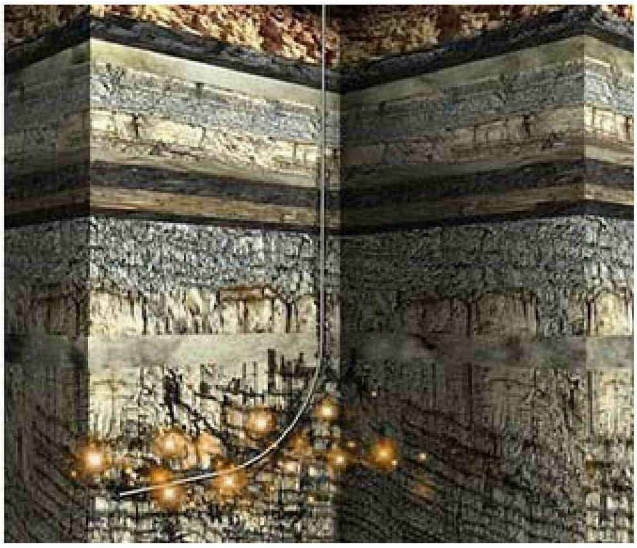
FRAC ATTACK:

RISKS, HYPE, AND FINANCIAL REALITY OF HYDRAULIC FRACTURING IN THE SHALE PLAYS



July 8, 2010

A Special Report

Jointly Presented By:

RESERVOIR RESEARCH PARTNERS

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To Our Institutional Clients and Industry Executives:

Good ideas and information are "where you find them" and we are pleased to jointly author this report with Ann Davis Vaughan and Reservoir Research Partners. After many years of speaking with Ann in her Wall Street Journal role, we are excited to be able to collaborate on this timely report on the fracturing business and the various issues currently swirling around it.

Happy Reading,

Dan Pickering and David Pursell

About Reservoir Research:

Reservoir Research Partners is an independent research firm that provides highly customized, in-depth intelligence on companies, managers and trends to institutional investors. It applies investigative-reporting tools, well-honed interview skills and sophisticated, targeted analysis to give clients exclusive insights in detailed reports. By drawing on a reservoir of contacts and research know-how, the firm answers questions and detects problems and opportunities that numbers alone can't reveal.

The firm was founded in 2010 by Ann Davis Vaughan after two decades as an award-winning investigative and financial journalist, including nearly 14 years as a senior writer at The Wall Street Journal. Under the byline "Ann Davis," she led The Journal's global energy and commodity markets coverage from Houston. Prior to 2006, she covered Wall Street and the securities industry from New York. She is a recipient of the Gerald Loeb award, one of the highest honors in business journalism, for deadline reporting on the natural-gas markets in 2007.

Reservoir Research is committed to the integrity and independence of its research and adheres to an industry-leading set of compliance best practices.

For more information, please visit Reservoir Research Partners' website at www.reservoirresearch.com, write to Ms. Vaughan at ann@reservoirresearch.com, or contact the firm at (713) 951-4059.

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Summary

Public debate about the safety of hydraulic fracturing, a gas-drilling technique that has unlocked vast new sources of domestic energy, has escalated dramatically in recent months. We set out to push through the noise, inspect claims on both sides of the gas-drilling boom, and give investors a road map to the risks that producers may face. We start with the headline.

Hydraulic fracturing - or fracing - is unlikely to be banned. Given the scientific evidence available today and the economic impact of shutting down shale gas drilling, we don't see an outright ban sticking federally, nor in New York or Pennsylvania, and certainly not in the energy patches of the Gulf Coast and the West. The job losses, higher energy prices and landowner-rights challenges that would result are too unpalatable for Democrats, even those that don't like the energy business. PA has literally bet its budget on drilling by leasing state land – a nut that's hard for a financially troubled state to make up elsewhere. The likely passage of PA's much-anticipated new production tax will make it even more reliant on drilling. This report addresses the regulatory climate in pivotal fracing regions.

The threat of new federal oversight is more serious in the wake of the BP oil-spill disaster. If you think no one will connect deepwater oil to onshore shale, think again. Both the oil spill and recent gas-drilling accidents spotlight the inherently difficult nature of the oil and gas business and have tarnished industry credibility. Groups opposed to fracing have wasted no time making connections between the two.

Fracturing is currently regulated by the states—vigorously, according to industry; inadequately and inconsistently, according to opponents. Opponents want federal oversight under the Safe Drinking Water Act (SDWA), from which fracing was exempted in 2005. BP and others had been making headway this spring preserving state jurisdiction in a Senate climate bill. But BP can no longer ask for favors, and it's a bigger risk today for politicians to champion perceived "exemptions" for drillers.

In just the past few weeks, a camp of gas producers broke ranks to negotiate a potential compromise with the staunchest critic in Congress of fracing, Rep. Diana DeGette of Colorado. A draft that surfaced mandates disclosure of fracing chemicals under the SDWA. Industry stalwarts strongly oppose this, warning EPA could stick its nose further in the tent and exert control on drilling. This rift could get ugly.

Whether or not the feds take charge, compliance and environmental costs will increase. The industry will have no choice but to spend more money to protect itself from liability and reputational risk as the shale-drilling boom marches on. Some companies are in fact already choosing to spend more; one major producer told us, "We don't see the costs as that overwhelming."

The reasons for more precautions are simple: Horizontal drilling and multi-stage fracing can be disruptive to communities, and accidents have increased as drilling ramps up. New shale production needs checks and balances to gain public acceptance. Some state regulators who publicly defend their record told us privately they need to update drilling and waste-disposal standards to fit the surge in new

activity. Some big producers told us stiffer state rules work in their favor, by weeding out bad actors whose sometimes haphazard efforts help run environmentalists' campaigns for them.

The other reason companies will take more precautions is that shale drilling is profitable even at $4 to $5 gas, where tempers are the hottest. In PA, where the economy is already transformed by the drilling boom, producers told us it is simply worth it financially to go up against a wall of opposition to drill a well. Even in some regions of NY, we believe companies with strong nerves and a willingness to control their environmental footprint will drill profitable leases--eventually. (It just won't be in the NYC watershed.)

The added tab per well, without federal regulation, could reach $200,000 to $500,000, on top of current costs per well between $2.5 million and $10 million. Bigger-ticket items include extra well casing, more rigorous cementing and water treatment. Figures vary with locale and geology. This report provides intelligence on steps producers have already taken--or may have to take later on--and how this affects shale economics.

If Congress does mandate EPA oversight of fracing, the industry predicts further costs of $125,000 to $250,000 per well. We think costs could be less than that, given changes companies are making voluntarily. Still, federal jurisdiction could dramatically slow drilling in Pennsylvania and New York, which are among the minority of states that don't already help enforce EPA underground injection rules. They would need to apply for a delegated type of authority called "primacy." It's also possible the fracing process itself will have to be reengineered somewhat—to greater expense.

An EPA study on fracing is just getting underway and could slow down the legislative train. Last year, Democrats who introduced the Fracturing Responsibility and Awareness of Chemicals Act—or FRAC Act, which calls for broader federal oversight of fracing—asked EPA to reexamine the relationship between fracing and drinking water.

We attended hearings in April on the study's design. EPA officials outlined plans for a kitchen-sink study of shale drilling's impacts across its "life cycle." Barring a major onshore accident, Democrats may wait to push federal drilling standards until scientists weigh in. (Chemical-disclosure standards could come sooner.) The agency aims to finish the study in 2012. We think it could take longer, up to 2013.

The EPA study will most likely identify risks to public health from sloppy drilling practices. We expect the agency to call for better well design and materials-handling. States are already stiffening their standards in an effort to head off federal action.

The EPA study may end up as a positive for producers, by buying time to achieve wider adoption of drilling "best practices". As one lobbyist told us, if you can't beat the enemy, try to write its rules. The bigger question is how far the industry will go. We detected a schism among companies who want to preempt federal mandates by improving practices, and smaller independents who argue that if they give an inch, regulators will make them go a mile.

While the EPA study continues, opposition to fracing and gas drilling will escalate, not die down. Attacking natural gas has become a key strategic goal of many environmental organizations. Why so, if gas has a clean-energy image? Critics' answer: it's dirtier than people realize. But there's another reason: Widescale adoption of newly abundant, cheap natural gas throws off a mass embrace of renewable energy for a generation. Even if attacking gas means a short-term win for coal and foreign energy, environmentalists' longer-term agenda is weaning the country off fossil fuels. Coal requires less environmentalist focus because it is the enemy of the past; consensus has already turned against it.

Hollywood will help fan irrational fears—and raise awareness of legitimate concerns. Gasland, a documentary we previewed this spring that won the Sundance public jury award, debuted on HBO June 21. A Penn State official who attended a screening compared it to "showing a movie of airplane crashes to show what airlines do." Some of its depictions are now out of date, but viewers won't know what has improved. The industry will attack its lack of rigor; landowners will worry.

The national conversation about fracing will continue to be loaded with disingenuous arguments–and we found both sides guilty. Environmentalists use the term "fracing" for alleged sins not directly tied to the completion technique. They are claiming there is no oversight for drilling processes which the states, in fact, do regulate. They claim there is no information about the content of frac fluids, when much of it is disclosed to regulators. Why, then, are they demonizing a 60-year-old technique, instead of sloppy waste handling? It plays better politically. Fracing was exempted from the Safe Drinking Water Act in a 2005 bill originally supported by then-Vice President Dick Cheney and his former company Halliburton.

