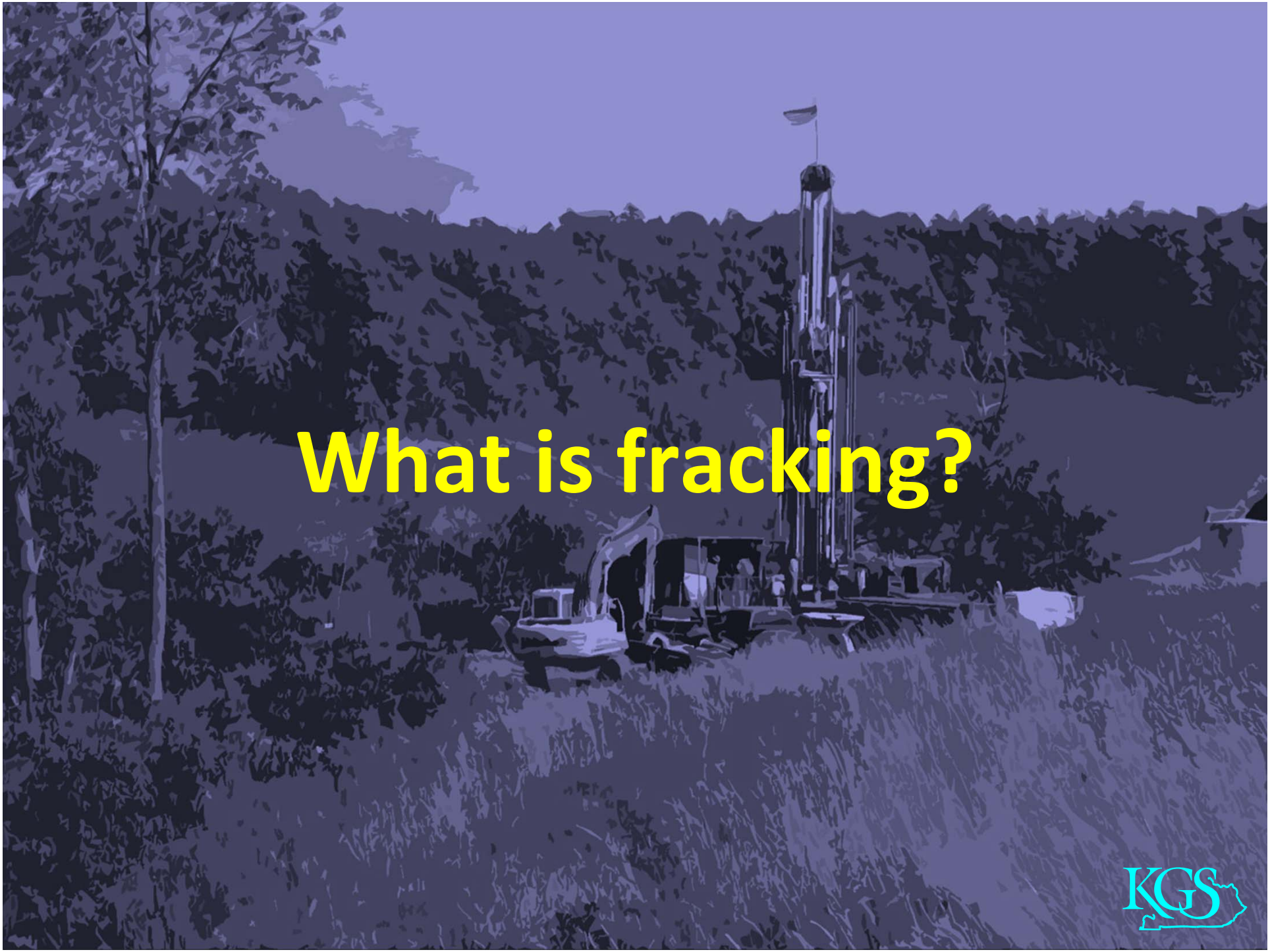
Fracture Stimulation in Kentucky

Brandon C. Nuttall

Kentucky Geological Survey

UK
UNIVERSITY OF KENTUCKY

Kentucky Environmental Quality Commission
Frankfort, Kentucky, 21-Feb-2013

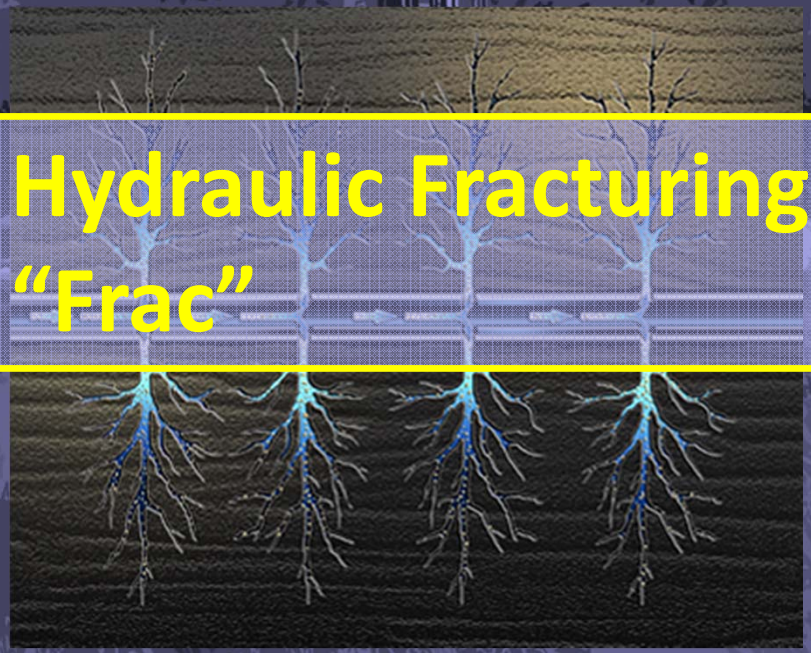


What is fracking?

Fracking is a completion method used to enhance production.
KGS

Fracture stimulation uses pressurized fluids to crack rock underground.

- Explosives
  - Black powder
  - Nitroglycerine
  - ANFO
- Energized Liquids
  - Water
  - Diesel
  - Carbon dioxide
  - Propane
- Gas
  - Nitrogen (foam)
  - "Gas" jet



FracFocus.org

KGS

An oil or gas reservoir has porosity, permeability, and a seal.

Marbles (sediment)

Porosity – space to hold fluid

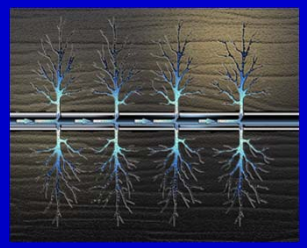
Permeability – "Connectedness"

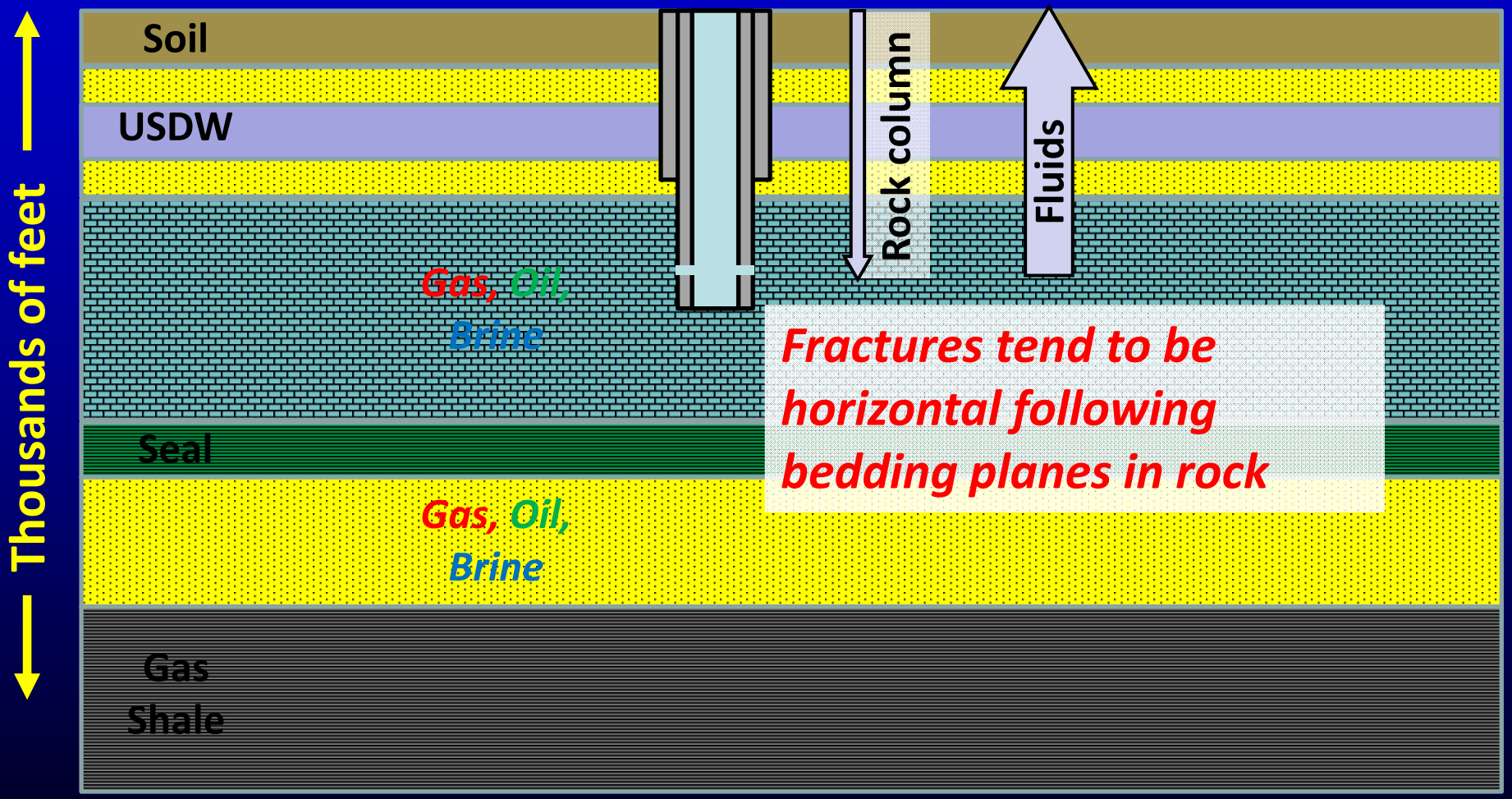
Seal – (Jar & gasket) forms a trap

Rocks with little porosity or permeability often form seals.

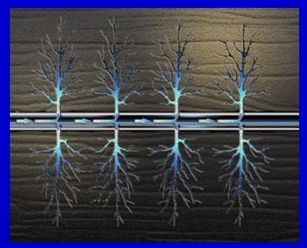
Much like trying to squeeze a brick, shale must be fractured to recover the oil and gas it contains.

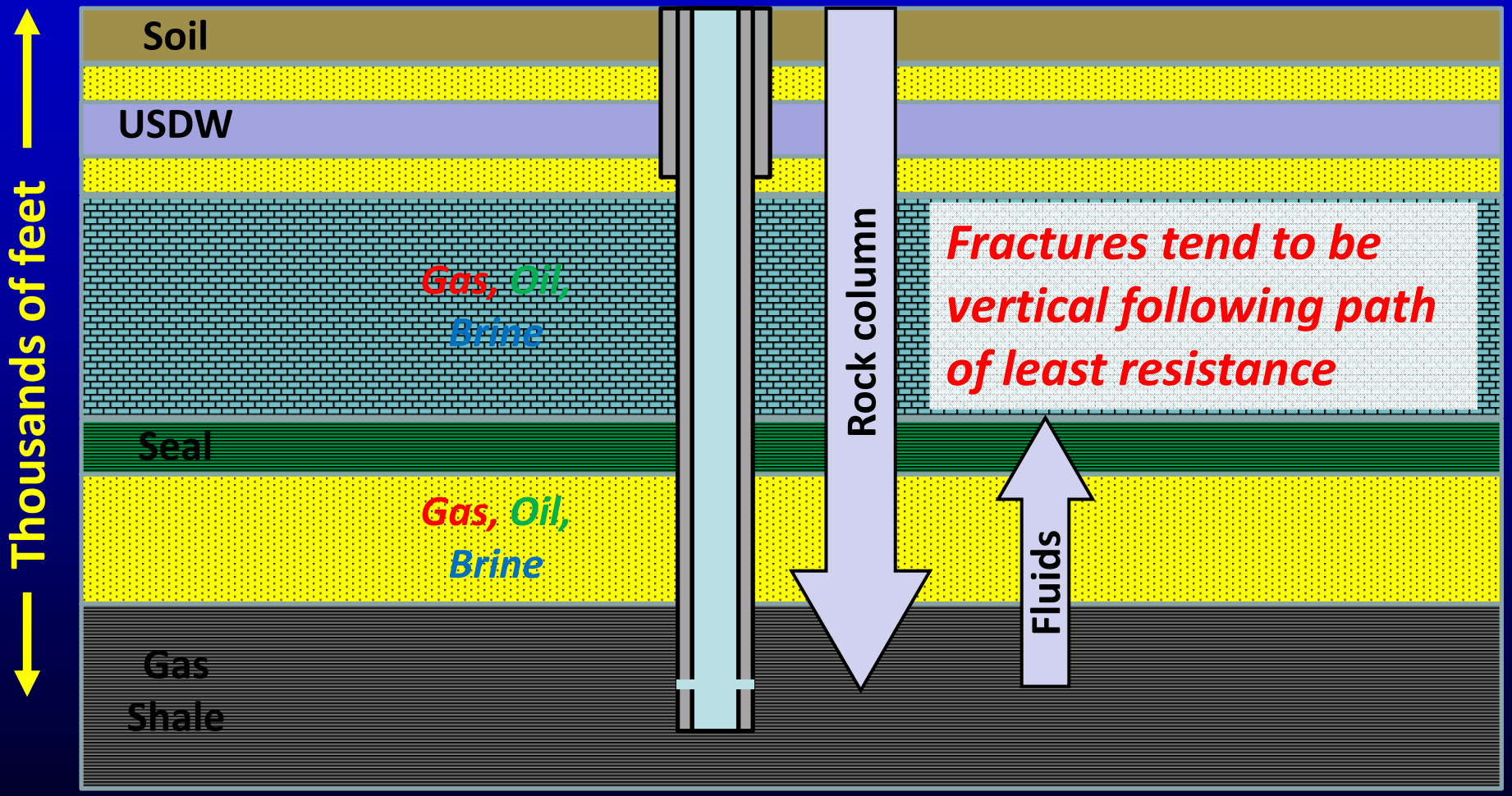
Horizontal fractures radiate from the wellbore in shallow wells.



