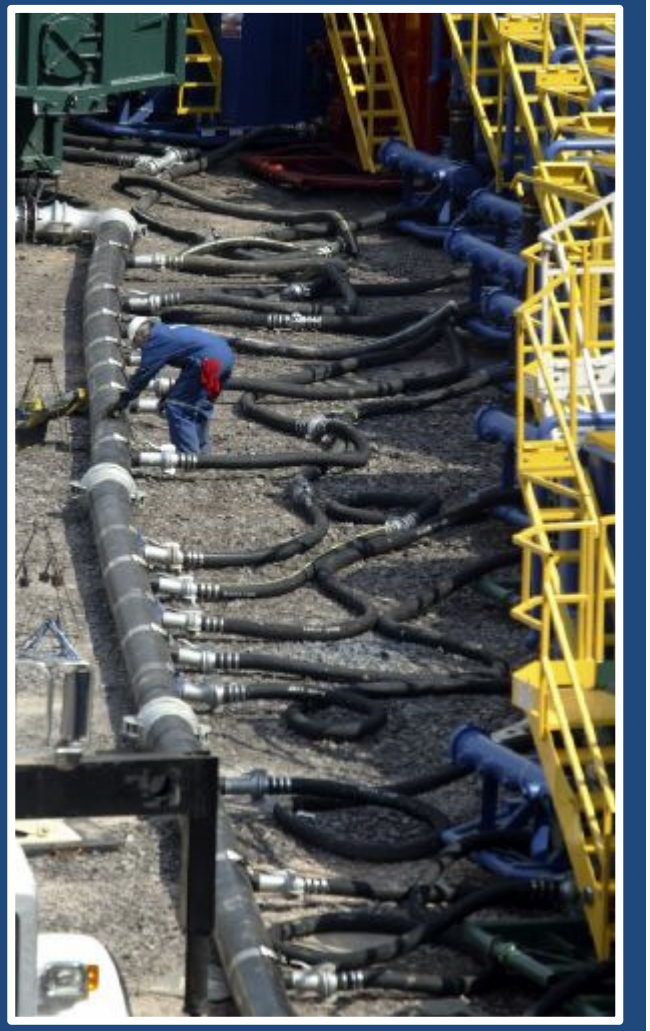
Traffic

Traffic

Vehicular traffic:

Water: 5,000,000 gal @3000 gal/truck= 1667 truckloads of water

Proppant: 1,500,000 lbs @2000 lbs/truck= 750 truckloads of proppant



Traffic

- Exposures
  - Diesel Exhaust
  - Dust
  - Noise
    - Engine breaks
    - Grinding gears
  - Spills
- Safety concerns
  - School routes
  - Collisions
  - Degraded roads

Health Symptoms Temporally Associated with Gas Drilling Activities

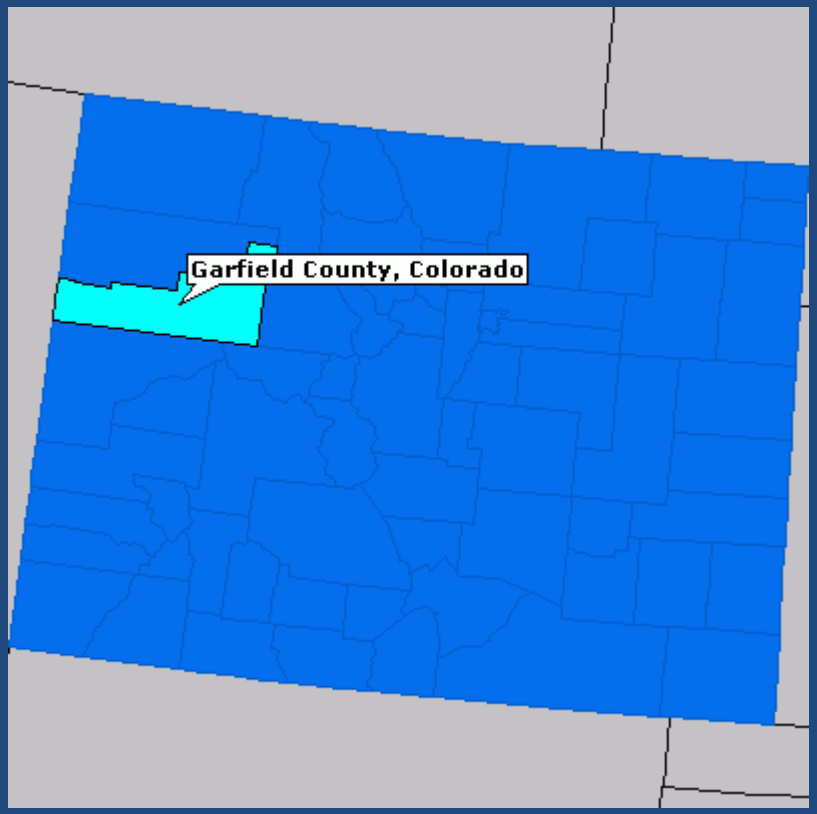
- Most common symptoms experienced by individuals evaluated by Dr. Saberi and by Denise DeJohn FNP
- N = 44