The industry is guilty of lack of rigor too. It keeps repeating the mantra that "not a single case" has tied hydraulic fracturing to drinking water contamination. That's useful in a lawsuit, but not in the court of public opinion. Spills, well blowouts and inadequate treatment of flowback water--none of it fracing per se--have caused trouble for some communities and impacted some water supplies. States have learned from trial and error that they need to take greater care disposing of produced water from fraced wells because it has much higher salinity and other impurities than freshwater. Drilling in shale rock sometimes brings to the surface naturally occurring radioactive material that municipal water treatment plants are not designed to handle.

Over time, the conversation will shift from a hard-to-prove allegation—that fracing fluid can migrate from deep underground to contaminate shallow aquifers—to a broader, more addressable set of objections. Drilling opponents argue that fracturing fluids injected 5,000 to 12,000 feet underground can defy gravity and rock mechanics and migrate thousands of feet upward through solid rock. Petroleum engineers and geologists mostly say it's impossible, but their financial interest in the debate draws skepticism. Meanwhile, credible concerns remain about well design and waste-handling.

We set out to identify the relatively limited set of studies that each side claims puts them in the right. We also took stock of the most well-publicized incidents where landowners blamed fracing for contaminating drinking water. We don't purport to be scientists capable of snuffing out this debate, but we list some salient facts with which to evaluate them.

Investors may rightly wonder if regulators are fining companies and forcing them to plug wells, is there something fundamentally wrong with fracing? We think it's a matter of learning from mistakes.

The gold-rush-like endeavor called shale drilling will morph from trial-and-error into a more institutionalized affair. New industries are already growing up in shale territories to treat wastewater and replace some chemicals with greener ingredients. Some steps, such as recycling water, can even save money. Bigger companies will have a growing advantage, because they can better afford to prevent spills and leaks and correct them when they happen. Less-well-capitalized companies face the greatest risk from tighter regulation--a PA producer told us flatly, "You're going to have to have some really big pockets" to participate. And tighter regulation, to a greater or lesser degree, is coming.

With and Without Fracing

What does shale gas and hydraulic fracturing represent to the energy supply and the U.S. economy? Answer – a ton. We don't find it practical to consider a ban on fracing given our view that, when done properly, it does not constitute a dangerous or deadly activity. As regulators and politicians incorporate the realities and impact of fracing, we expect increased oversight and a slower and more expensive drilling and fracing process. But the work will continue!

ENERGY SUPPLY

- **SHALE GAS** extracted via horizontal drilling and hydraulic fracturing **HAS SINGLEHANDEDLY TURNED THE UNITED STATES FROM A NATION OF DECLINING GAS PRODUCTION TO ONE OF RISING PRODUCTION.** The Potential Gas Committee, an industry body, says shale gas discoveries are the primary reason we now have gas to supply the nation for the next 100 years. The Barnett Shale gas play in Texas already produces 6 percent of all natural gas produced in the Lower 48 states.[1]
- **NINETY PERCENT OF OIL AND GAS WELLS NOW REQUIRE USE OF HYDRAULIC FRACTURING**, according to the Independent Petroleum Association of America. Horizontal drilling and fracturing allow operators to produce 10 times the amount of energy by drilling fewer than 1/10th the number of wells.[2]
- The U.S. Energy Information Administration forecast in May in its Annual Energy Outlook 2010 that, **WITH FRACING OF LOW-PERMEABLE ROCK SUCH AS SHALE, GAS PRODUCTION WILL RISE to ~26 TRILLION CUBIC FEET BY 2035,**[3] **A 24% INCREASE** over the agency's 2009 production estimates of ~21 TCF.[4]
- **THE RECOVERABLE RESOURCE BASE** in the lower 48 states **WILL INCREASE WITH FRACING BY 88%,** to ~650 TCF from ~350 TCF, according to the 2010 outlook.[5]
- **WITHOUT FRACING, GAS PRODUCTION WILL FALL 17%,** to 17.4 TCF by 2035 from ~21 TCF in 2009. **PRICES WILL BE SIGNIFICANTLY HIGHER.**[6]

[1] http://www.api.org/policy/exploration/hydraulicfracturing/shale_gas.cfm
[2] http://www.energyindepth.org/2010/05/evidence-is-not-the-plural-of-anecdote/
[3] http://www.eia.doe.gov/oiaf/aeo/pdf/issues.pdf
[4] http://www.eia.doe.gov/dnav/ng/hist/n9070us2A.htm
[5] http://www.eia.doe.gov/oiaf/aeo/pdf/issues.pdf
[6] http://www.eia.doe.gov/oiaf/aeo/pdf/issues.pdf

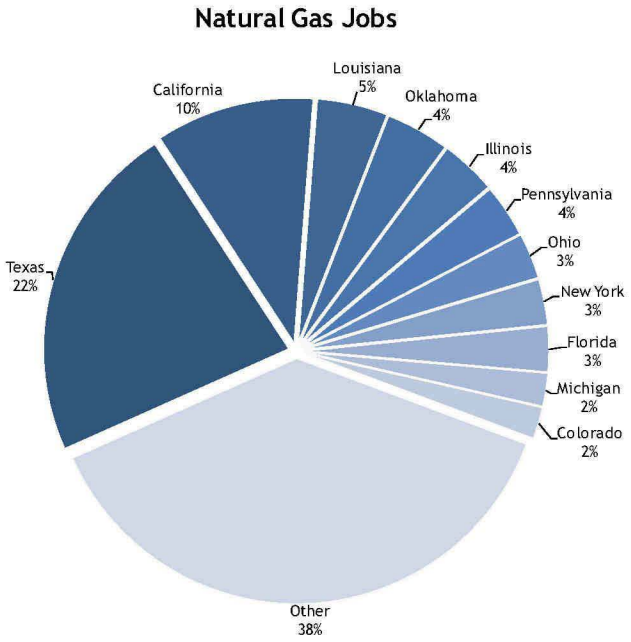
- Other estimates have found the impact to be even greater. An American Petroleum Institute (API) study performed by IHS Global Insight found that in five years, if fracturing were eliminated, the number of wells completed in the U.S. would drop by 79% and gas production would fall 57% by 2018.[7] Another 2009 report, published by the U.S. Department of Energy with Advanced Resources International, found that under a stringent scenario of future regulation, over 35% of onshore wells in the U.S. would shut down and exploration work associated with shale gas would fall by as much as 50%.[8]
- Bottom Line – If hydraulic fracturing is banned or significantly restricted, **NATURAL GAS PRODUCTION GROWTH WOULD TURN TO DECLINE AND $10+/MCF GAS PRICES** would be here to stay. LNG imports would increase and any talk of energy independence would be just that…talk!

[7] http://www.api.org/policy/exploration/hydraulicfracturing/, then scroll to: Executive summary of the national effects of federal hydraulic fracturing regulation

[8] Letter to U.S. Senators Henry A. Waxman and Edward J. Markey, Senate Committee on Energy and Commerce, from U.S. Representatives Dan Boren and Tim Murphy, Natural Gas Caucus, March 12, 2010.

U.S. ECONOMY

The natural gas industry employs over 600,000 people.[9] According to the American Petroleum Institute, it supports nearly 4 million jobs and adds more than $385 billion to the national economy.[10]



Regional impacts have been large and will grow, according to several recent studies:[11]

- Drilling for Dollars: An Assessment of the Economic Impact of the Barnett Shale (Perryman Group)
- The Economic Impacts of the Pennsylvania Marcellus Shale Natural Gas Play: An Update (Penn State University)
- The Energy Sector: Still a Giant Economic Engine for the Louisiana Economy (LMOGA/Scott)
- Economic Impact of the Haynesville Shale on the Louisiana Economy in 2008 (La. Dept. of Natural Resources)
- An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play (PSU College of Earth & Mineral Sciences, Dept. of Energy and Mineral Engineering)

(Note: Opponents have criticized some of these studies because they received industry funding.)

[9] http://www.anga.us/wp-content/uploads/anga_fs_national_r5_LowRes.pdf
[10] http://www.api.org/aboutoilgas/natgas/
[11] http://www.energyindepth.org/library/studies-jobs-revenues/

The Worries About Fracing and Why They're Surfacing Now

Snapshot of Fracing Concerns

- ***Groundwater contamination***
- ***Hassle factor: traffic and industrial activity in densely populated areas***
- ***Chemical handling: increased accidents and surface spills***
- ***Waste disposal***
- ***Air quality***
- ***Water use***

Whether fair or not, the issues above are frequently raised as the dangers or problems of fracing. We address/discuss each in some detail below. We see well design and chemical handling/waste disposal as the areas where the industry will have to work hardest, or make the most improvements, to quiet fears.

Hydraulic fracturing and advances in horizontal drilling have revolutionized industry's ability to extract natural gas from shale-rock—at a far lower price tag than imagined a few years ago. Fracturing involves pumping water, sand and chemicals under high pressure into deep rock formations as much as two miles underground to create fissures in the rock. This allows the well to release gas at commercially viable rates. (For a primer on how fracing works, please turn to the Appendix at the end of this report.)

GROUNDWATER CONTAMINATION. The headline fear is that fracing will contaminate groundwater by accidental injection of chemicals near or into aquifers. An array of geologists and engineers—some affiliated with the industry, others independent--say this is implausible because the fracturing takes place thousands of feet below the aquifer. The force of gravity and a mile-thick ceiling of rock, they argue, keeps frac fluids from traveling any more than a few hundred feet.

Opponents of fracing contend that the chemicals used in hydraulic fracturing fluid such as lubricants, thickeners and biocides, some of which stay underground after a frac job, will migrate to unwanted places years or decades later. Because fracing occurs under high pressure, opponents argue the small-scale seismic activity could create new paths.