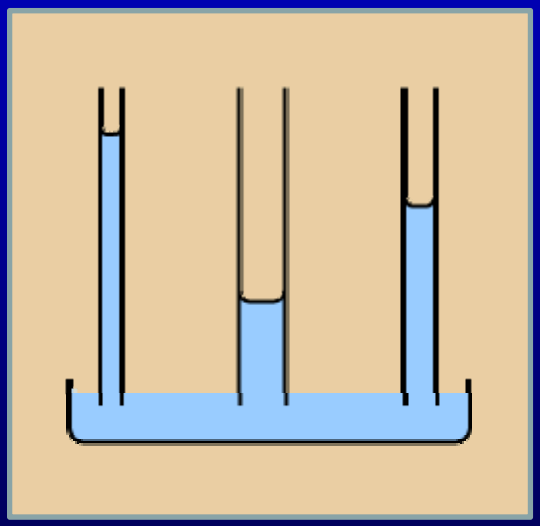


Vertical fractures radiate from the wellbore in deeper wells.



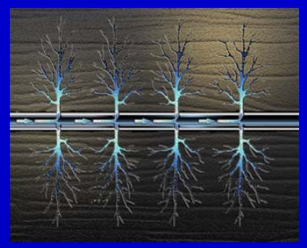


Now for some physics: Why is a leak unlikely?



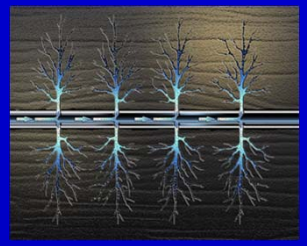
- *Overcome capillary forces*
- *Displace fluids*
- *Avoid dilution*

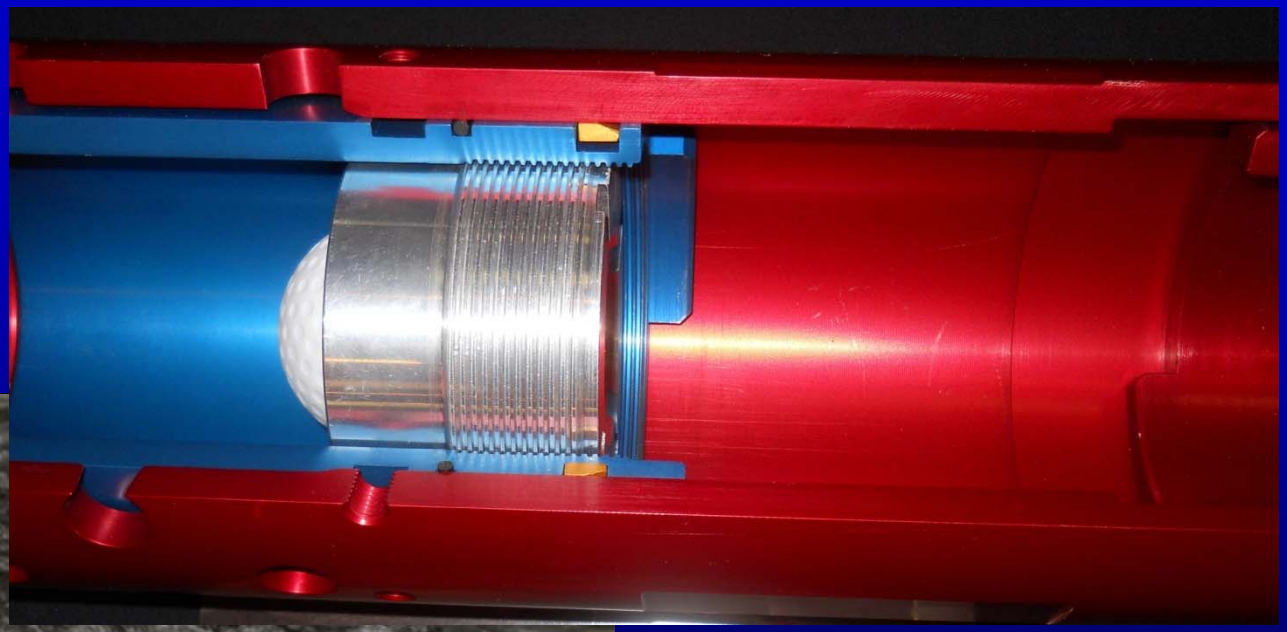
After the well is drilled, shale gas reservoirs require fracture stimulation.



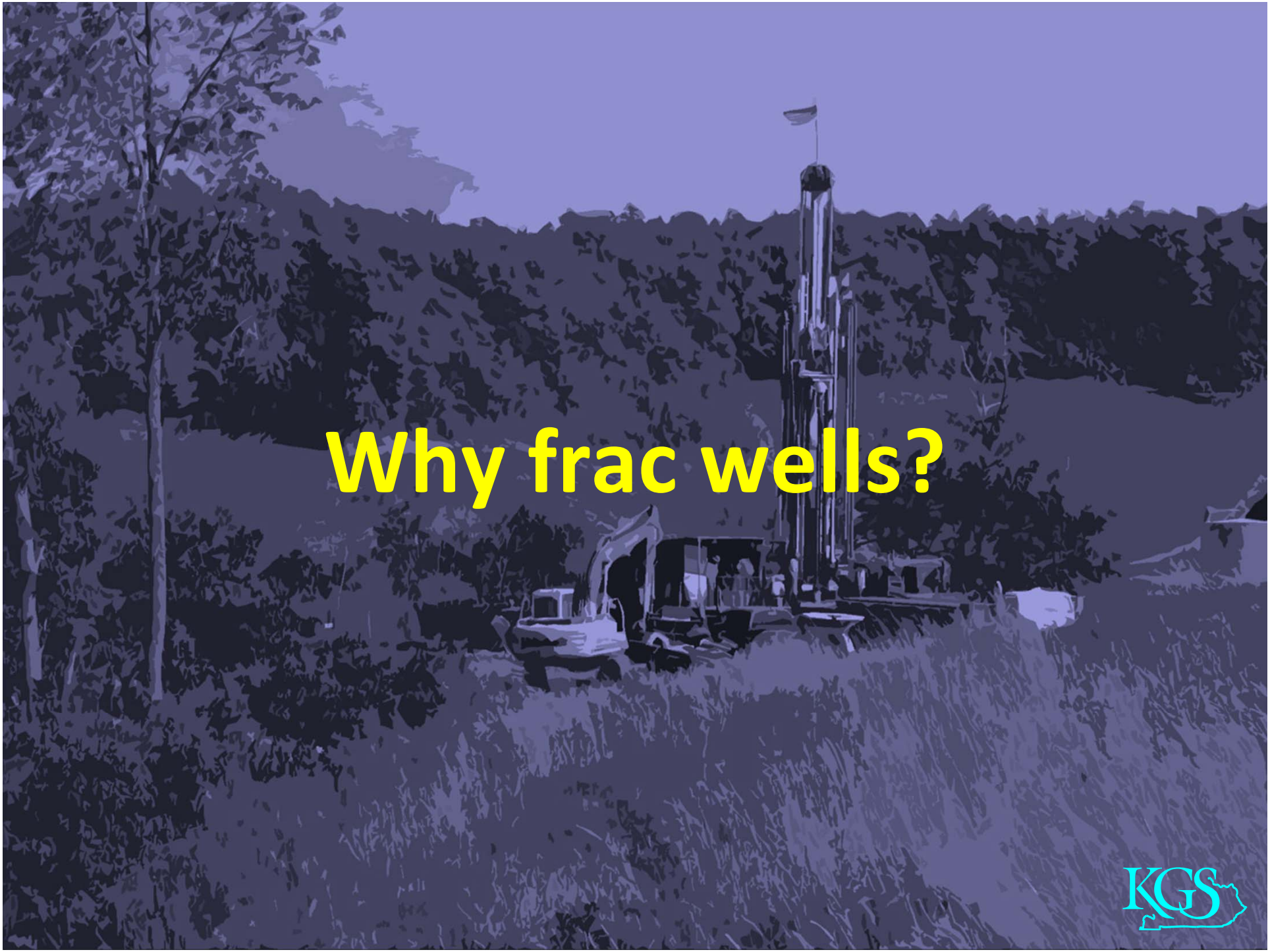
- Energized fluids (under pressure) enter existing fracture and pore system
- Pressure causes the rock to fail
  - Opens a new fracture
  - Increases effective surface area connected to the well
- Sand added to prop the new fracture open
- Release pressure to recover fluid and gas