Skin rash or irritation	19
SOB or other breathimg difficulties	12
Sinus problems	5
Headaches	6
Nose bleeds	6
Throat irritation	6
Abdominal pain or cramps	16
Nausea or vomiting	11
Dizziness	6
Sleep disturbance	7
Anxiety	7

Social Disruption

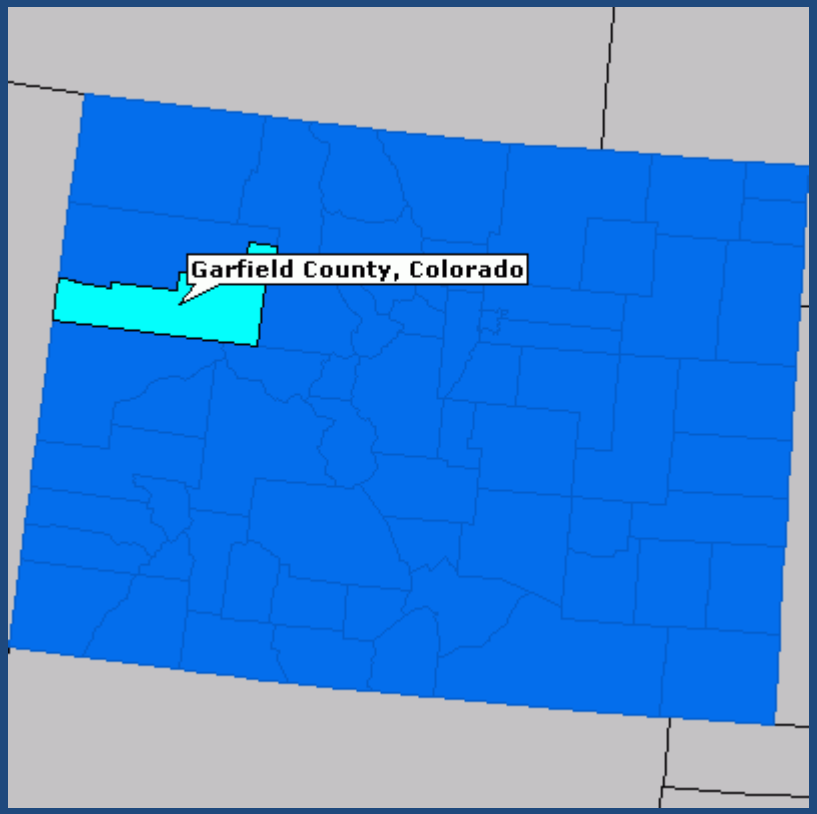
- "Community Impacts of Natural Gas Development and Human Health."

  Roxanne Witter *et al.*, Colorado School of Public Health
- Workshop on the Health Impact Assessment of New Energy Sources: Shale, IOM April 30-May 1, 2012