The technique is more than 60 years old and no cases have definitively tied fracing to groundwater contamination. But there is limited peer-reviewed science on the technique, so the debate rages on. See our section entitled Quality of the Evidence, on page 28, where we summarize key studies on hydraulic fracturing and shale drilling.

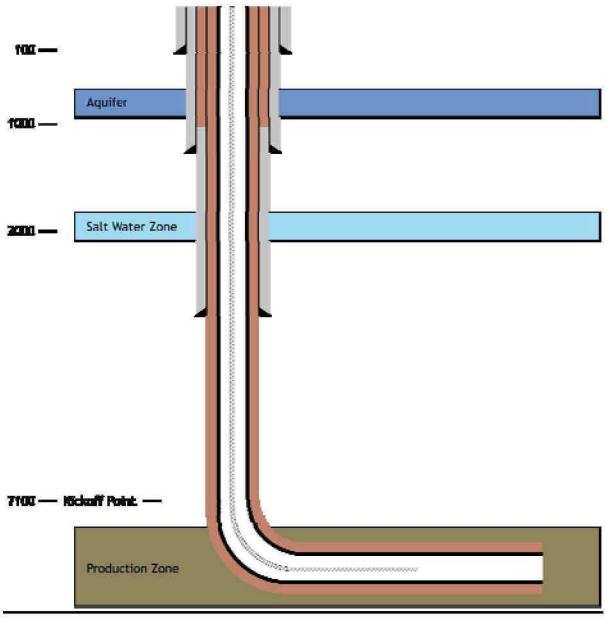
STUDIES USED TO SUPPORT HYDRAULIC FRACTURING		
Date	Author	Title
2003	Interstate Oil and Gas Commission	"States' Experience with Hydraulic Fracturing"
June 2004	U.S. EPA	"Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs"
April 2009	U.S. Department of Energy and Ground Water Protection Council	"Modern Shale Gas Development in the United States: A Primer"
May 2009	U.S. Department of Energy and Ground Water Protection Council	"State Oil and Gas Regulations Designed to Protect Water Resources"
2009	ICF International	"Analysis of Subsurface Mobility of Fracturing Fluids"
September 2009	NY State Department of Environmental Conservation	"DRAFT Supplemental Generic Environmental Impact Statement"
June 2010	MIT Energy Initiative	"The Future of Natural Gas: An Interdisciplinary MIT Study, Interim Report"
STUDIES USED TO OPPOSE HYDRAULIC FRACTURING		
Date	Author	Title
April 2005	Oil & Gas Accountability Project of EARTHWORKS	"Our Drinking Water at Risk: What EPA and the Oil and Gas Industry Don't Want Us to Know about Hydraulic Fracturing"
October 2007	Natural Resources Defense Council	"Drilling Down: Protecting Western Communities from the Health and Environmental Effects of Oil and Gas Production"
January 2009	Southern Methodist University for Environmental Defense Fund	"Emissions from Natural Gas Production in the Barnett Shale Area and Opportunities for Cost-Effective Improvements"
December 2009	NYC Department of Environmental Protection and Hazen and Sawyer	"Impact Assessment of Natural Gas Production in the New York City Water Supply Watershed"
December 2009	Harvey Consulting LLC	Review of NY State's Draft Supplemental Generic Impact Statement
January 2010	TX Commission on Environmental Quality	"Health Effects Review of Barnett Shale Formation Area Monitoring Projects"

We also provide a chart of incidents that have attracted recent publicity and tell you what investigators really found. (See "Incidents that Have Fueled the Fire," page 23.)

The rhetoric gets confusing, so we'll get straight to a point many are missing: *any* drilling has the potential to contaminate groundwater *if the well is drilled and cemented improperly*. In fact, any penetration of a fresh water aquifer (gas well, water well, coal mine, etc.) has the potential to contaminate fresh water if not properly designed.

To imagine pipe casing in a well, think of a telescope that gets narrower as it extends deeper. Drillers place a series of concentric pipes into the ground. First, a large diameter hole (maybe 16") is drilled below the water table. Casing (steel pipe) is inserted into the ground and the gap between the earth and the pipe (the "annulus") is cemented. The drilling continues with a smaller drill bit (smaller hole) and another string of casing is run and the annulus is cemented. This is repeated until the well reaches the desired depth. In many cases four or more separate casing strings are run.

Occasionally, a cement job has an incomplete bond with the walls of the well, and that can be big trouble, because contaminants can then leak into water supplies. *But this has no direct connection to hydraulic fracturing*, which occurs a full mile or so below that aquifer in the horizontal part of the well.



SOURCE: U.S. Department of Energy and Ground Water Protection Council, "Modern Shale Gas Development in the United States: A Primer," April 2009

We see well design as a significant practical concern for the industry, even more so after the Macondo offshore oil spill where well design has proven to be a big factor. One of the greatest risks of contamination by frac fluids comes from their potential to migrate upward within the well casing during the fracturing process. The most effective means of preventing that contact is proper cementation.

All this, many companies argue, is not new. They've been designing wells and have been fracing for decades.

So the next question is why this common technology is attracting so much opposition today. There are several reasons—and they don't all have to do with politics.

REASON #1: Today's frac jobs are not the frac jobs of old. While producers have long pumped fluids into bore holes to extract trapped hydrocarbons, the wells were vertical and often far shallower. Companies pumped smaller frac jobs which used much less water and required much less equipment per well. Today's shale wells are deeper, and producers are injecting fluids at much higher pressure and volumes into impermeable rock. More of the fluid stays underground. To break open the Haynesville Shale of Louisiana, producers drill down more than two miles--11,000 to 13,000 feet—grinding through layer upon layer of solid rock. The scale of everything—pump trucks and other needed equipment, the miles of pipes, the water requirements, and certainly the energy harvested—dwarfs your grandfather's frac jobs.

*Comparison of "Old" and "New" Frac Jobs**		
	Cotton Valley circa 1985	*Haynesville Shale circa 2010*
Type	*Vertical*	*Horizontal*
Depth	*10,000*	*11,000*
Frac stages	*1*	*10+*
Sand	*2 mm lbs*	*4 mm lbs*
Water used	*0.8mm gals*	*4mm gals*

We compared the Cotton Valley and the Haynesville Shale because they are plays in the same areas of East Texas and North Louisiana.

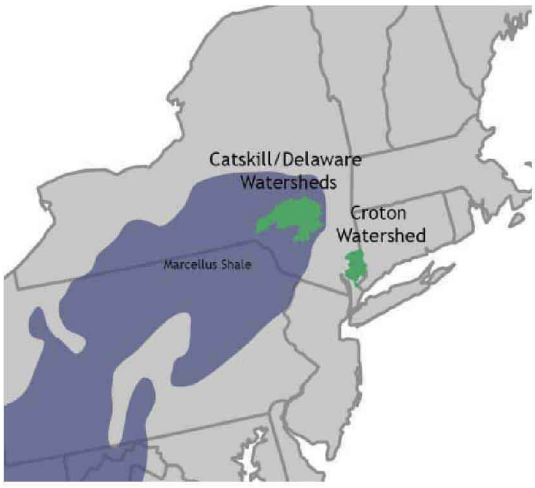
REASON #2: The absolute number of accidents has increased with more drilling, even if the rate of accidents has not. Regulators told us this repeatedly—and the more accidents happen, the worse the industry looks, so the regulators crack down. Record horizontal gas-directed drilling is evidence that gas shale drilling is occurring at a fevered pitch. While even one accident is too many, spills, illegal disposals, well blowouts/fires and other incidents have happened in the past and they will in the future.

REASON #3: Today's big shale discoveries often lie in densely populated areas unaccustomed to oil and gas neighbors. Even in gas friendly towns like Fort Worth, TX and Shreveport, LA, rigs feel different next to churches and schools. More people see it, smell it, hear it, and wonder about it than when the rig was in a flat field in relatively unpopulated East Texas. Most people in Pennsylvania and New York have never depended on oil and gas for a living; what they depend on is cattle and dairy farming, timber, manufacturing, tourism…Wall Street. Whether they are profiting from a lease or not, or need the money or not, a rural or suburban town where drilling ramps up feels industrial pretty fast.

U.S. Map of Southeast and Northeast Shale Territories and proximity to Urban Areas.

SOURCE: TPH

REASON #4: Because of the populations at stake, the protection of the water supply is front and center. The geographically largest shale territory, the Marcellus, covers a wide swath of Appalachia from northeastern Tennessee to upstate New York. Parts of it lie directly under the Catskill/Delaware watersheds which supply water to 17 million people, including 90% of New York City residents.



Source: New York City Department of Environmental Protection

In short, as with any resource extraction, there are real risks and valid objections that must be managed. Opponents get more traction by attacking underground fracturing, but the everyday risks of shale drilling center more on surface disturbance.

THE HASSLE FACTOR. Shale drilling today is a 24-7 operation, on and off, for a year or more. Crews often operate all day and all night. This is why goodwill and small gestures will matter.

SOURCE: See footnote.[12]

SOURCE: see footnote.[13]

[12] http://travel.webshots.com/photo/1271002101034885681rlwrXO

[13] http://www.aussiestockforums.com/forums/showthread.php?p=521758. (Activity photographed is in Texas.)

Long-bodied trucks that haul fracturing fluid, water, waste and multi-ton loads of equipment share the road with school buses and commuters. In the mountainous terrain of Pennsylvania, drivers get stuck for long periods behind stacked-up frac trucks because the thoroughfares are two-lane mountain roads. Some water and wastewater systems that companies tap into are more than 100 years old.

Equipment trucks take a heavy toll on local roads. A New York City Department of Environmental Protection report found that hauling of water, wastewater, and equipment to and from the drill site requires on the order of 1,000 or more truck trips per well.[14] Many municipalities we visited have begun sending bills to drillers for crumbled roads.