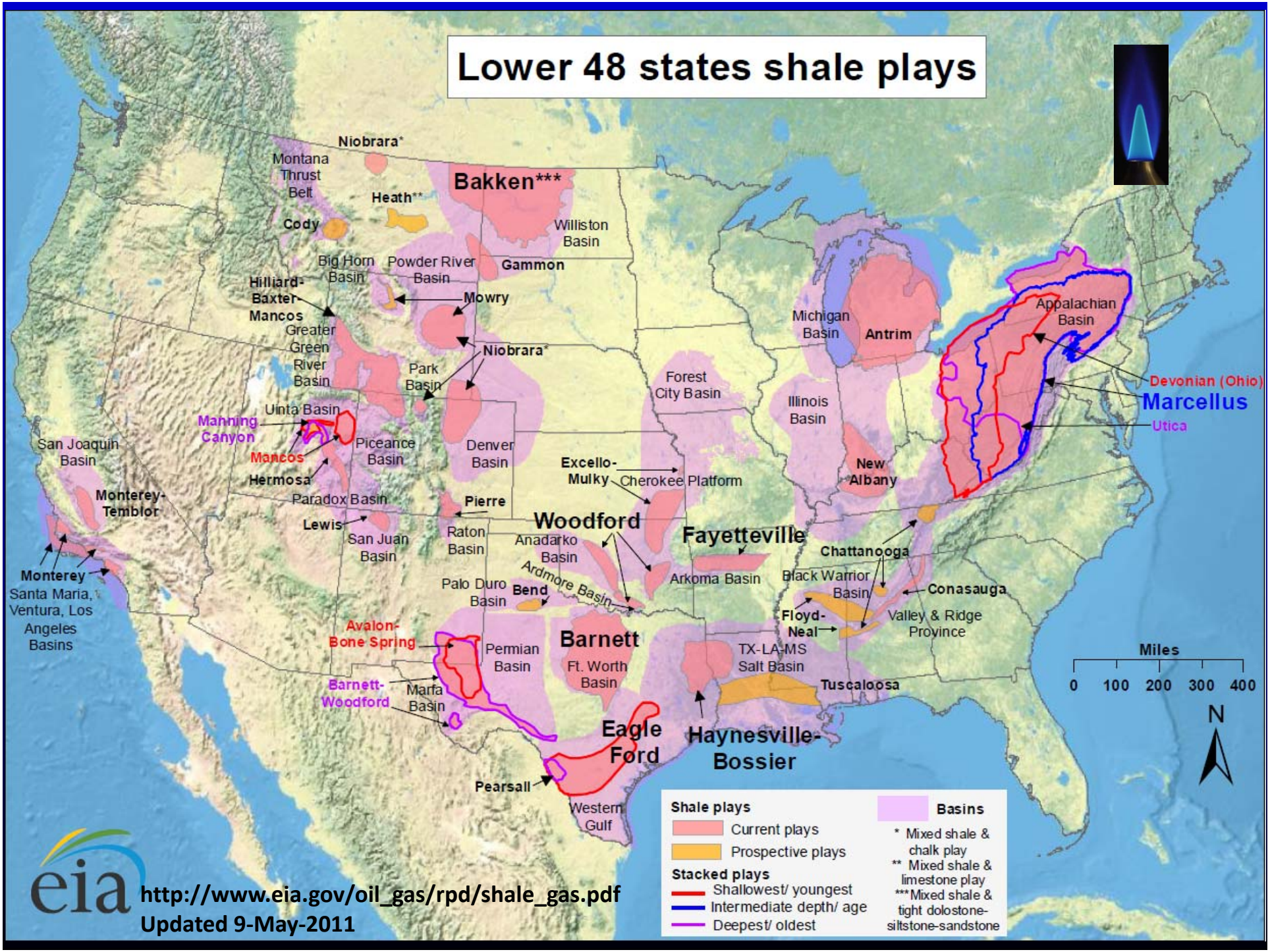
Multi-stage Ported Completion Tool





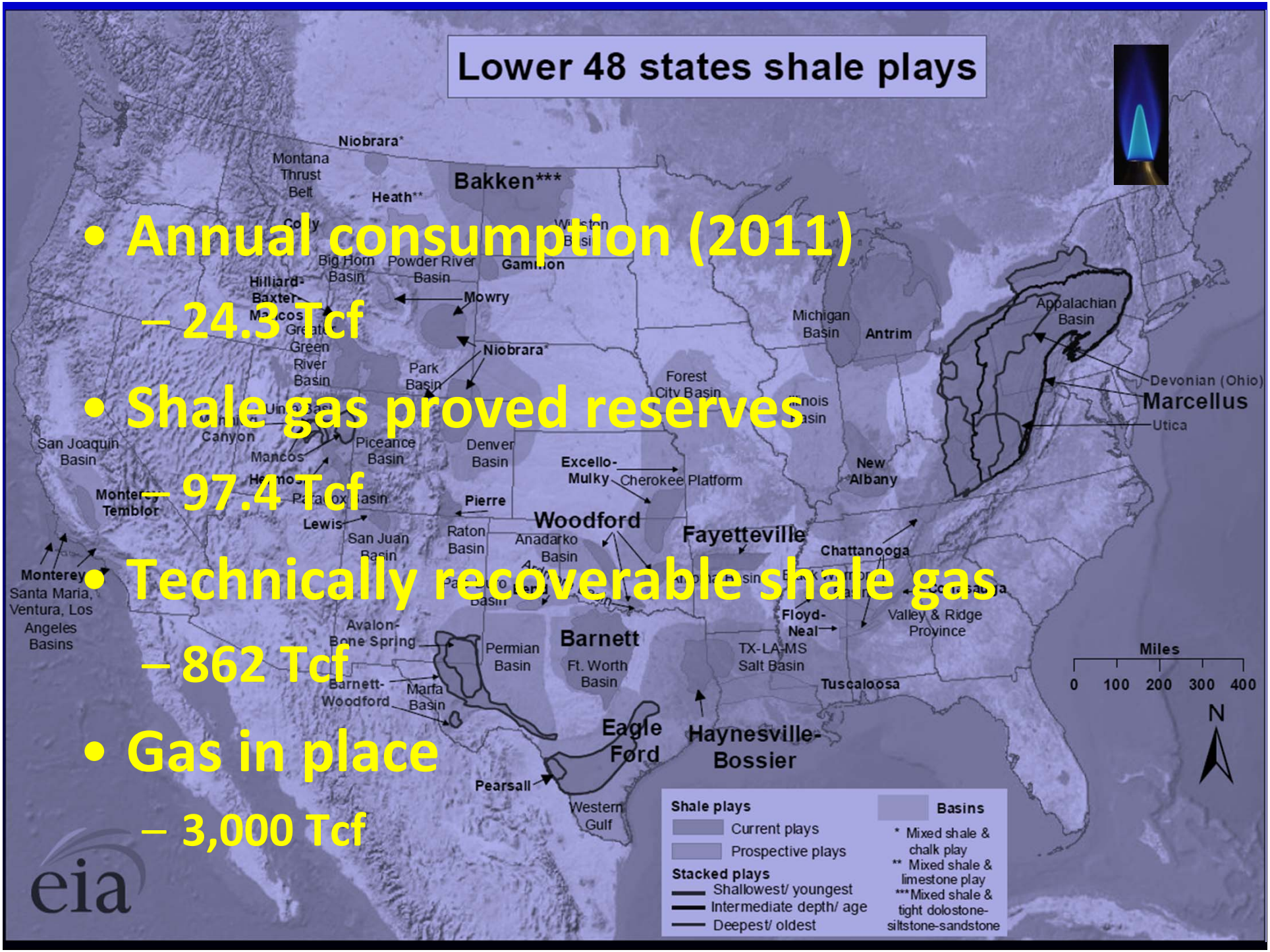
Ball seats and forces blue sleeve to slide into open position

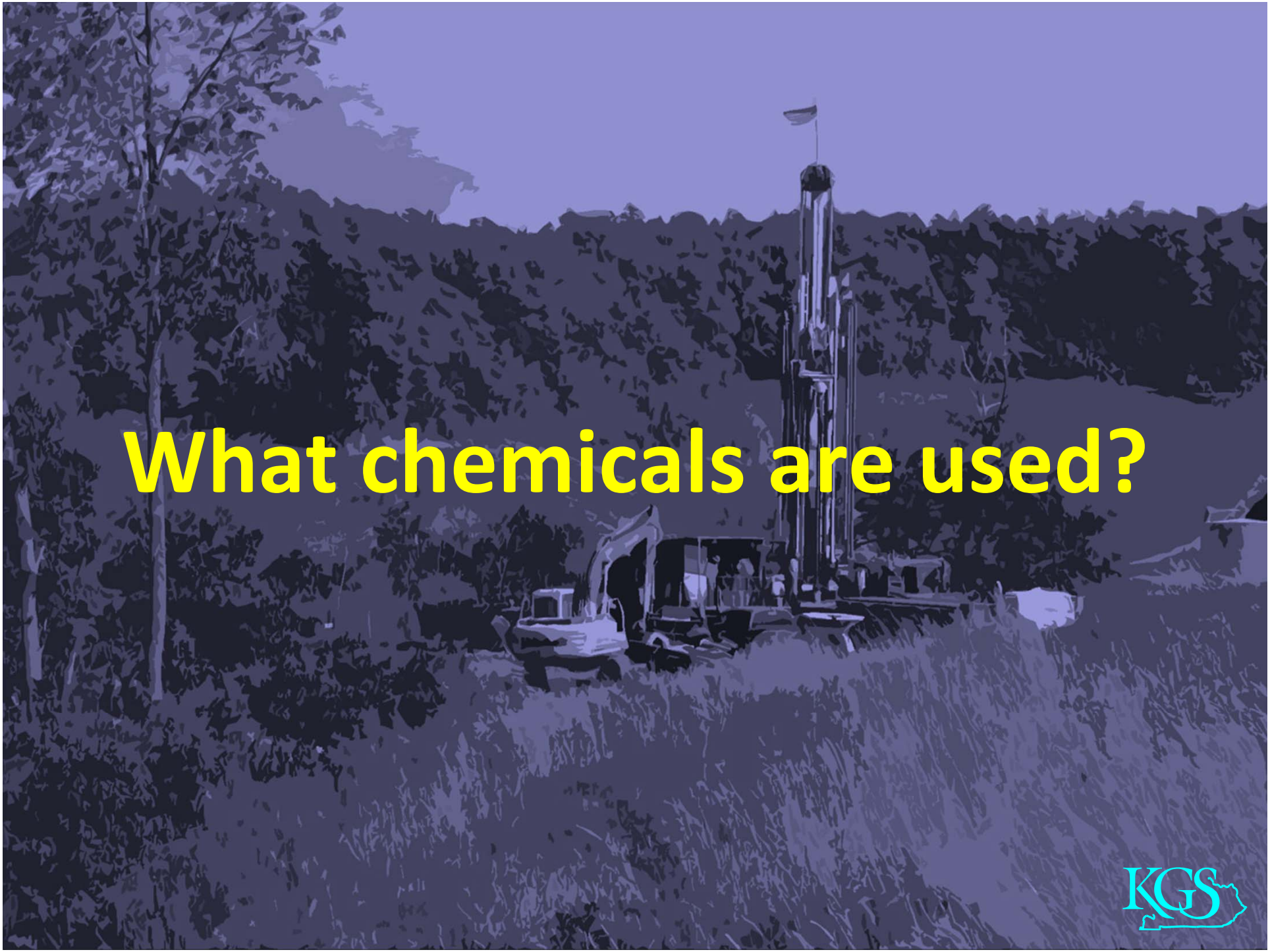

Why frac wells?
KGS


Lower 48 states shale plays
Niobrara*
Montana Thrust Belt
Heath**
Bakken***
Cody
Williston Basin
Big Horn Basin
Powder River Basin
Gammon
Hilliard-Baxter-Mancos
Mowry
Greater Green River Basin
Niobrara*
Park Basin
Forest City Basin
Michigan Basin
Antrim
Appalachian Basin
Devonian (Ohio)
Marcellus
Utica
Illinois Basin
Uinta Basin
Manning Canyon
Mancos
Hermosa
Piceance Basin
Denver Basin
San Joaquin Basin
Monterey-Temblor
Paradox Basin
Pierre
Excello-Mulky
Cherokee Platform
New Albany
Lewis
San Juan Basin
Raton Basin
Woodford
Anadarko Basin
Fayetteville
Chattanooga
Monterey
Santa Maria, Ventura, Los Angeles Basins
Ardmore Basin
Arkoma Basin
Black Warrior Basin
Conasauga
Palo Duro Basin
Bend
Floyd-Neal
Valley & Ridge Province
Avalon-Bone Spring
Permian Basin
Barnett
TX-LA-MS Salt Basin
Ft. Worth Basin
Barnett-Woodford
Marfa Basin
Tuscaloosa
Eagle Ford
Haynesville-Bossier
Pearsall
Western Gulf
Miles
0 100 200 300 400
N
Shale plays
Current plays
Prospective plays
Stacked plays
Shallowest/ youngest
Intermediate depth/ age
Deepest/ oldest
Basins
* Mixed shale & chalk play
** Mixed shale & limestone play
***Mixed shale & tight dolostone-siltstone-sandstone
eia
http://www.eia.gov/oil_gas/rpd/shale_gas.pdf
Updated 9-May-2011

Lower 48 states shale plays

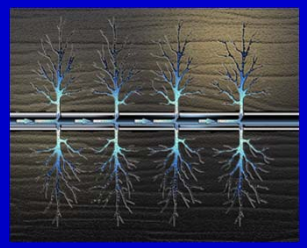
- Annual consumption (2011)
  - 24.3 Tcf
- Shale gas proved reserves
  - 97.4 Tcf
- Technically recoverable shale gas
  - 862 Tcf
- Gas in place
  - 3,000 Tcf

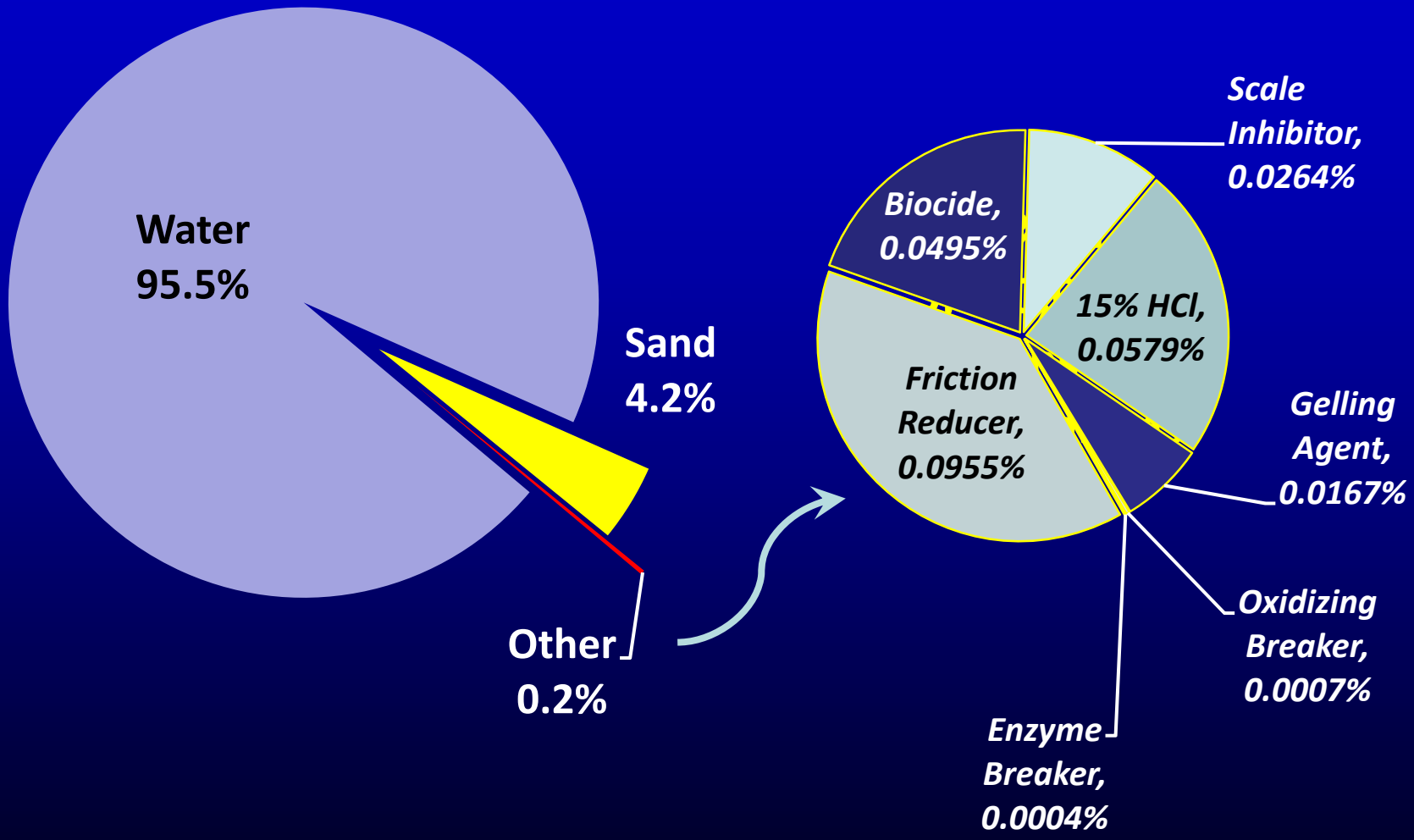




What chemicals are used?