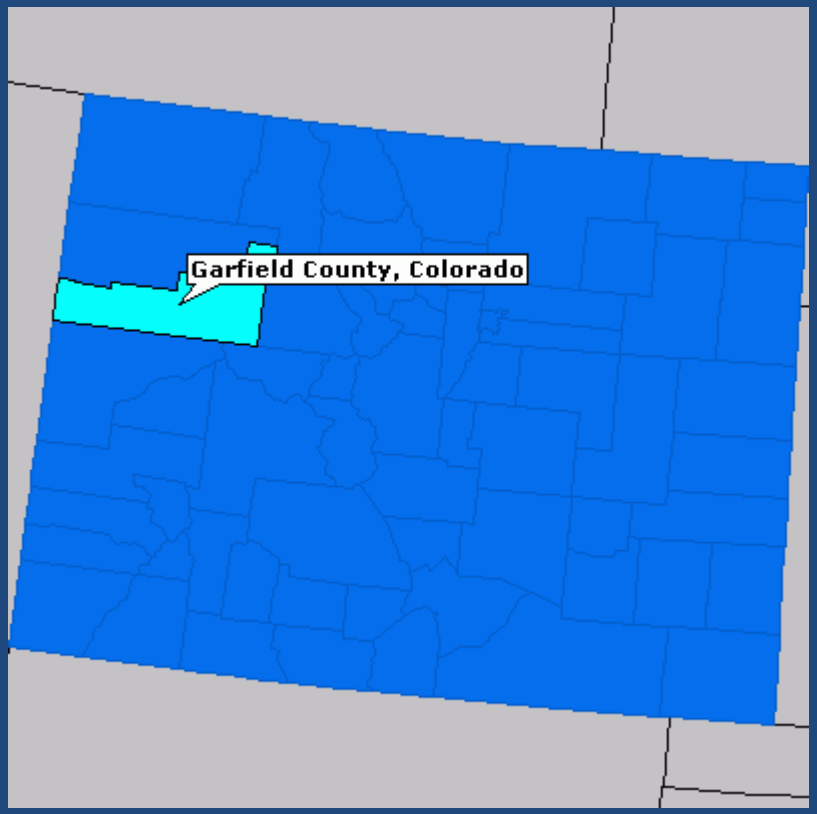
Social Disruption

- Potential Sources of Social Disruption
  - Rapid Population Influx
  - Local governments without jurisdiction or resources to control or respond to changes occurring in community and local environmental
  - Industry's monopoly on information
  - Changes in the environment



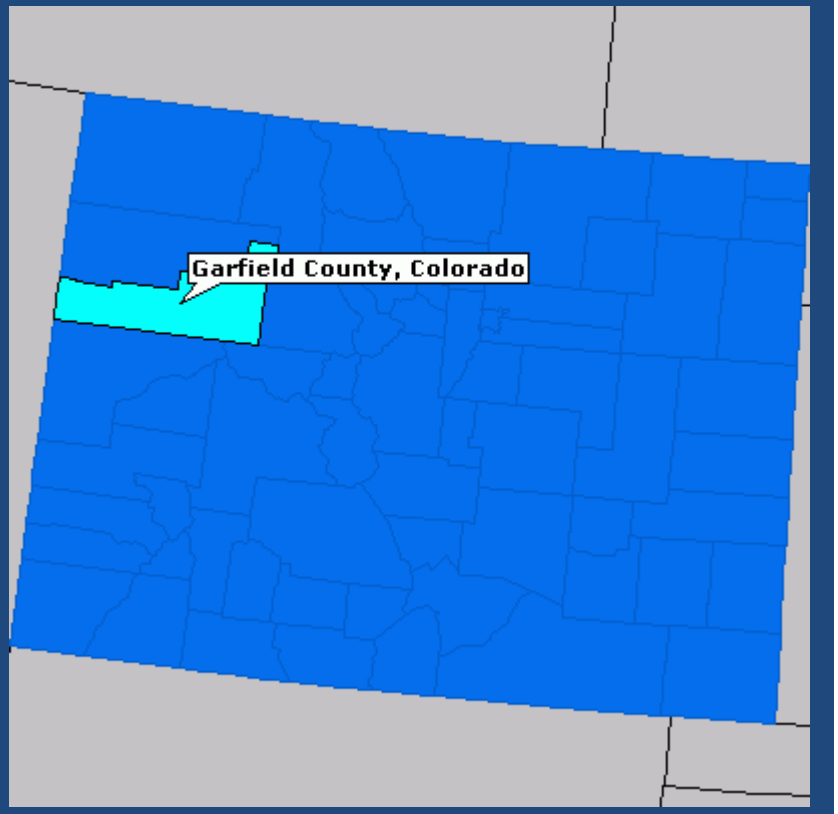
Social Disruption

- What they observed during peak years of drilling activity:
  - Increased rates of crime, as measured by police arrests
  - Increased rates of sexually transmitted diseases
  - Increased overall school enrollment, with rapid turnover of students during the school year



Social Disruption

- Reactions to changes expressed by community members included anger, depression, anxiety, helplessness, and uncertainty about the future.