Although horizontal drilling allows companies to disturb less surface area than vertical-only drilling, the footprint of a drill pad, from which 4 to 8 horizontal wells can radiate, is significant. When it is time to frac the well, the equipment assembled on a single site resembles a massive industrial parking lot.

SOURCE: http://www.marcellus-shale.us/

Source: EXCO Resources

The nuisance factor is an acceptable tradeoff to many landowners who benefit financially and cheer the use of cleaner-burning, domestic energy. (It might go over less well in Europe, where shale plays are just getting started and many people don't own mineral rights on their land.) But shale drilling poses other, more serious risks that need to be carefully managed.

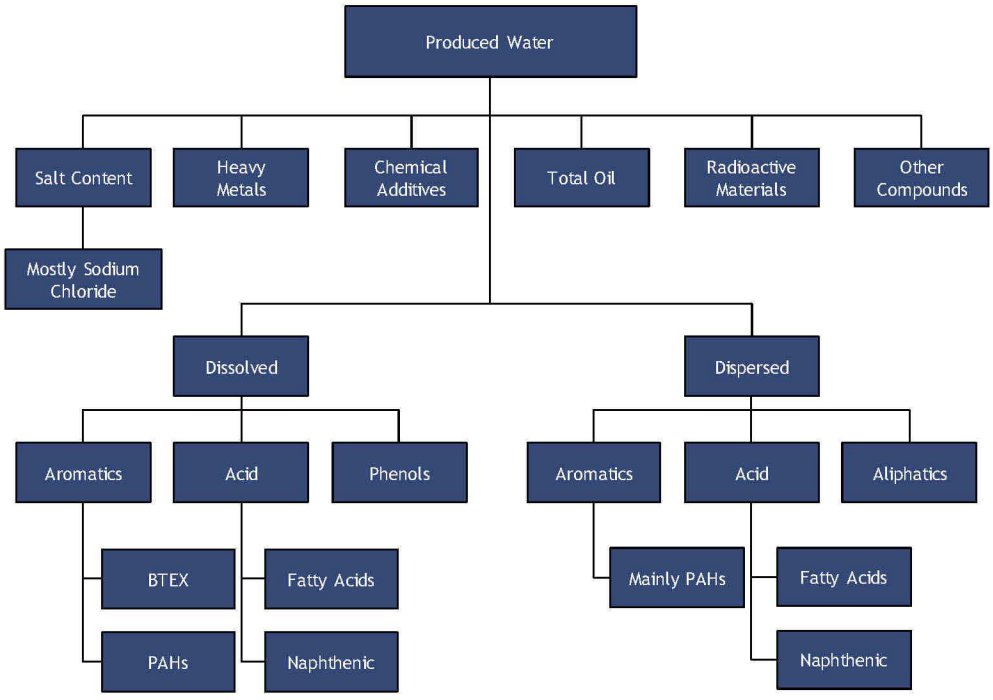
CHEMICAL HANDLING AND WASTE DISPOSAL. We believe waste disposal and safe materials-handling poses among the biggest challenges to gas producers. Simply put, fracing chemicals and drilling waste are more hazardous above ground than several miles underground.

Bill Kappel, a U.S. Geological Survey official, argued this spring that contamination of water supplies is more likely to happen as companies process the waste water from fracing. In some instances, municipal water systems that treat the water have reported higher levels of heavy metals and radioactivity.[15] Here is a breakdown of the issues.

[14] http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/12_23_2009_final_assessment_report.pdf, page ES-1.
[15] Ian Talley, Dow Jones Newswires, "EPA Launches Hydraulic-Fracturing Study on Water Supplies," March 18, 2010.

Flowback water and aquatic habitat. Shale rock was once part of an ancient seabed. The briny fracturing fluid that flows back out of a shale well with natural gas – known as "flowback," or "produced water"— can be five times saltier than ocean water. In Texas and Louisiana, it is common to dispose of produced water by injecting it into deep underground disposal wells which are regulated by the EPA. In Pennsylvania, which has few of these injection sites, produced water is more commonly collected in tanks or retention ponds, treated (if allowed) via municipal water treatment facilities and released into lakes, rivers and streams. Proper treatment is critical: disposal of water with high salt concentrations into rivers and other bodies of water can threaten aquatic life.

Flowback water and hard-to-remove compounds. Shale rock releases naturally occurring radioactive material (NORM) into the produced water. Benzene and other hazardous substances may be present. The concentrations of NORM in the Marcellus Shale has presented challenges for municipal wastewater treatment in Pennsylvania because they are often not equipped to effectively remove it or the salts and minerals. As a result, the risk of surface pollution increases.



http://www.gwpc.org/meetings/forum/2009/proceedings/Li_Liang.pdf

Chemical spills. Producers use lined, open-air pits called impoundments near many well sites to store fresh water, produced water, and sometimes drilling muds used when drilling the wells. The liners can tear and the pits can collect storm water and overflow. Trucks hauling fracturing chemicals and produced water sometimes overturn. Tanks or pipes may leak. Some producers still use diesel, which contains known carcinogens, in drilling muds or frac fluid. "We don't have a problem with hydraulic fracturing—we don't see it as a problem," a Pennsylvania regulator told us. 'We do see a problem with spills."

Gas drilling pit uphill from homes in Pennsylvania.

SOURCE: http://www.marcellus-shale.us/impoundments.htm

Volume of waste. The volume of waste being created today is growing with the marked increase in drilling.

Chesapeake Energy met with controversy this year when it applied to dispose of water from Pennsylvania in a converted gas well near Syracuse, N.Y.; concerns flared about the old well's proximity to the Finger Lakes. Residents likened the disposal plan to "Love Canal," the iconic chemical-waste dumping grounds in Niagara Falls, N.Y. that helped spawn the Superfund Act and where a population had to be evacuated.[16] Chesapeake calls the comparison "completely inaccurate and irresponsible" because it was merely applying for a disposal well that would have been strictly regulated by the EPA.

Marcellus disposal challenges have led many Pennsylvania producers to recycle 100% of their produced water for new fracing jobs. Those who recycle now call it a competitive advantage. But that option works best for companies with contiguous drilling sites, because it can be costly to move fluids between locations and the trucking of fluid can lead to spills.

[16] http://en.wikipedia.org/wiki/Love_Canal

AIR QUALITY. This is a valid worry, but correctable with better safeguards.

Concerns have surfaced recently about airborne emissions of hazardous chemicals from tanks at well sites, open-air pits and gas compression and processing stations. In regions where the gas is "wet," it naturally contains other hydrocarbons that can form liquids at surface conditions (ethane, propane). Some hydrocarbons and produced water itself contain benzene, a known carcinogen. The Texas Department of Environmental Quality recently released air-monitoring results around the Barnett Shale in Fort Worth and found elevated levels of benzene and other chemicals, and it has said some subsequent tests near that region have warranted further review.[17] Producers and regulators in Louisiana and Pennsylvania told us they expect fewer issues with benzene emissions because they have drier gas than the Barnett shale.

Recent tests suggest that once hazardous emissions are detected, companies install equipment to control them. (Tip: Go long companies that sell vapor recovery units in Fort Worth.) Even a widely discussed 2009 paper on air quality in the Barnett Shale by Dr. Al Armendariz, then an engineering professor at Southern Methodist University and now Region 6 Administrator of the EPA, argues: "Cost effective control strategies are readily available that can substantially reduce emissions."[18]

WATER USE. No small issue, but water management is rapidly improving.

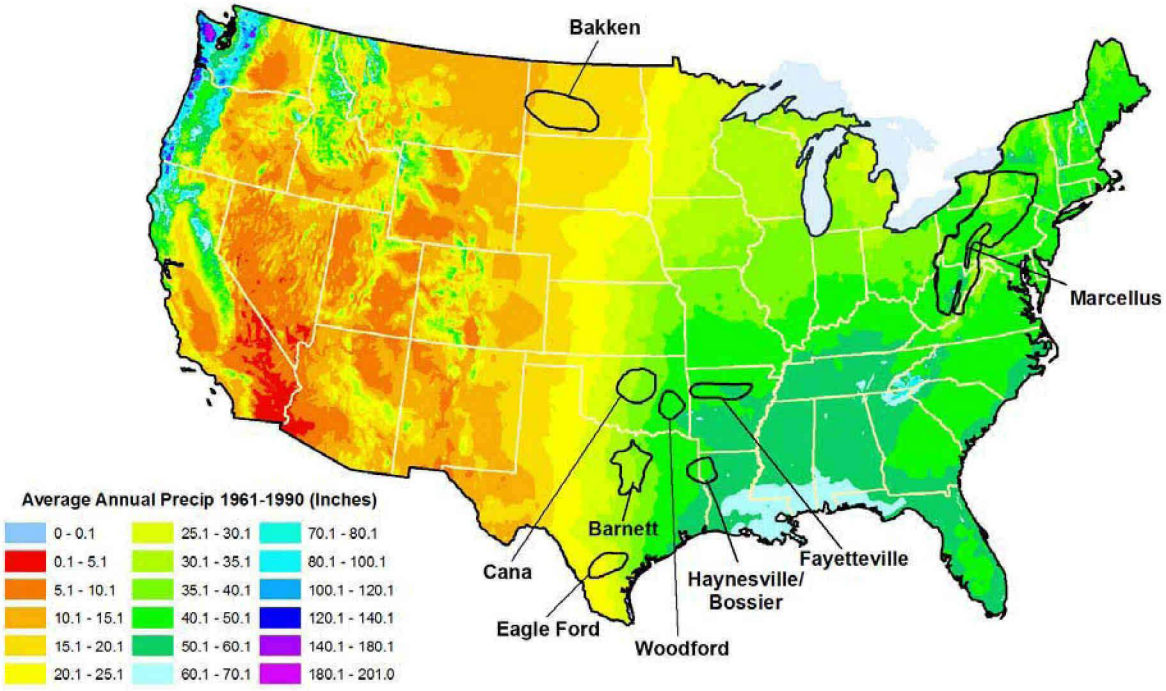
Water is critical to shale gas extraction. A typical well in one of the Big Four shales uses 4 to 6 million gallons of water for the drilling and fracturing process, according to Chesapeake Energy. We agree with this statistic.