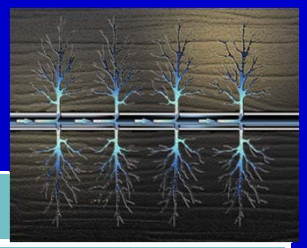
Hydraulic fracturing uses mostly water with some sand.





http://www.eqt.com/docs/pdf/FluidCompositions/Sample%20Fluid%20Composition-Halliburton.pdf

Information on the additives is available on the web.

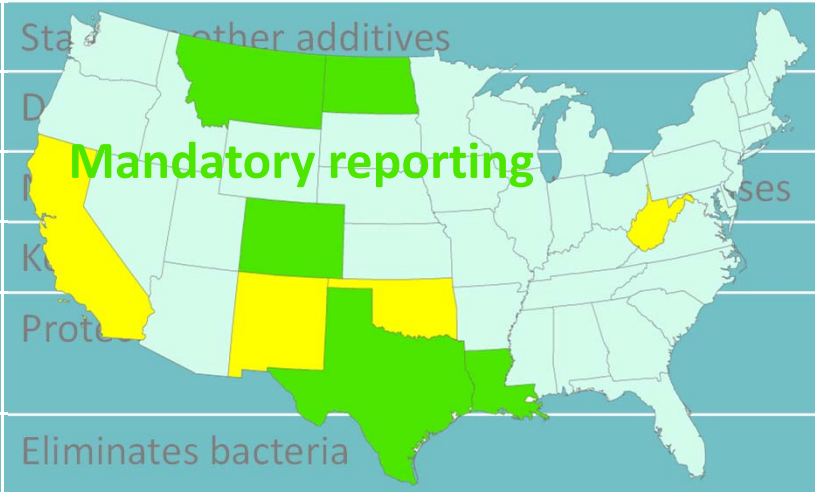


FracFocus.org

GWPC

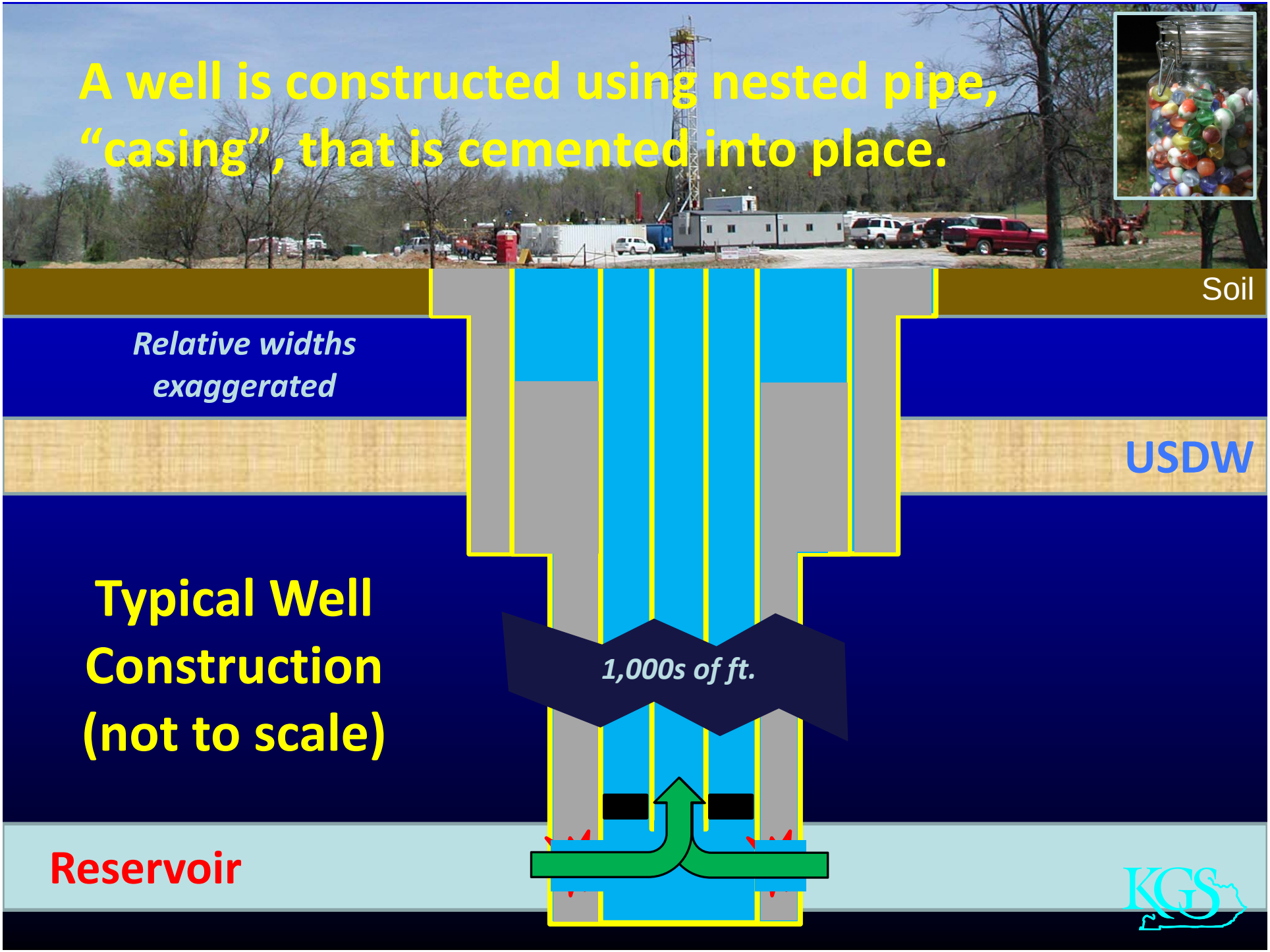
IOGCC

Additive	Compound	Purpose
Acid	HCl *(pool, brick cleaner)*	Helps initiate cracks
Friction Reducer	Petroleum distillate	Minimizes friction for fluid movement
Surfactant	Isopropanol *(glass cleaner)*	Reduces surface tension, improving liquid recovery
Gel	Guar gum or cellulose	Helps water carry sand
Scale Inhibitor	Ethylene glycol *(antifreeze)*	Protects pipe
pH Adjusting	Na_2CO_3 or K_2CO_3 *(water softeners)*	Stabilizes other additives
Breaker	Ammonium persulfate *(hair dye)*	Delays gelling
Crosslinker	Borate salts *(detergents)*	Maintains fluid viscosity
Iron Control	Citric acid	Keeps metals in solution
Corrosion Inhibitor	Formamide *(plastics)*	Protects pipe
Antibacterial	Glutaraldehyde *(hospital disinfectant)*	Eliminates bacteria
Clay Stabilizer	KCl *(low sodium salt substitute)*	Prohibits fluids from reacting with clays

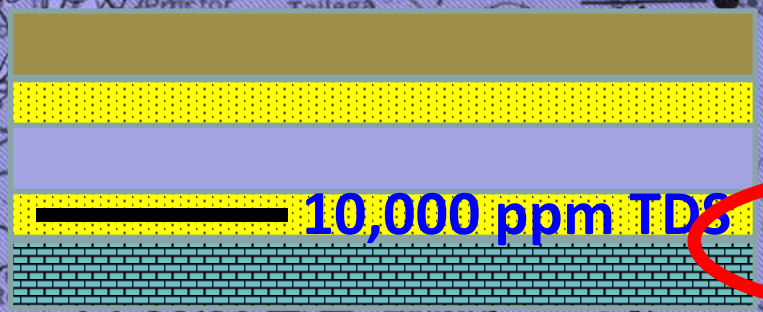


http://www.chk.com/Media/MarcellusMediaKits/Marcellus_Hydraulic_Fracturing_Fact_Sheet.pdf

How is water protected?
KGS


A well is constructed using nested pipe, "casing", that is cemented into place.
Soil
Relative widths exaggerated
USDW
Typical Well Construction (not to scale)
1,000s of ft.
Reservoir
KGS

In Kentucky, fresh water resources are protected by KRS 353.



- Adopted 1960
- Requires
  - Permit
  - Construction standards
  - Drilling records
  - Plugging

The drinking water standard is 600 ppm TDS or less.

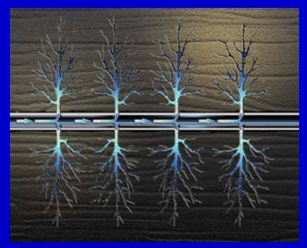
Hopkins (1966) Fresh-saline water interface map (available online at KGS)

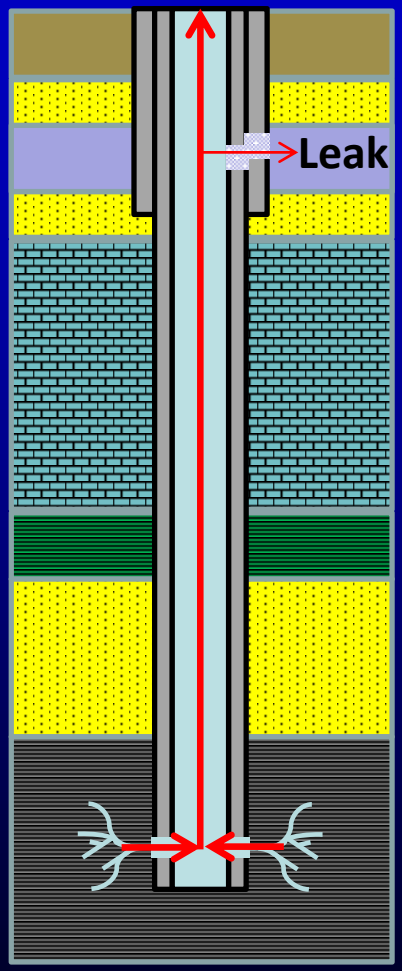
Spill Prevention Control and Counter Measures (SPCC)

www.epa.gov/osweroe1/content/spcc/index.htm

What can go wrong?
KGS

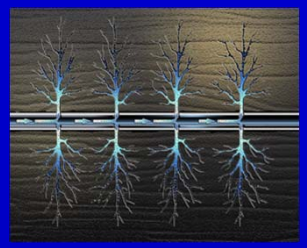
Things can go wrong and fluids can contaminate groundwater.