Social Disruption
Bradford County, Pennsylvania

- "Documenting and Evaluating Social Change in Bradford County, PA during the Marcellus Shale Gas Boom."
- Simona Perry, PhD
- Rensselaer Polytechic Institute
- Ongoing research since July, 2009

Social Disruption
Bradford County, Pennsylvania

- Rural county, with deep family ties to the land

Photos used with permission Simona Perry

Social Disruption
Bradford County, Pennsylvania

- Quality of life
  - Clean water
  - Fresh air
  - Fertile soil
  - Rural way of life
    - Farming
    - Hunting and Fishing
    - Walking the land
    - Knowing your neighbors
  - Economic security
  - Family, past, present and future

Social Disruption
Bradford County, Pennsylvania

- Initially community members largely embraced the benefits of the boom in natural gas drilling.
  - Savior of local economy
  - Sense of Patriotic Duty
    - Decrease reliance on foreign oil
    - Bringing the troops home
  - Believed government agencies would not allow if dangerous

Social Disruption
Bradford County, Pennsylvania

- Initial rapid changes
  - Increased traffic
    - Congestion
    - Accidents
    - Damaged roads
  - Large influx of workers and their families
    - Increased rents
    - Increased enrollment in schools
  - Exodus of city and county employees to work for the gas industry, resulting in decreased personnel to address problems

Social Disruption
Bradford County, Pennsylvania

- On a day to day basis, the major factor diminishing quality of life was the traffic, with noise being the source of most complaints. Residents also commented on the need to change their daily routines due to traffic patterns and damaged roads. There was also fear for their safety while driving.

Social Disruption
Bradford County, Pennsylvania

- As the number of water buffalos appearing increased and the news of industrial spills spread, a growing number of community members became disillusioned with both the gas industry and the agencies that were supposed to protect them.
- Within a previously harmonious community acrimonious divisions grew between supporters and critics of the gas industry.

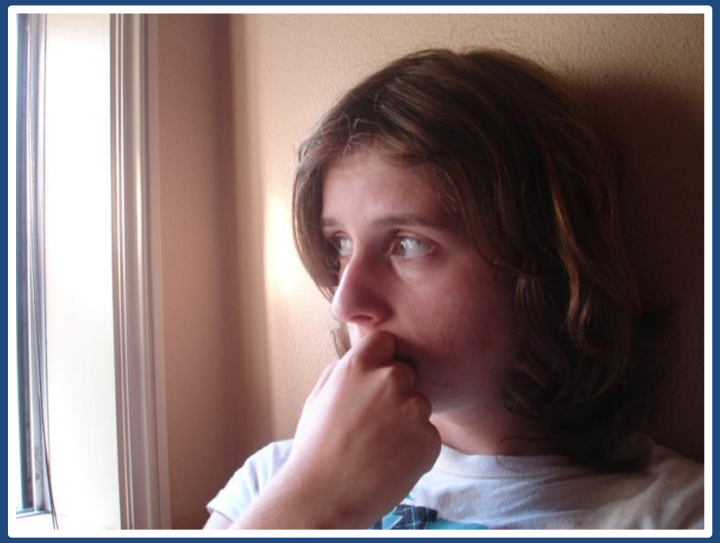
Social Disruption
Bradford County, Pennsylvania

- In Dr. Perry's focus groups, residents expressed:
  - Concern that the gas boom had irreversibly changed their relationship to the land, past, present and future.
  - A sense of dread, that all they loved most was being taken away.

Robert Donnan ©2011

Social Disruption

- Among individuals evaluated by the SWPA EHP, the most common emotions temporally related to gas drilling include:
  - Depression
  - Worry
  - Irritability
  - Feeling overwhelmed



Conclusions: Unconventional Gas Extraction Potential Health Concerns

- Both chemical and non-chemical exposures produced by gas drilling activities pose health risks to residents living in gas production areas.
- Rapid change resulting from introduction of gas drilling activities into rural communities carries risk of social disruption and mental health consequences.