Producers are constantly looking for new sources of water to frac a well. Some companies have drawn fire for depleting water from small streams. Much of the water used to frac shale wells stays underground and isn't recovered and returned clean to its source.

Despite this, we don't consider water use one of the industry's top liabilities for several reasons. First, the state and regional water authorities we interviewed told us they have learned on the job and made permitting conditions stricter to prevent unnecessary depletions. Necessity then becomes the mother of good ideas: EXCO Resources has struck a deal with International Paper to recycle water from a mill in Louisiana's Haynesville shale region. EXCO reduces water withdrawals, and, in so doing, gets wastewater low in oxygen. This, in turn, sharply reduces its need to use controversial biocides in frac fluid to control bacteria.

[17] For ongoing information, check: http://www.tceq.state.tx.us/implementation/barnettshale/fw_sampling
[18] Al Armendariz, Ph.D., "Emissions from Natural Gas Production in the Barnett Shale Area and Opportunities for Cost-Effective Improvements," January 26, 2009, http://www.edf.org/documents/9235_Barnett_Shale_Report.pdf

In addition, most shale basins lie in areas with moderate to high levels of annual precipitation—nature is replenishing the water supply.



SOURCE: U.S. Department of Energy and Ground Water Protection Council, "Modern Shale Gas Development in the United States: A Primer," April 2009

Lastly, while water withdrawals must still be judged based on local limitations, the water footprint of fracing isn't as large on a relative basis as other fuels per unit of energy produced.

Energy Resource	Range of Gallons of Water Used per MMBTU of Energy Produced
Shale Natural Gas*	0.60-1.80
Natural Gas	1-3
Coal (no slurry transport)	2-8
(with slurry transport)	13-32
Nuclear (processed uranium ready to use in plant)	8-14
Conventional Oil	8-20
Synfuel-Coal Gasification	11-26
Oil Shale Petroleum	22-56
Tar Sands Petroleum	27-68
Synfuel-Fisher Tropsch (Coal)	41-60
Enhanced Oil Recovery (EOR)	21-2,500
Fuel Ethanol (from irrigated corn)	2,510-29,100
Biodiesel (from irrigated soy)	14,000-75,000

Source: Chesapeake Energy 2009 presentation to the Ground Water Protection Council, citing Chesapeake well estimates for shale gas and a U.S. Department of Energy water use report (footnoted below).

Chesapeake says that the water it uses to frac an average shale well is the same amount consumed by a coal-fired power plant in 12 hours. It is what New York City consumes in seven minutes. Even recreation compares unfavorably: a golf course drinks the same amount in 25 days – and then drinks that same amount every month, year after year. [19]

[19] Chesapeake gave us its sources on these facts. Coal plant water consumption: "Energy Demands on Water Resources," U.S. Department of Energy, December 2006, http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf. NYC water consumption: New York City Department of Environmental Protection. Golf course consumption: Colorado State University Agricultural and Resource Policy Report, April 2004.

The Companies With The Most To Gain Or Lose

The following tables show the companies that are most leveraged to shale plays, and therefore the most exposed to regulatory issues highlighted in this report.

Companies exposed to Barnett

	Total NAV	Barnett	Barnett % of NAV
CRZO	$31	$14	46%
KWK	$21	$8	39%
CHK	$43	$4	10%
EOG	$140	$4	3%
DVN	$93	$5	5%
RRC	$65	$1	2%

NAV current as of 6/30/2010

Companies exposed to Eagle Ford

	Total NAV	Eagle Ford	Eagle Ford % of NAV
ROSE	$24	$12	50%
HK	$47	$20	43%
GDP	*$27*	*$8*	*29%*
EOG	$140	$31	22%
PXD	$81	$17	21%
NFX	$72	$6	8%

***GDP has value in Eagle Ford* only if we include 4P value**

NAV current as of 6/30/2010

Companies exposed to Haynesville

	Total NAV	Haynesville	Haynesville % of NAV
GMXR	$20	$15	74%
GDP	*$27*	*$20*	*73%*
XCO	$26	$14	55%
HK	$47	$23	49%
PXP	$46	$11	24%
CHK	$43	$7	17%
QEP	$53	$7	13%
EOG	$140	$10	7%
DVN	$93	$2	3%
SWN	$55	$1	1%
APC	$75	$1	1%

GDP has more potential exposure if we include 4P value

NAV current as of 6/30/2010

Companies exposed to Marcellus

	Total NAV	Marcellus	Marcellus % of NAV
RRC	$65	$38	59%
REXX	$15	$8	50%
COG	$61	$24	40%
CHK	$43	$13	31%
XCO	$26	$6	23%
CRZO	$31	$6	20%
SGY	$21	$3	15%
APC	$75	$11	14%
UPL	$66	$9	14%
SWN	$55	$2	4%
EOG	$140	$4	3%

NAV current as of 6/30/2010

Companies exposed to Fayetteville

	Total NAV	Fayetteville	Fayetteville % of NAV
SWN	$55	$43	77%
HK	$47	$3	6%
CHK	$43	$1	2%

NAV current as of 6/30/2010

We drilled down by region, because the risks are different in each of the shales. We see costs for a host of items rising in Pennsylvania and New York because new proposals and regulatory reviews are already on the table. The flip side is that it is cheaper to drill there--at least in PA—because wells aren't as deep as in the Haynesville and it is closer to high-priced markets.

In Louisiana, Arkansas and Texas, the friendlier regulatory climate means more of the new costs could be optional.

If fracing withstands the scrutiny and gas drilling continues at today's strong pace, how do the added costs change returns? See "What's The Tab?" section on page 53.

Incidents that Have Fueled the Fire

There are many allegations out there about fracing–some with little supporting evidence. But industry rebuttals can also downplay problems. So we took some of the most well-publicized incidents that have hurt the industry's reputation and categorized them for this report. **This list is not meant to be exhaustive and contains primarily recent incidents.**[20]

The cases where methane (natural gas) appears to have infiltrated drinking water aren't tied to underground fracing, regulatory investigations have found. Instead, gas much closer to the surface seeped into water supplies because of faulty well-casing and cement jobs. This distinction has allowed industry to claim there are "no confirmed incidents" that tie deep-underground fracing to aquifer contamination. But **mistakes in well design**—an age-old topic in the oil and gas industry--**are problems that shale drillers can't afford to keep repeating --for both safety and image reasons.** Worth repeating – anytime an aquifer is penetrated (gas well, water well, coal mine), the potential exists to contaminate drinking water if not done properly.

Several incidents involve handling of drilling chemicals and waste. These illustrate why the anti-frac corner is able to keep blaming activities associated with fracing.

In company interviews, we heard lots of frustration from industry executives about "bad actors" who were sloppy, or even worse, unapologetic. The savvier players cited two cardinal rules on accidents: 1) Never, ever, EVER make a regulator look bad. If you mess up, fess up and let the state agency look proactive. 2) Don't dismiss public concerns just because you're worried about liabilities. Going above and beyond to make amends—quickly--makes a huge difference--even if you don't accept blame.

Lawyers may disagree…but see our section called The Conversation About Fracing--and Who's Controlling It, Page 38. One company had several spills within a tight time period and regulators alleged it allowed gas to migrate into well water in one Pennsylvania township. The state repeatedly accused the company of failing to make fixes promptly. The company says it met applicable standards and points out that the gas that migrated into wells came from shallow deposits, not Marcellus Shale. But the presence of pre-existing gas is hard to prove without pre-drill water sampling (which is a now routinely being performed). Meanwhile, environmentalists have seized on the situation to attack the overall fracturing and well drilling process. By contrast, when EXCO Resources had to evacuate over 100 Louisiana households in April over another gas leak, it moved rapidly to stop the leak, plugged its wells, and paid hotel costs without prodding. Regulators told us EXCO earned their goodwill even as mistakes came to light.

[20] For discussion of other incidents, see a report prepared for the EPA by The Cadmus Group, "Hydraulic Fracturing: Preliminary Analysis of Recently Reported Contamination," September 2009. Report doesn't appear to be posted online but author's website is: http://www.cadmusgroup.com/home.