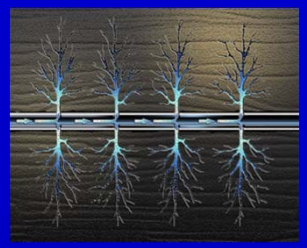
- Bad well construction (casing & cement)
  - Including domestic water supply wells
- Frac out of zone
  - Encounter an unexpected fracture or old well bore
  - Kentucky plugging fund
- Induced seismicity
  - Barnett, Texas
  - Fayetteville, Arkansas

The U.S. EPA has investigated degraded water quality



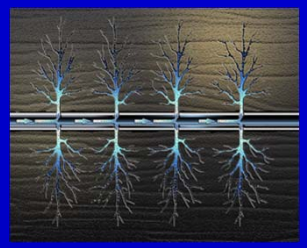
- Famous incidents
  - Pavillion, WY, 2011
  - Dimock, PA, 2008-2010
- Findings
  - Lack of baseline data
  - Found diesel & gasoline in USDWs
  - Cabot in PA
    - Activities affected USDWs
    - Signed consent order to remediate
    - Fulfilled their obligations (2011)
  - EPA calls for transparency on chemicals used

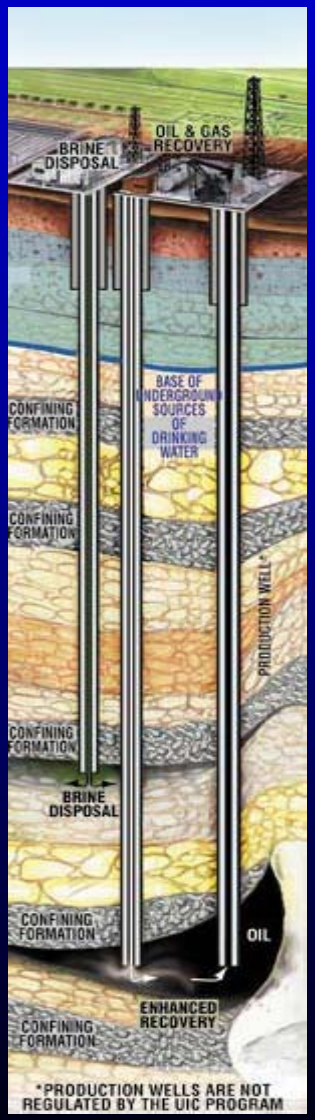
Reports of burning water have been investigated by EPA and state regulators.



- **Famous incidents**
  - GasLand (film), CO
  - Parker County, TX
- **Findings**
  - Gas is commonly co-produced with water from shallow aquifers
  - Historic occurrences predate fracking by centuries
  - Natural
  - Flawed data collection and analysis
  - Poor water well construction?

USGS & National Research Council: fracking rarely causes quakes.



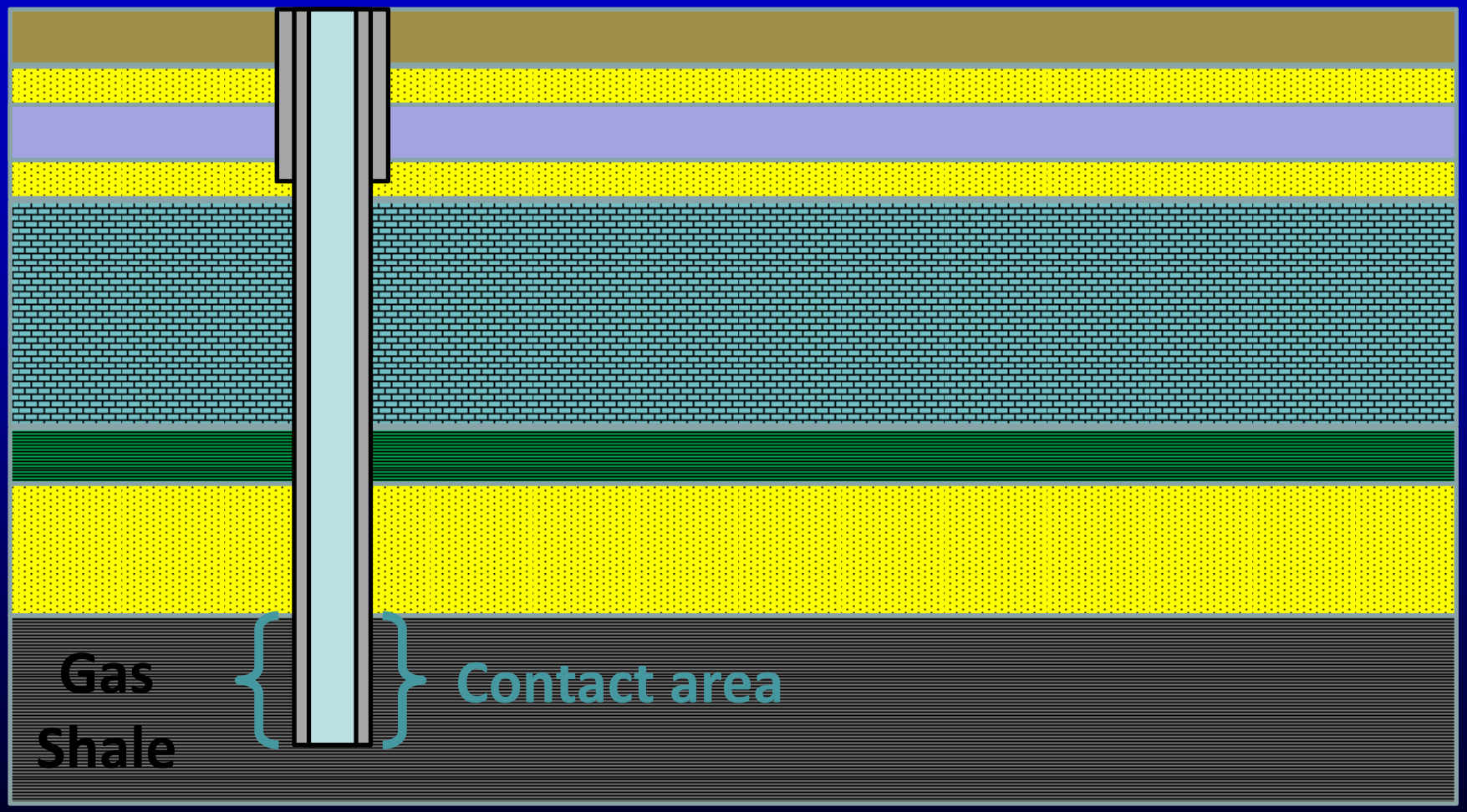


- Risk is higher for wastewater disposal and injection wells
- Waste injection is safe and regulated to protect fresh water
  - Many thousands of disposal wells
  - Few dozens with potential problems
- <u>No property damage</u>
- <u>No injuries or fatalities</u>

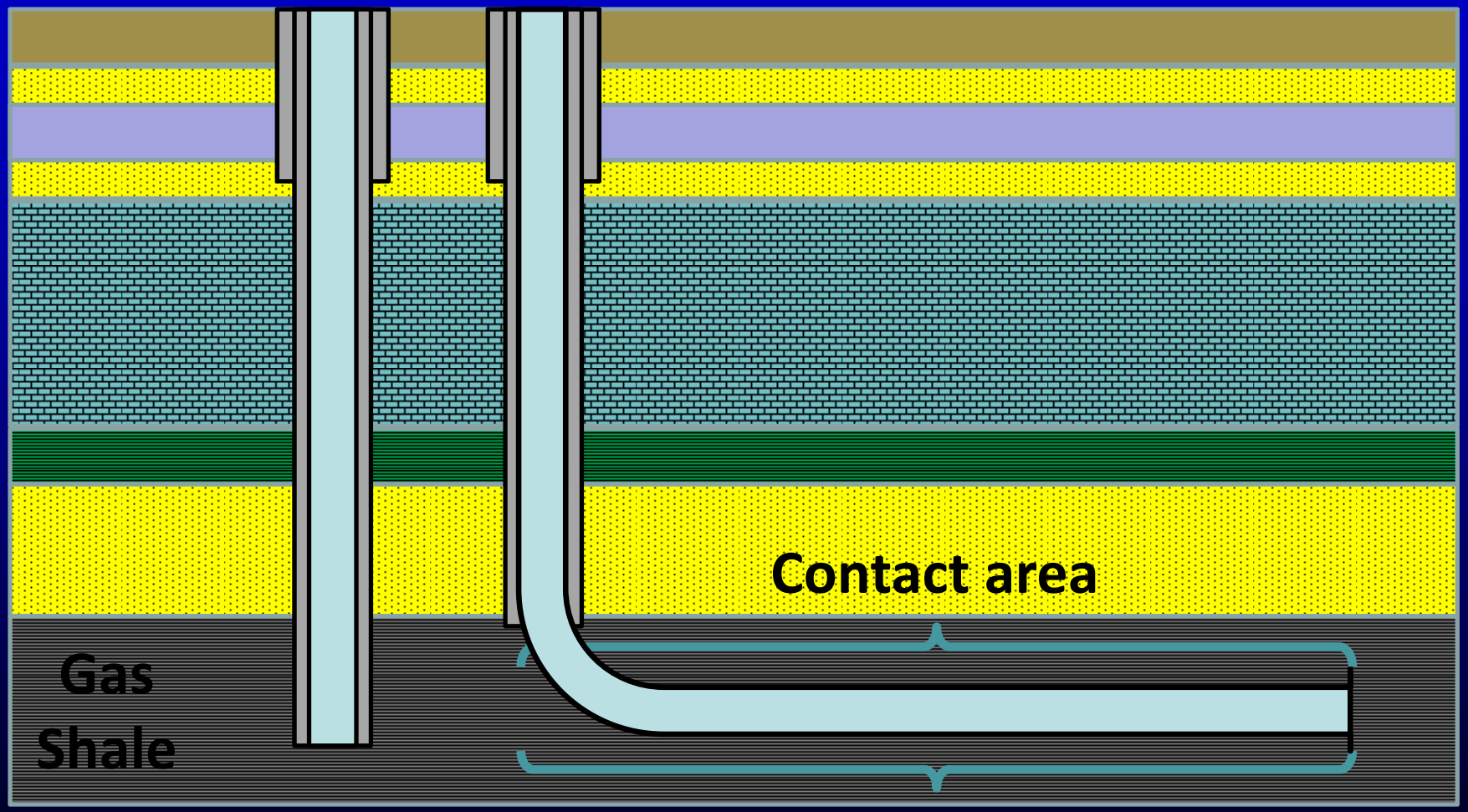
U.S. EPA UIC Class II
water.epa.gov/type/groundwater/uic/class2/index.cfm

Why horizontal wells?

A vertical well intersects only a small part of the reservoir volume.

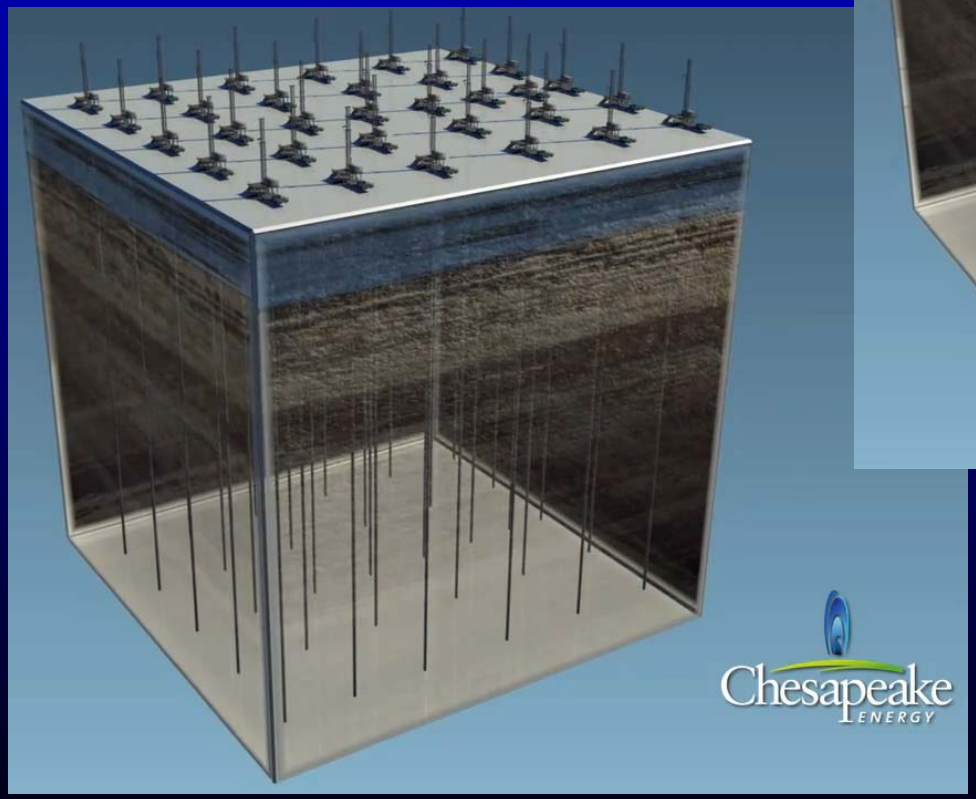


A horizontal well intersects much more of the reservoir volume.



Horizontal wells minimize surface impact of drilling.

Many surface locations



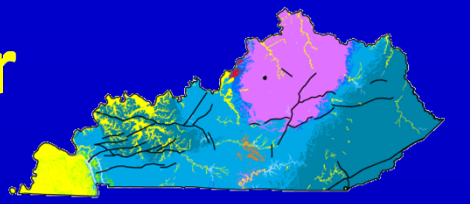
Many underground laterals

What is happening in Kentucky?

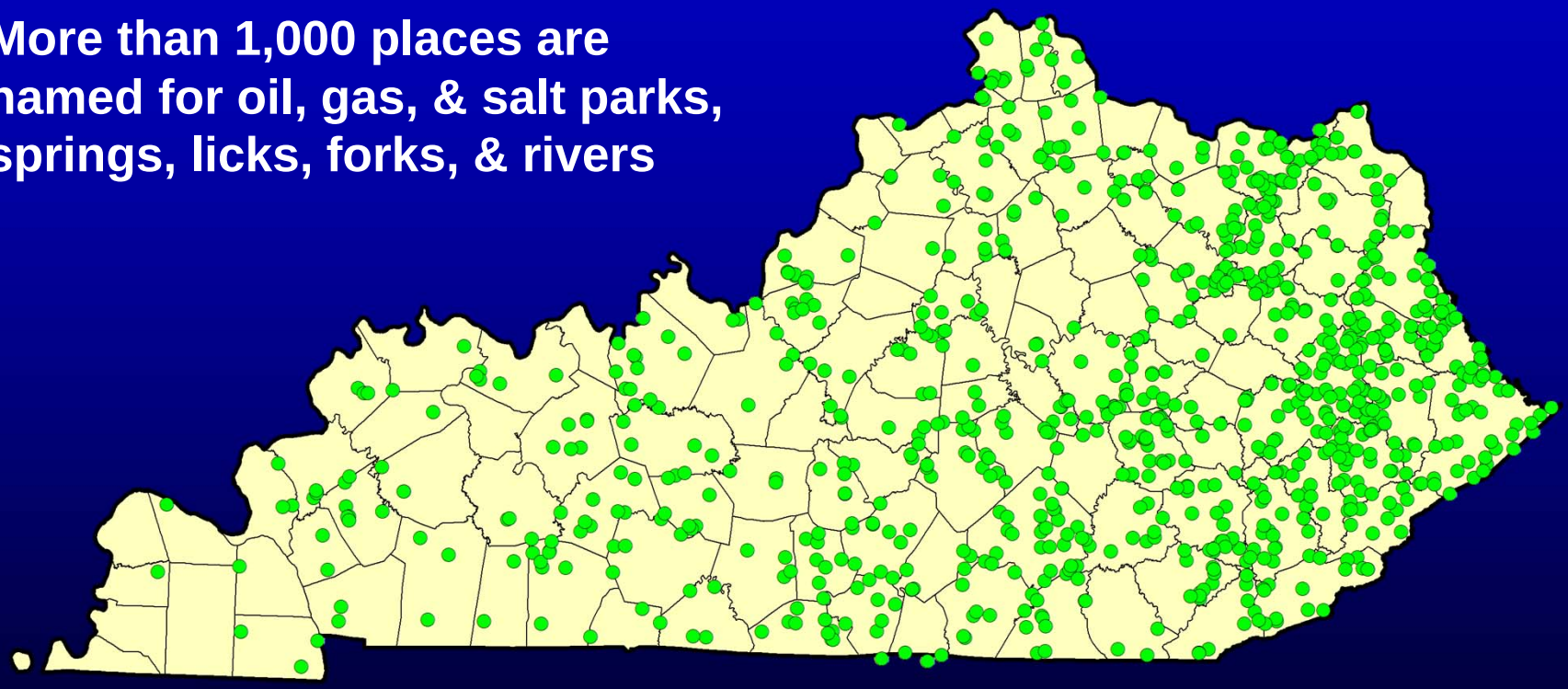
Kentucky's resources have always been important.
Big Bone Cr.
Salt Springs
the large medicinal spring
Bones are found here
Banklick Cr.
Bird's War Road
LICKING RIVER
Clark's
Eagle Cr.
Mill Cr.
the Twins
Severn
Shoemaker's Cr.
Drennon's Lick
Raven Cr.
F A Y E T T E

Filson, 1784

Natural springs and seeps affect water quality.

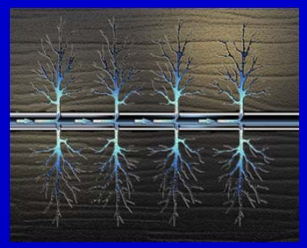


More than 1,000 places are named for oil, gas, & salt parks, springs, licks, forks, & rivers



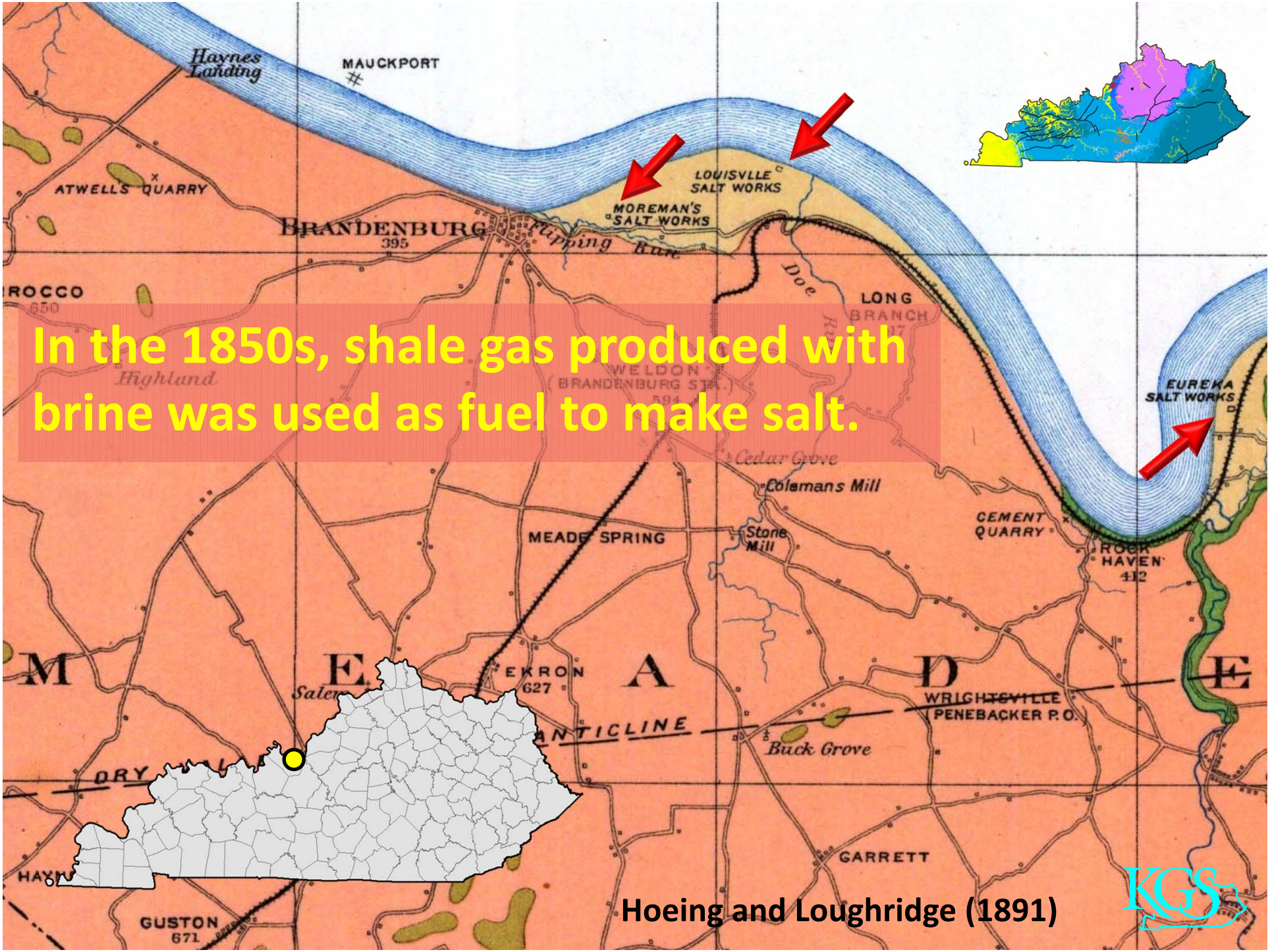
Lack of baseline water quality data and water well construction standards makes it difficult to distinguish nature from surface spills and other pollution.

Fracture stimulation has been used in Kentucky for more than 200 years



- 1806: John R. Shaw describes using explosives to improve water wells
- 1888: 1st use of explosive fracturing in oil wells ("shot")
- 1966: Hydraulic fracturing
  - 1946: 1st in U.S. (Kansas)
- 1972: Nitrogen (and foam) frac
- Since late 1970's shale gas wells in Kentucky have been stimulated with <u>nitrogen</u>

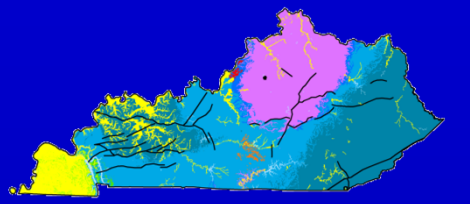
Kentucky has a shale gas play.



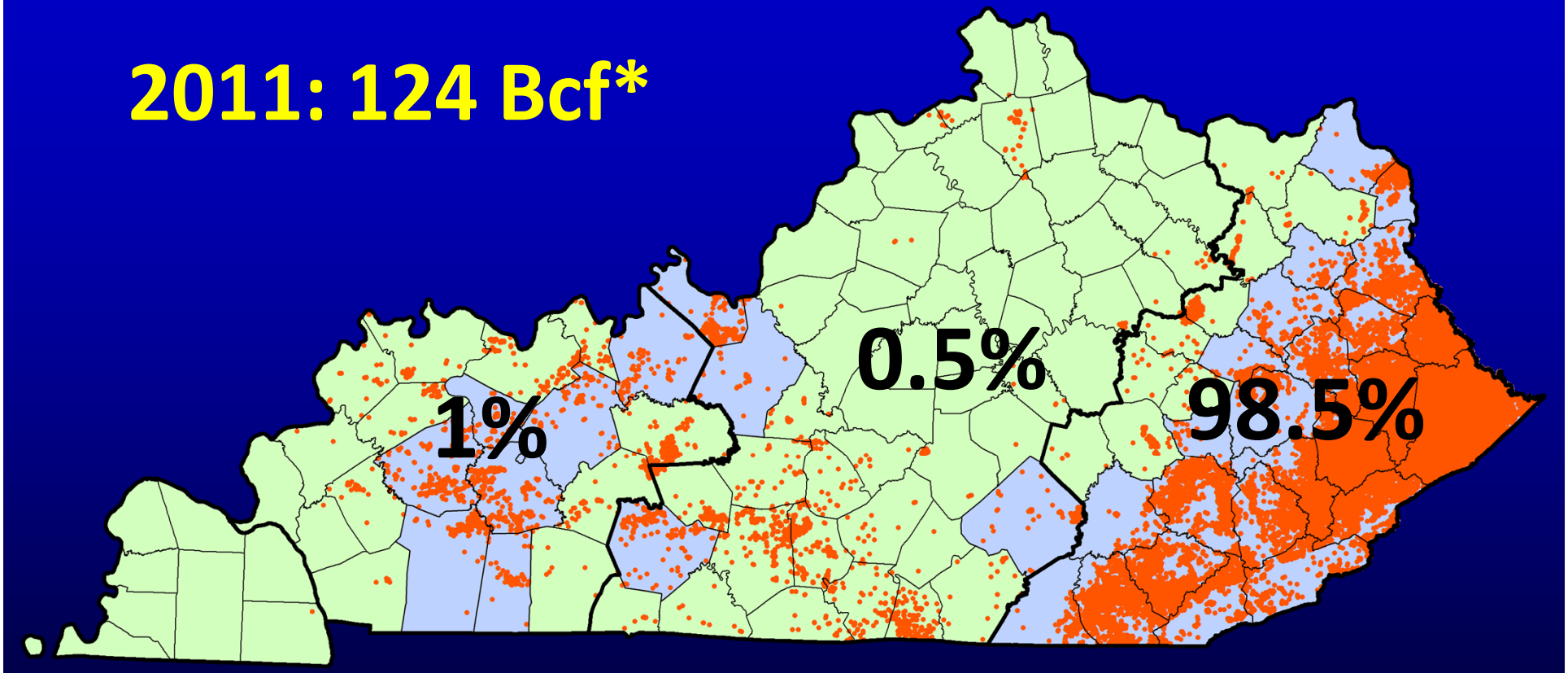
In the 1850s, shale gas produced with brine was used as fuel to make salt.

Hoeing and Loughridge (1891)

In 2011, 35 Kentucky counties reported natural gas production.