Incidents that Have Fueled the Fire					
Where	When	Incident and Company Involved	Assessment of Incident	Is Underground Hydraulic Fracturing a Direct Cause?	Are Other Drilling Practices at Issue?
Well Integrity					
Dimock Township, north central PA	2009/2010	**CABOT OIL & GAS.** Issues began with a water well explosion. Gas escaped into aquifer and built up until pressure caused explosion. Residents and national environmental groups alleged Cabot drilling contaminated this and other wells and complained of foul smells and flammable water. Cabot said deep-underground fracing couldn't have been the cause and on this point PA regulators agree: they told us it was "not Marcellus gas." Cabot provided water to residents involved and litigation is ongoing. Attracted intense national media coverage and attention from environmentalists.	PA regulators blamed Cabot's well design and cement job for allowing naturally-occurring shallow gas to migrate into water supplies of 14 homes; it pointed out last year that despite finding well problems, "hydro fracturing activity has not impacted local wells." It forced Cabot to plug three wells in April, fined the company, barred it from drilling new wells in Dimock for a year, and criticized its slow response. Cabot acknowledges it didn't test water wells for pre-existing gas (common in this region). It says it believes its operations didn't cause the gas migration, and subsequent tests show that a majority of area wells contain measurable quantities of naturally occurring gas.	NO	YES
Caddo Parish, near Shreveport, LA	2010	**EXCO RESOURCES.** EXCO Resources contacted authorities and over 100 homes were temporarily evacuated at company expense in April when the company struck a layer of gas thousands of feet above the Haynesville shale and it escaped into the air and bubbled up through the ground. EXCO had not yet done any fracing of the well.	LA regulators worked with company to investigate cause of gas migration; officials told us they believe a cement job from an adjacent well is at fault. EXCO has agreed to plug 2 wells and says it is continuing to test the water; it says it will incorporate lessons learned into new well designs.	NO	YES
Bainbridge Township, Geauga County, OH	2007	**OHIO VALLEY ENERGY SYSTEMS CORP.** Natural gas seeped into an aquifer and led to an explosion in the basement of a home. The discovery of gas in water supplies drew allegations that fracing by Ohio Valley Energy Systems Corp. had pushed gas to the surface. Residents weren't injured and the company worked with regulators to evacuate and house the displaced residents, and stop gas flow.	OH regulators concluded in a lengthy report that the cause was a defective cement job in the well casing, compounded by operator error. The investigation found no evidence of hazardous drilling chemicals in the wells and said the problem would have occurred even if the well had never been hydraulically fractured.	NO	YES
Clearfield County, PA	2010	**EOG RESOURCES.** A June 3 blowout of a gas well sent gas and at least 35,000 gallons of drilling wastewater into the sky and over the ground for 16 hours. This incident occurred during the post-frac flowback period. The incident occurred in a rural, relatively unpopulated area.	PA regulators temporarily suspended EOG's drilling and fracing activities statewide until it investigated the cause and have allowed drilling to resume. EOG said its preliminary assessment was that the seal integrity between the pipe rams of a blow-out preventer and tubing was compromised.	YES--CONTROL OF FLOWBACK WASTE	YES

Incidents that Have Fueled the Fire					
Where	When	Incident and Company Involved	Assessment of Incident	Is Underground Hydraulic Fracturing a Direct Cause?	Are Other Drilling Practices at Issue?
Well Integrity					
Garfield County, CO	2001 and 2004	**ENCANA.** A resident, Laura Amos, alleged her water well was contaminated by frac fluids from wells near her house and that the fluids caused an adrenal tumor. Her case has been extensively publicized and she has appeared in a number of environmental groups' reports. fracing operations near her home occurred 2,000 feet underground and her well is 225 feet deep. (This depth is considerably shallower than shale wells in PA, LA, TX and AK.)	CO regulators tested her water repeatedly and did not find contaminants associated with frac fluids, including benzene. Encana denied fracing contaminated her water, but Colorado regulators found it in violation of state rules preventing freshwater contamination by gas. Amos has settled with Encana. A study has found correlation of oil and gas drilling with the country's water characteristics.	NO	UNCLEAR
Pavillion, WY	Past 10 years	**ENCANA.** EPA tested wells in an area where residents have complained over a decade about effects of gas drilling on their water. In 2009, EPA said it had found chemicals that environmental groups allege are used in the hydraulic fracturing process. EPA says the chemicals "might not be attributable to well components" and also noted agricultural activity nearby.	EPA cautions it doesn't yet know if there is an oil and gas link and that it will release further study results in August 2010. Encana told us the chemicals at issue are not used in fracing and it needs to see additional results before commenting further.	ALLEGED, NOT PROVEN	UNCLEAR
Surface Handling					
Caddo Parish, near Shreveport, LA	2009	**CHESAPEAKE ENERGY.** Seventeen cattle were found dead near a Chesapeake Energy drilling site. Chesapeake said Schlumberger was the service company on the job. Both companies denied wrongdoing. The incident attracted extensive coverage; one company not involved told us that when it happened, "nobody wanted to talk about anything else" when it called on state and local officials. Witnesses reported hearing cows bellow before they fell over dead.	LA regulators concluded fluid leaked from a well pad and ran into an adjacent pasture. It fined each company $22,000. Chesapeake says after testing that the cause of death to cattle was inconclusive. Chesapeake and Schlumberger say they have taken a leading role in "enhancing the standard" for well site construction and liquids handling.	NO, BUT HANDLING OF FLUID ABOVE GROUND AT ISSUE	YES
Dunkard Creek, southwest PA	2009	**COMPANY LINK UNCLEAR.** A fish kill along a 43-mile span of the creek due to an invasive saltwater species of golden algae was tied by a number of organizations to hydraulic fracturing. The algae thrives in salty water, and discharge of shale well "flowback water" was suspected because it has high salt content. A gas drilling organization argued drilling activity hadn't taken place near the relevant portion of the stream. The fish kill continues to be a heated topic among fly-fishing and outdoor enthusiasts.	An interim EPA report blaming golden algae for the kill cited coal mine discharges of briny water as potential contributing causes but said the algae can also be spread by migratory birds, fishermen and industrial equipment. PA regulators say they still haven't ruled out fracing fluid as a potential contributor but mine drainage, agriculture runoff and other industrial discharges are also a potential cause.	NO, BUT HANDLING OF FLOWBACK WATER FROM FRACTURING AT ISSUE	UNCLEAR

Incidents that Have Fueled the Fire					
Where	When	Incident and Company Involved	Assessment of Incident	Is Underground Hydraulic Fracturing a Direct Cause?	Are Other Drilling Practices at Issue?
Surface Handling					
Lower Monongahala River, southwest PA	2008	**COMPANY LINK UNCLEAR.** The U.S. Army Corps of Engineers sounded alarms when the salt level (or "total dissolved solids" level) spiked "dramatically" on the river in October 2008, according to a letter from the Corps to EPA. Although low rain, acid mine drainage and industrial discharge can also increase salinity of water, it cited "increased gas drilling in the Marcellus Shale" as an aggravating factor. Earlier this year it urged PA to stiffen water treatment standards, saying "conditions are reversing on Pennsylvania's rivers" and it was becoming apparent that the ability of some rivers to receive more salt content was near its limits "and simply cannot sustain" additional levels as a result of gas drilling.	PA environmental regulators cited the Corps' river results and the Dunkard Creek fish kill in April to call for more stringent rules on treatment of discharge water. The new, tougher standards are incentivizing more companies to recycle flowback water rather than treat and dispose of it in PA rivers and streams.	NO, BUT HANDLING OF FLOWBACK WATER FROM FRACTURING AT ISSUE	YES
Hopewell Township, southwest PA	2009	**RANGE RESOURCES.** A spill of diluted frac fluid from a Range Resources drilling operation into a small tributary killed small fish, salamanders and frogs. A relatively small amount of fish were affected, the company said.	PA regulators fined Range $141,175 in May 2010 for the spill. The cause was a broken joint in a transmission line transporting the fluid.	NO, BUT HANDLING OF FLUID ABOVE GROUND AT ISSUE	YES
Dimock, PA, north central PA	2009	**CABOT OIL & GAS.** Cabot Oil & Gas had three spills of fracing water and gel totaling 8,000 gallons within a week. The spills entered a creek and nearby wetland, according to regulatory documents.	PA regulators fined Cabot $56,650 and urged the company to "do a better job in the future of overseeing its contractors . " Cabot said the spills were 99.5% water and the material was not hazardous. It said its policy is zero spills.	NO, BUT HANDLING OF FLUID ABOVE GROUND AT ISSUE	NO

Incidents that Have Fueled the Fire					
Where	When	Incident and Company Involved	Assessment of Incident	Is Underground Hydraulic Fracturing a Direct Cause?	Are Other Drilling Practices at Issue?
Water Use					
North central PA	2008 through 2010	**VARIOUS.** Several companies withdrew water from PA rivers and streams without permits from a regional water authority, according to the Susquehanna River Basin Commission.	The SRBC notified gas operators in mid-2008 that they must have approval from the commission to withdraw water to develop shale gas wells and has continued to issue orders to companies to stop water-related work at drilling sites when it discovers withdrawals without permits. The SRBC has streamlined procedures for obtaining water permits and said last year that the gas industry as a whole has operated in compliance with water regulations.	NO	NO, BUT CASES HIGHLIGHT STILL EVOLVING WATER-USE REGULATIONS HERE AND IN OTHER STATES
Air Quality					
DISH, TX near Forth Worth	2009	**VARIOUS COMPRESSOR STATIONS.** DISH, TX is home to several gas compressor stations that connect to pipelines; Mayor Calvin Tillman asserts that residents have been exposed to toxic air emissions from Barnett shale gas activities. EARTHWORKS, a high-profile environmental opponent of hydraulic fracturing, published a brief report in December claiming a link between health problems of DISH residents and exposure to chemicals that a private environmental consulting firm found in DISH's air. Tillman has lately sought to cultivate a national profile as an advocate for oil and gas accountability, going on several speaking tours in the Northeast. His allegations gained credence when the Texas Commission on Environmental Quality said in January it found elevated levels of benzene and other chemicals at well sites, open-air pits and gas processing stations in the Barnett--including in Dish.	The Texas Department of State Health Services reported May 12 that biological test results of DISH residents showed their exposure to contaminants was not greater than the general U.S. population. The only four residents with elevated benzene levels in their blood were smokers who were expected to have higher readings. The other chemicals found "in a few people" at higher levels are commonly found in people drinking from chlorinated water systems and using common household products. The findings "did not indicate that community-wide exposures from gas wells or compressor stations" were occurring. Since then, Texas CEQ has found some air samples around Ft. Worth with benzene levels that it said warrant further review.	NO	NO

Quality of the Evidence

We sought to identify the handful of scientific studies or reports that have been the most influential in the debate—what do they really prove? Is the safety of fracing as cut and dry as the industry claims? Do the opponents "have the goods"?