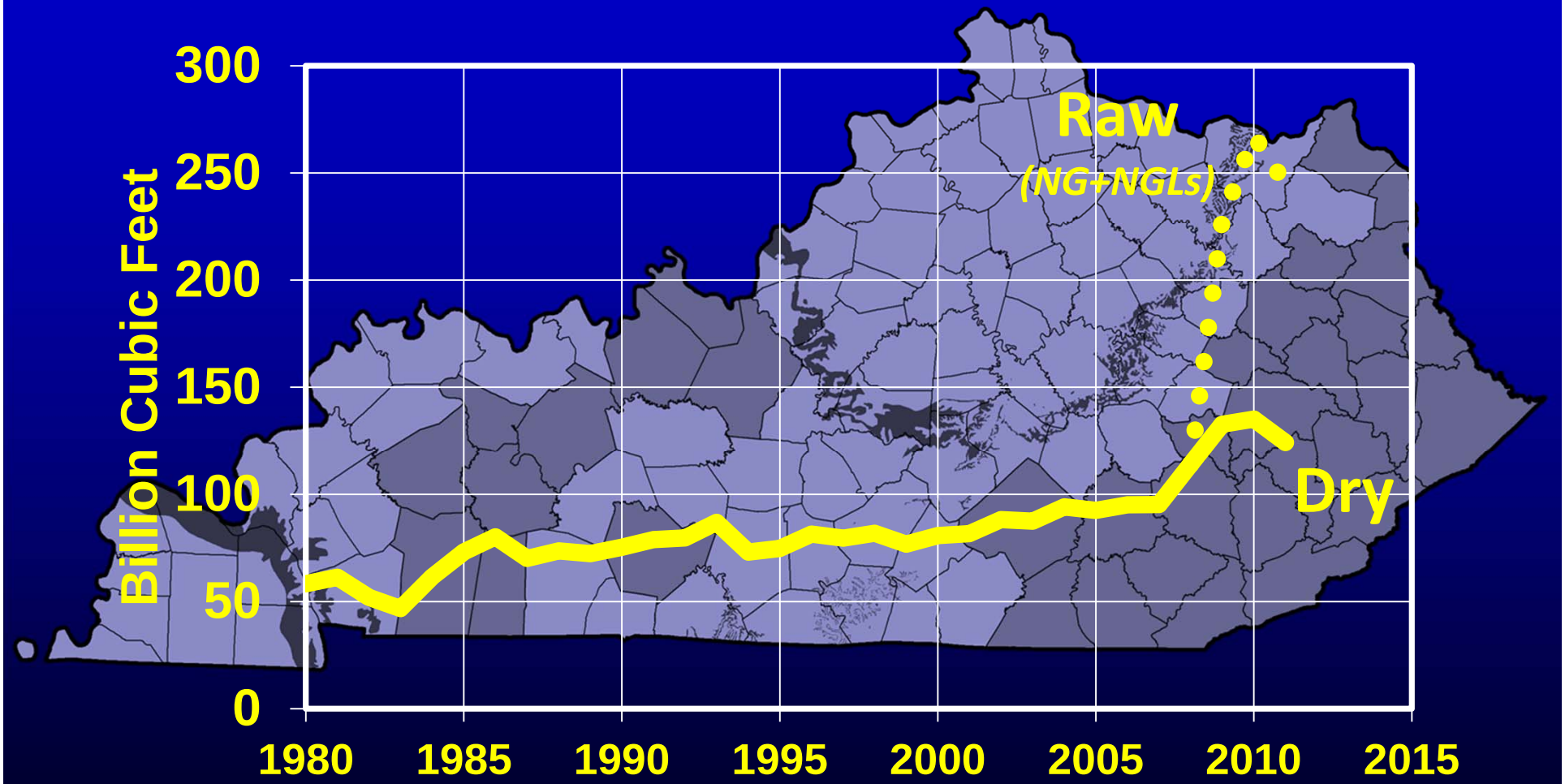


2011: 124 Bcf*

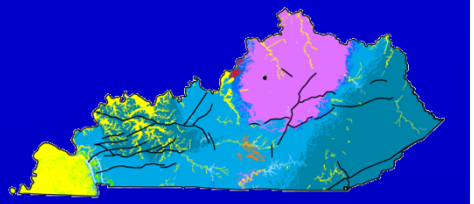


* Severance tax was paid on 245 Bcf of raw gas, proportions of natural gas and NGL is estimated.

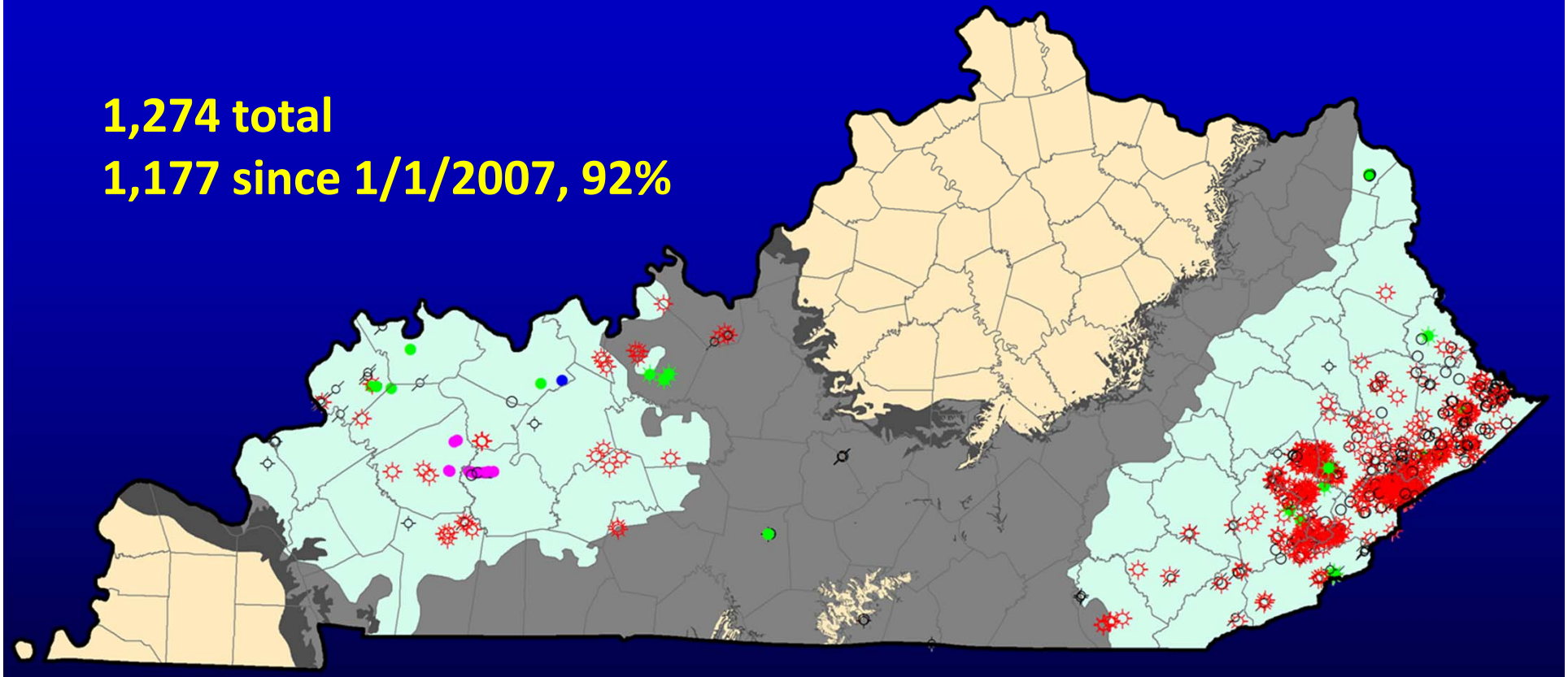
Kentucky Natural Gas Production



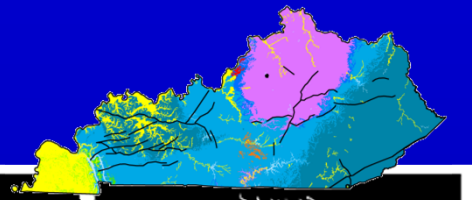
Horizontal Wells in Kentucky



1,274 total
1,177 since 1/1/2007, 92%



Acid/Foam Fracture Stimulation



Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Date 06/20/2007	Date 06/20/2007	Date 06/20/2007	Date 06/20/2007	Date 06/20/2007
FracType Variable Foam	FracType Variable Foam	FracType Variable Foam	FracType Variable Foam	FracType Variable Foam
Zone Lower Huron	Zone Lower Huron	Zone Lower Huron	Zone Lower Huron	Zone Lower Huron
# of Perfs port collar	# of Perfs port collar	# of Perfs port collar	# of Perfs port collar	# of Perfs port collar
From/To 6,579— 6,579	From/To 6,197— 6,197	From/To 5,790— 5,790	From/To 5,468— 5,468	From/To 5,059— 5,059
BD Press 2,850	BD Press 2,001	BD Press 2,236	BD Press 2,848	BD Press 2,032
ATP Psi 3,475	ATP Psi 3,595	ATP Psi 3,085	ATP Psi 3,070	ATP Psi 3,020
Avg Rate 46	Avg Rate 50	Avg Rate 50	Avg Rate 50	Avg Rate 50
Max Press Psi 4,067	Max Press Psi 4,223	Max Press Psi 3,570	Max Press Psi 3,711	Max Press Psi 3,386
ISIP Psi 0	ISIP Psi 0	ISIP Psi 0	ISIP Psi 0	ISIP Psi 0
10min SIP 0 5 min.	10min SIP 0 5 min.	10min SIP 0 5 min.	10min SIP 0 5 min.	10min SIP 0 5 min.
Frac Gradient 0.00	Frac Gradient 0.00	Frac Gradient 0.00	Frac Gradient 0.00	Frac Gradient 0.00
Sand Proppant 501.20	Sand Proppant 502.92	Sand Proppant 504.36	Sand Proppant 501.97	Sand Proppant 501.37
Water-bbl 328	Water-bbl 330	Water-bbl 292	Water-bbl 303	Water-bbl 274
SCF N2 962,043	SCF N2 892,454	SCF N2 849,660	SCF N2 804,447	SCF N2 831,270
Acid-gal 1,350 gal 3%MSA	Acid-gal 1,300 gal 3%MSA	Acid-gal 1,300 gal 3%MSA	Acid-gal 1,300 gal 3%MSA	Acid-gal 1,280 gal 3%MSA

HCl: Stomach acid ~ 0.5%, brick cleaner ~ 32 %

Courtesy Brint Camp, NGAS

How do you verify it's being done properly?

Energy and Environment Cabinet

Department for Natural Resources

Home | Agencies | Online Services | Resources | Programs | Open Records | About Us

Division of Oil and Gas

eec.ky.gov Search

Division of Oil and Gas

The mission of the Division of Oil and Gas is to regulate the crude oil and natural gas industry in the Commonwealth; protect the correlative rights of mineral owners, fresh water zones and minable coal seams; and conserve and protect oil and gas reserves in Kentucky.

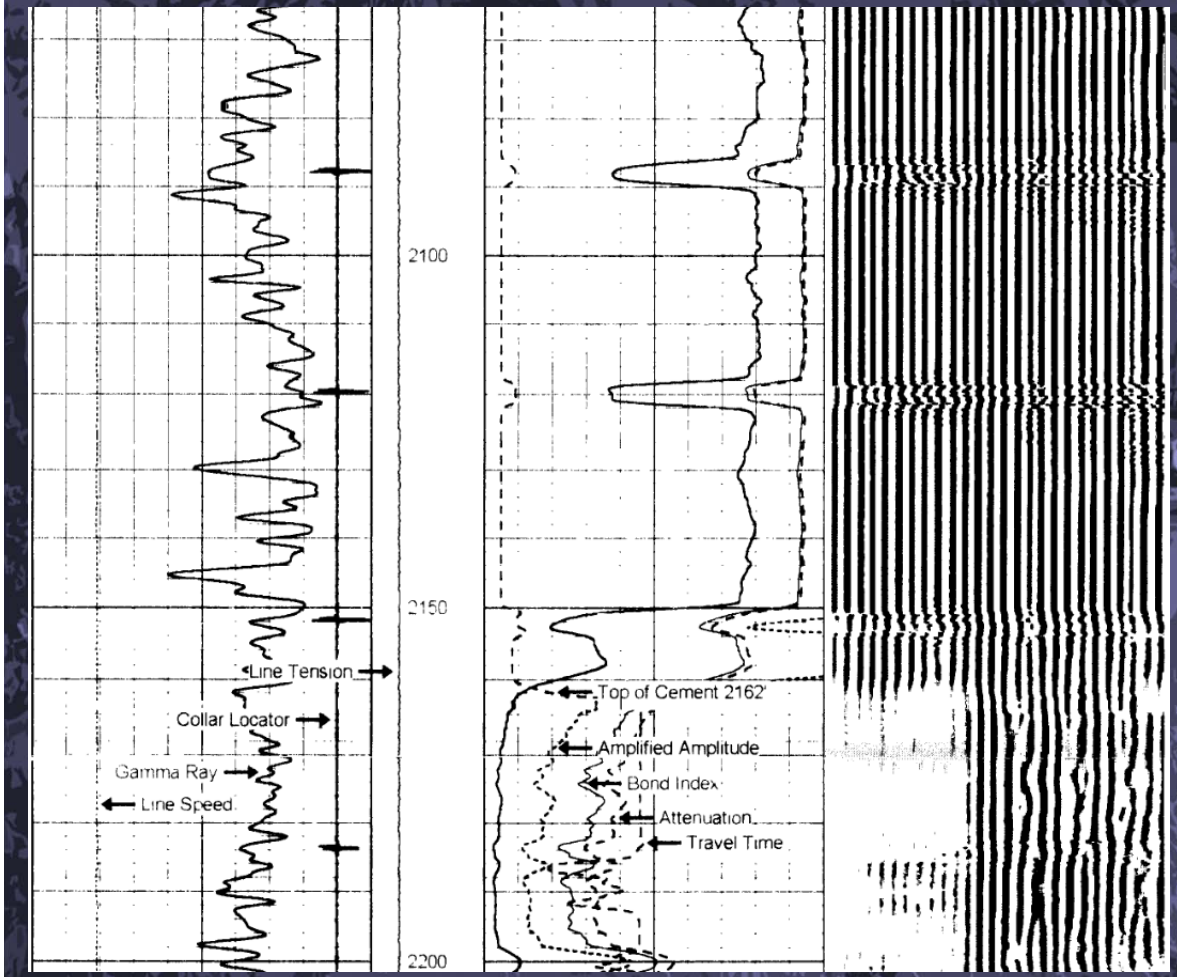
The Division of Oil and Gas maintains a well history database for each well containing data relative to the permit, operator, well location, pertinent dates and well completion. Currently, there are 136,286 wells stored online. This information is shared with the Kentucky Geological Survey (KGS) to assist in the compilation of oil and gas data.