Somewhat surprisingly, all sides see the need for more peer-reviewed scientific research. Environmentalists say we don't know enough. EPA Administrator Lisa Jackson recently criticized her agency's own 2004 study on fracturing as a "literature review"—not surprising, since she needs to justify the agency's do-over. Amy Mall, a senior policy analyst for the Natural Resources Defense Council, says "Independent, unbiased scientific inquiry into hydraulic fracturing is critical."

But petroleum engineers and industry geologists are also calling for more study, presumably because they think science will prove deep hydraulic fracturing is not a risk. ExxonMobil has said it welcomes peer-reviewed research on this question. Noble Energy told the EPA in a March 29 letter: "We believe that government, environmental groups, and the general public's opinion of HF has been misrepresented by inadequate studies. These published papers lack some key elements that are integral to include before they can be considered scientific papers."

Remember, we don't purport to be scientists, just analysts trying to handicap the odds for busy investors. So don't shoot the messenger--read for yourself who has more ammo. (We cite what we view as the most significant reports first. Links to reports are provided.)

Studies Used to Support Hydraulic Fracturing

The industry's main evidence is…a lack of confirmed evidence.

The industry has used hydraulic fracturing for over 60 years to frac over one million wells. Only in the last few years has this become especially controversial. The industry says the absence of proof over decades tells us a lot. Here is what regulatory agencies that have overseen frac jobs for years say[21]:

- *"After 25 years of investigating citizen complaints of contamination, DMRM [Division of Mineral Resources Management] geologists have not documented a single incident involving contamination of ground water attributed to hydraulic fracturing."*
  --Scott R. Kell, deputy chief, Ohio Department of Natural Resources, letter to Ground Water Protection Council, May 27, 2009
- *"DEP has not concluded that the activity of hydraulic fracturing of these formations has caused wide-spread groundwater contamination. After review of DEP's complaint database and interviews with regional staff that investigate groundwater contamination related to oil and gas activities, no groundwater pollution or disruption of underground sources of*

[21] Appendix 15 of http://www.dec.ny.gov/energy/58440.html

drinking water has been attributed to hydraulic fracturing of deep gas formations. All investigated cases that have found pollution, which are less than 80 in over 15 years of records, have been primarily related to physical drilling through the aquifers, improper design or setting of upper and middle well casings, or operator negligence."
--Joseph J. Lee, Jr., P.G., chief, Source Protection Section, Division of Water Use Planning, Pennsylvania Department of Environmental Protection, letter to Ground Water Protection Council, June 1, 2009

- *"While we do currently list approximately 421 ground water contamination cases caused by pits and approximately an equal number caused by other contamination mechanisms, we have found no example of contamination of usable water where the cause was claimed to be hydraulic fracturing."*
  --Mark E. Fesmire, PE, Director, New Mexico Oil Conservation Division, New Mexico Energy, Minerals and Natural Resources Department, letter to Ground Water Protection Council, May 29, 2009
- *"I can state with authority that there have been no documented cases of drinking water contamination caused by such hydraulic fracturing operations in our State."*
  --David E. Bolin, Deputy Director, State Oil and Gas Board of Alabama, letter to Ground Water Protection Council, May 27, 2009
- *"The Railroad Commission of Texas is the chief regulatory agency over oil and gas activities in this state. Though hydraulic fracturing has been used for over 50 years in Texas, our records do not indicate a single documented contamination case associated with hydraulic fracturing."*
  --Victor G. Carrillo, Chairman, Railroad Commission of Texas, letter to Ground Water Protection Council, May 29, 2009.

Environmental Protection Agency, "Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs," June 2004.[22]

The agency initiated this study in 2000 in response to court litigation over fracturing in Alabama. The study found that hydraulic fracturing in coal-bed methane—where the gas is substantially closer to water tables than the shale gas at issue in this report—"poses little or no threat" to drinking water supplies and "does not justify additional study at this time." This report has been attacked by environmentalists both for alleged research gaps and reliance on input from industry. EPA Administrator Lisa Jackson (not in charge when the 2004 study was released) told the House Energy and Commerce subcommittee in April: "That study is widely cited as saying, 'see, that proves it's safe,' and I don't think that's a fair or accurate summation of that study. I think that's an overbroad reading. We need some data."

[22] http://www.epa.gov/safewater/uic/wells_coalbedmethanestudy.html

(We would add that without data from industry, studies will be significantly limited. It is extremely expensive and potentially impractical to drill wells wholly to obtain control data and samples; meanwhile, decades of industry data is available to test hypotheses.)

Among its key points:

- EPA frowned mainly on one practice: injecting frac fluid with diesel into coalbed methane reservoirs.
- EPA's conclusions are "based primarily on existing literature."
- EPA found no confirmed water-well contamination cases linked to injecting frac fluid into coalbed methane wells.
- The dilution of fracing chemicals with water, the removal of much of the fluid after fracing, and the potential biodegradation of remaining fluid underground can mitigate potentially adverse effects.
- The low permeability of shale rock may act as a barrier to fracture height growth and fluid movement.

Action taken by EPA after study: Initially no action. Then, this year, it announced a study to reexamine these results. It is currently holding public meetings on study design.

New York State Department of Environmental Conservation, "DRAFT Supplemental Generic Environmental Impact Statement On The Oil, Gas and Solution Mining Regulatory Program, Well Permit Issuance for Horizontal Drilling And High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs," September 2009[23]

This 804-page tome represents one of the more recent, exhaustive reviews of hydraulic fracturing. After receiving requests to issue drilling permits for wells in the Marcellus Shale, the state launched a review of whether its regulations adequately covered hydraulic fracturing. It disappointed environmentalists with its preliminary conclusion that it didn't see significant risks to groundwater from fracturing. The state has pledged to review and address a massive number of new comments and submissions before it makes the final decision on whether and how to issue high-volume fracing permits. Just one rebuttal, from the Natural Resources Defense Council, is 283 pages and alleges that it would be "illegal" for New York to proceed with drilling based on the draft findings, in part due to the failure to assess "cumulative impacts" even when an individual well may not have significant impact. Most parties, including environmentalists, expect the state to reaffirm its prior conclusions by the end of this year or early next year but require more restrictions on drilling under New York watersheds.

[23] http://www.dec.ny.gov/energy/58440.html

Key points:

- Adequate well design "prevents contact between fracturing fluids and fresh ground water sources."
- "Ground water contamination by migration of fracturing fluid is not a reasonably foreseeable impact."
- A variety of safeguards, setbacks and controls protect surface waters.
- Full disclosure of chemicals should be required for any open pits to determine the best controls.

Actions taken by NY DEC: While it develops its final regulatory assessment, it has announced a stricter, separate review for shales directly under unfiltered water supplies. But its website defends fracing, saying it has been used in New York safely in vertical wells since at least the 1950s.

ICF International, "Analysis of Subsurface Mobility of Fracturing Fluids," report prepared for NYDEC for its draft impact statement (above), 2009. [24]

This study, commissioned by New York State, found that fracing of shale "does not present a reasonably foreseeable risk of significant adverse environmental impacts to potential freshwater aquifers." Among the points:

- Shales are separated by aquifers by at least 1,000 feet of rock (usually many thousands of feet)
- Fracturing pressures are applied for short periods of time, typically less than a day, whereas the time required for fluid to move into aquifers under those pressures would take years.
- Some chemicals left behind would be "adsorbed" by and bound to organic-rich shales, transforming them.
- Experience with tens of thousands of wells is consistent with the analytical conclusion. There are no known incidents of groundwater contamination due to hydraulic fracturing.

[24] Appendix 11 of http://www.dec.ny.gov/energy/58440.html

MIT Energy Initiative, "The Future of Natural Gas: An Interdisciplinary MIT Study, Interim Report," June 2010[25]

This well-respected Massachusetts Institute of Technology initiative has previously published studies on coal and nuclear power. Authors are MIT scientists and professors, but the group is also advised by environmental organizations (Natural Resources Defense Council, Sierra Club) and industry (Hess).

Relevant findings:

- Natural gas will assume an increasingly important part of the energy mix over the next several decades, particularly to meet greenhouse gas reduction goals.
- The environmental record on shale gas development "is for the most part a good one," but "one must recognize the inherent risks and the damage that can be caused by just one poor operation." Recommends government research on "all subsurface aspects" of U.S. shale drilling and on ways to reduce water use.
- More transparency and disclosure should be required of fracturing operations, including contents of frac fluids, and water management of gas drilling. "Transparency is key."
- *"Good oil-field practice and existing legislation should be sufficient* to manage" the risks of underground fracturing. [emphasis added]
- Waste disposal is a bigger challenge and regional coordination can help create integrated water use and disposal plans.

U.S. Department of Energy and the Ground Water Protection Council, "State Oil and Gas Regulations Designed to Protect Water Resources," May 2009[26]

The GWPC (a non-profit organization of state groundwater regulatory agencies) helped DOE evaluate whether state oil and gas regulations protect water.

- Study looked at permitting, well construction, hydraulic fracturing, temporary abandonment, well plugging, tanks, pits and waste handling and spills.
- Regulations are "adequately designed" but could be reviewed for more specificity. (Several recommendations made on best practices.)
- Claims that oil and gas industry is unregulated "are not supported by the findings."
- Enactment of national regulations would be duplicative and costly.