DIVISION OF OIL & GAS

Quick Links

- Kentucky Geological Survey

Cement bond logs examine the annulus between the borehole and the casing.



- *Specialized log analysis*
- *In Kentucky, not required to become public information*

Public records are available through online services at www.uky.edu/kgs.

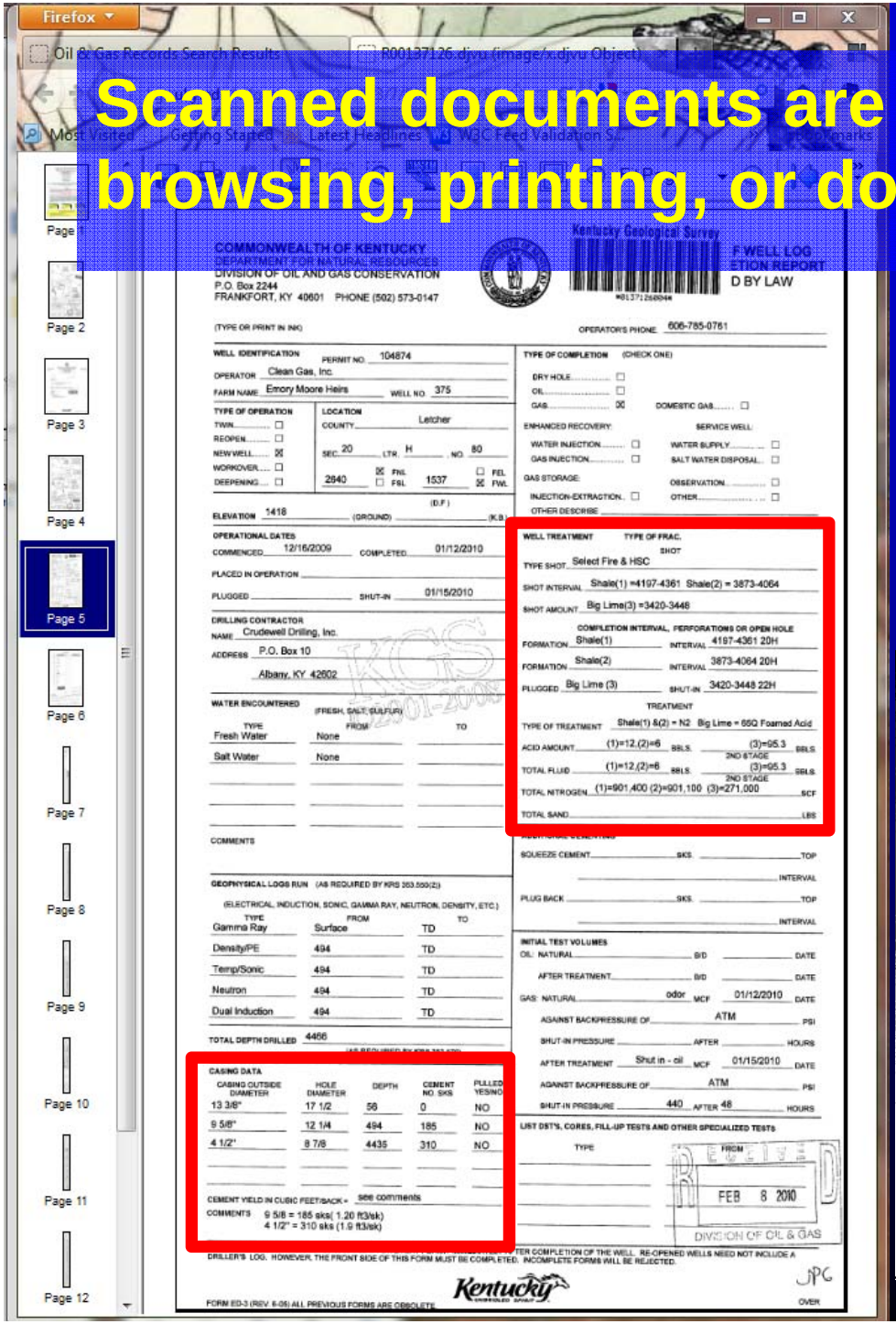
Online search

Interactive maps

Enable pop up windows!

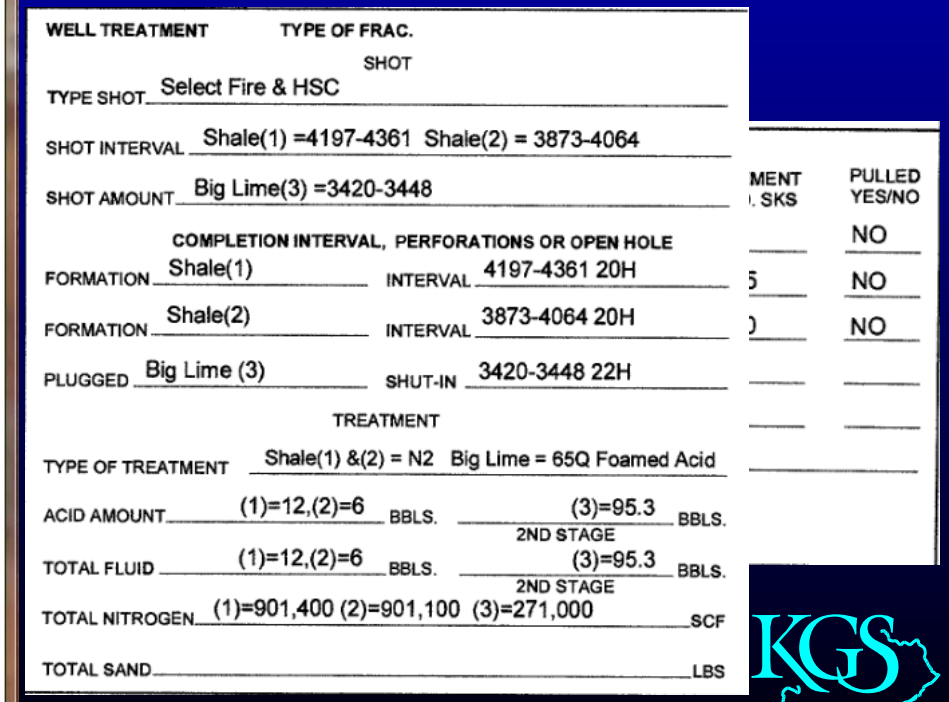
KGS home page

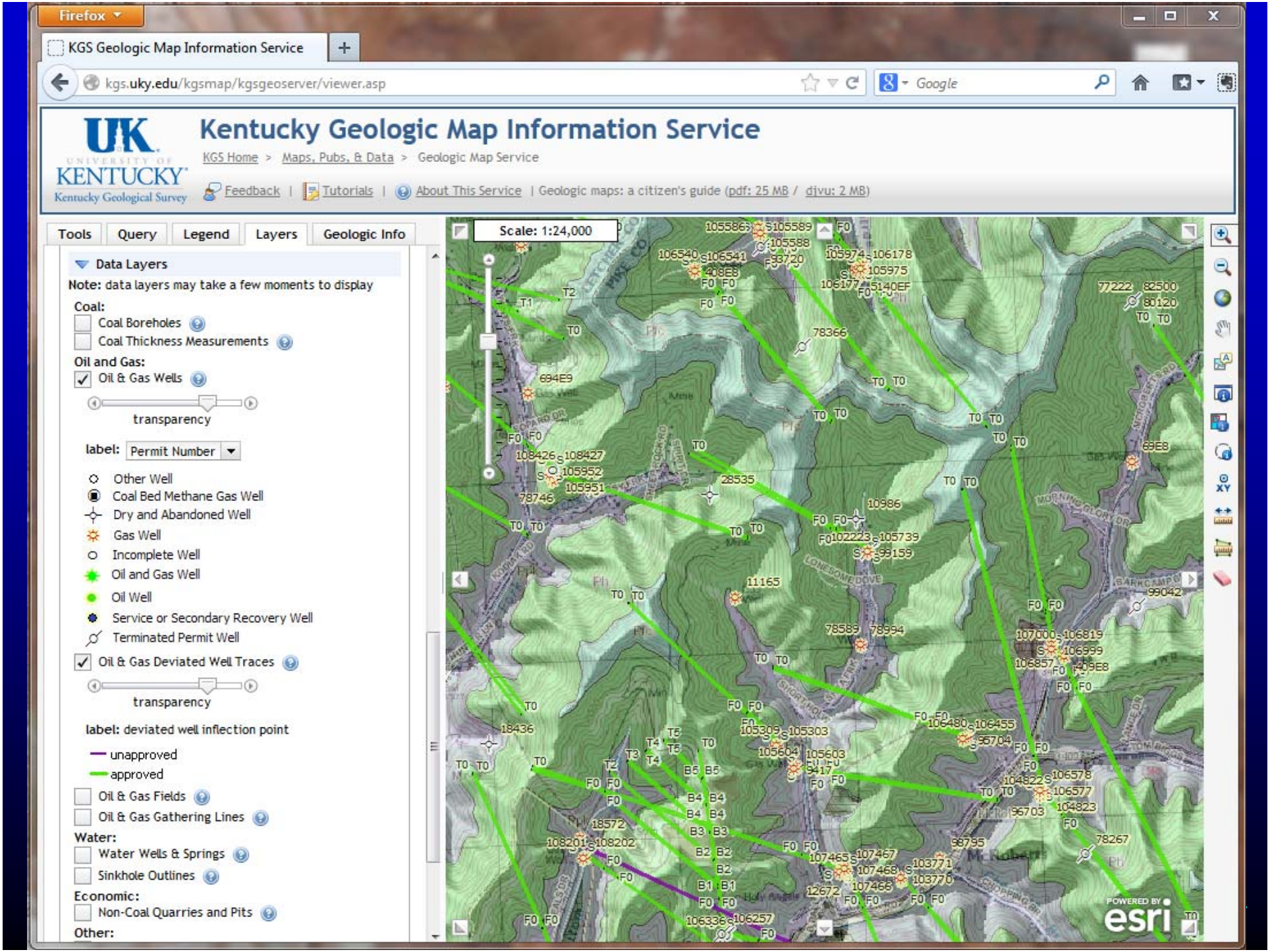
Scanned documents are available for browsing, printing, or downloading.



Public records

Completion and stimulation




Firefox
KGS Geologic Map Information Service
kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp
Google
UK
UNIVERSITY OF KENTUCKY
Kentucky Geological Survey
Kentucky Geologic Map Information Service
KGS Home > Maps, Pubs, & Data > Geologic Map Service
Feedback | Tutorials | About This Service | Geologic maps: a citizen's guide (pdf: 25 MB / djvu: 2 MB)
Tools
Query
Legend
Layers
Geologic Info
Data Layers
Note: data layers may take a few moments to display
Coal:
Coal Boreholes
Coal Thickness Measurements
Oil and Gas:
Oil & Gas Wells
transparency
label: Permit Number
Other Well
Coal Bed Methane Gas Well
Dry and Abandoned Well
Gas Well
Incomplete Well
Oil and Gas Well
Oil Well
Service or Secondary Recovery Well
Terminated Permit Well
Oil & Gas Deviated Well Traces
transparency
label: deviated well inflection point
unapproved
approved
Oil & Gas Fields
Oil & Gas Gathering Lines
Water:
Water Wells & Springs
Sinkhole Outlines
Economic:
Non-Coal Quarries and Pits
Other:
Scale: 1:24,000
POWERED BY esri

Conclusions

- Focus on well construction
  - Oil and gas wells
  - Domestic water supply
- SPCC
- Support
  - Disclosure – FracFocus.org
  - Enforcement
    - Division of Oil and Gas
    - Division of Water
- Risk of earthquakes is small
  - Injection is safe
  - Probably new BMPs for siting, monitoring, & operation

Thank you

- bnuttall@uky.edu
- (859) 323-0544
- www.uky.edu/KGS

Scan these tags with your smart phone
Get the free mobile app at http://gettag.mobi