[25] http://web.mit.edu/newsoffice/2010/gas-report-0625
[26] http://www.gwpc.org/e-library/documents/general/State%20Oil%20and%20Gas%20Regulations%20Designed%20to%20Protect%20Water%20Resources.pdf

U.S. Department of Energy, Ground Water Protection Council and ALL Consulting, "Modern Shale Gas Development in the United States: A Primer," April 2009[27]

This is a broad overview of shale drilling and the issues associated with it; not a scientific study. It is positive toward industry and compiled with the help of industry.

- The use of horizontal drilling "has not introduced new environmental concerns. On the contrary, the reduced number of horizontal wells needed, coupled with multiple wells drilled from a single pad, has significantly reduced surface disturbances."
- Hydraulic fracturing "has proven to be a safe and effective stimulation technique."
- Groundwater is protected by casing and cement where the well is drilled and the thousands of feet of rock between fracture zone and aquifers.
- Solutions are emerging to many of the concerns.

Interstate Oil and Gas Commission, "States' Experience with Hydraulic Fracturing," 2002 survey[28]

A short one-page chart; no science; mainly reflects experience with vertical wells, not horizontal wells. The IOGCC at the time represented the governors of 37 states that produced virtually all the country's oil and gas.

- All states answered "NO" to whether fracing had caused harm to groundwater.
- The survey shows that fracing was done in Pennsylvania as early as the 1950s—earlier than the first well in Arkansas (1980s) and Louisiana (1960s) and the same as Texas (1950s.)
- A one-page document with the chart contends that 80% of injected fluid returns to the surface and an additional 15-20% is recovered through production (This is not true with horizontal wells; more stays underground.)

[27] http://www.fossil.energy.gov/programs/oilgas/publications/naturalgas_general/Shale_Gas_Primer_2009.pdf
[28] http://s3.amazonaws.com/propublica/assets/natural_gas/iogcc_survey_july2002.pdf

Studies Used to Oppose Hydraulic Fracturing

Oil & Gas Accountability Project of EARTHWORKS, "Our Drinking Water at Risk: What EPA and the Oil and Gas Industry Don't Want Us to Know about Hydraulic Fracturing," April 2005.[29]

This is a lengthy, blow-by-blow rebuttal to the EPA's 2004 conclusion that fracing "poses little or no threat." The report raises some good points about the limitations of the EPA study, and it is these arguments that have helped push the EPA to do a new study. Worth noting is that, when this report came out, Congress had not yet passed the energy bill that exempted fracing from the Safe Water Drinking Act. Put another way, lawmakers would have seen this Earthworks report before they affirmed that hydraulic fracturing would be regulated stateside. Its key points:

- The EPA found a number of worrisome cases but inexplicably cleared fracing of suspicion.
- EPA ruled out further study even as it saw gaps in scientific data.
- EPA's results were skewed by data selectively culled from oil and gas-friendly sources.
- EPA omitted information from earlier drafts.
- EPA failed to assess some hazards that opponents believe help prove the harmfulness of fracing or at least raise doubts. For example, the EPA cited a study conducted in six U.S. states, which found that, in 50% of coalbed methane hydraulic fracturing stimulations, the fracturing fluids moved out of the coals and into adjacent formations. This is one reason the Oil & Gas Accountability Project alleges the EPA shouldn't have concluded that fracing fluids can't contaminate underground drinking water sources.
- The understanding of fluid recovery from hydraulic fracturing is immature.
- EPA had major gaps in its study of "fracturing fluid toxicity, fracture behavior, quantities of fracturing fluid left stranded in the formation, chemical fate and transport of fracturing fluids trapped underground, and groundwater quality following fracturing events. Given the dearth of information, it is irresponsible to conclude that hydraulic fracturing of coal beds or any other geological formations does not pose a risk to drinking water and human health. Yet this is exactly what EPA does."
- Featured extensively in the report are the arguments of an EPA "whistleblower" named Weston Wilson, a veteran EPA engineer in Colorado, who accused the EPA of releasing a "scientifically unsound study" and became something of an environmental celebrity. Mr. Wilson has since become a key voice in anti-drilling documentaries.

[29] http://www.earthworksaction.org/pubs/DrinkingWaterAtRisk.pdf

New York City Department of Environmental Protection and Hazen and Sawyer, "FINAL IMPACT ASSESSMENT REPORT, Impact Assessment of Natural Gas Production in the New York City Water Supply Watershed," December 2009.[30]

Completed with assistance from Hazen and Sawyer, P.C., an environmental engineering firm, and sometimes referred to as the Hazen and Sawyer report. New York City sees hydraulic fracturing as a negative all around. NYC doesn't have the income-producing wells. It just drinks the water that flows above the Marcellus, so it sees itself as bearing all the risks. The City's concerns:

- 1,076 square miles of the NYC watershed contain Marcellus Shale and this land is not protected from gas drilling.
- Flowback water contains total dissolved solids (salts), hydrocarbons, heavy metals and radionuclides that aren't amenable to traditional wastewater treatment and must be disposed of using underground injection wells or industrial treatment facilities. The region has too few such facilities to handle the expected wastewater volumes from gas drilling.
- Impact to communities from truck hauling and industrial activity would occur not just for 1-3 years of drilling, but it would happen again and again. Companies re-fracture the wells multiple times.
- New York City currently doesn't have to filter its water because the sources are so pristine. The industrial activity and heightened risk of water contamination is "inconsistent with the expectations for unfiltered water supply systems."
- Subsurface contamination could subject "watershed residents and potentially NYC residents to chronic low levels of toxic chemicals."
- The difficulty of addressing contamination once it has occurred call for "a conservative approach towards natural gas drilling in the NYC watershed." A point with particular poignancy when viewed through the lens of the Gulf Oil spill.

Harvey Consulting LLC, "Review of DSGEIS and Identification of Best Technology and Best Practice Recommendations," December 28, 2009[31]

This study was done for the Natural Resources Defense Council and was submitted to NYDEC.

- It critiques the shortcomings of the New York State draft impact statement, saying it lacks sufficient data to conclude fracing is unlikely to impact groundwater.
- New York State should do additional analysis.

[30] http://www.nyc.gov/html/dep/pdf/natural_gas_drilling/12_23_2009_final_assessment_report.pdf
[31] http://www.riverkeeper.org/wp-content/uploads/2010/01/Harvey-Final-DSGEIS-Review.pdf

- New York State should update its regulations specifically for shale gas development, including to address concerns about handling of drilling fluids and wastewaters, well design, emissions, disruptive seismic activity, spills, surface pits and well abandonment.

Natural Resources Defense Council, "Drilling Down: Protecting Western Communities from the Health and Environmental Effects of Oil and Gas Production," October 2007[32]

Several environmental groups mentioned this Natural Resources Defense Council report to us as an influential one. It is a short report (48 pages) that consists largely of policy analysis, not hard science.

- It criticizes "decades of dealmaking" by the oil and gas industry to win numerous exemptions from federal legislation.
- It cites anecdotal evidence in numerous, brief profiles of Western landowners who tied health symptoms to oil and gas extraction on or near their property.
- The vignettes were light on detail about what local authorities' investigations actually proved.
- The NRDC calls for stiffer regulation on a variety of fronts, not just hydraulic fracturing, including removing exemptions that apply to the oil and gas industry for waste disposal and pollution laws.

Al Armendariz, Ph.D., Southern Methodist University, "Emissions from Natural Gas Production in the Barnett Shale Area and Opportunities for Cost-Effective Improvements," January 26, 2009.[33]

This report was produced for the Environmental Defense Fund.

- Barnett Shale oil and gas production activities are significant sources of air emissions in north-central Texas. Summertime emissions from these sources are projected to significantly exceed emissions from the region's airports and to slightly exceed on-road mobile emissions.
- Many cost-effective emission-control methods are available to reduce these emissions, including use of "green completions" to capture methane and volatile organic compounds during well completions, electric motors to drive gas compressors, vapor recovery units and improved valves and fittings.

[32] http://www.nrdc.org/land/use/down/down.pdf
[33] http://www.edf.org/documents/9235_Barnett_Shale_Report.pdf

Texas Commission on Environmental Quality, Interoffice Memorandum, "Health Effects Review of Barnett Shale Formation Area Monitoring Projects," January 27, 2010[34]

The Texas environmental regulator conducted a widely discussed study of air emissions in and around producing regions of the Barnett Shale near Fort Worth.

- The study found elevated levels of benzene and other chemicals at well sites, open-air pits and gas processing stations.
- It recommends additional long-term monitoring of emissions in the area to better assess the influence of oil and gas activity on the presence of volatile organic compounds over a long period of time. A particular concern is benzene, a known human carcinogen.

Since then, some other tests near that region have registered normal exposures. And biological tests conducted by the Texas Department of State Health Services found that residents of DISH, Texas, a town whose mayor is a vocal national opponent of hydraulic fracturing, did not indicate exposure to certain contaminants that was greater than that of the general U.S. population. The only residents with higher benzene levels in their blood turned out to be smokers, which is not unusual.[35]

[34] http://www.tceq.state.tx.us/assets/public/implementation/barnett_shale/2010.01.27-healthEffects-BarnettShale.pdf
[35] http://www.dshs.state.tx.us/news/releases/20100512.shtm

The Conversation about Fracing—and Who's Controlling It

It is fair game for environmentalists to hold companies accountable, and for analysts and journalists to ask tough questions. But much of the rhetoric the industry is battling is not scientifically rigorous. We looked at tactics and perceptions—and found a pretty well matched PR war.

The industry has a powerful message: It is delivering cleaner-burning domestic energy, and more of it, while drilling fewer holes to get to it. But residents in new shale country have a case to make too: There is nothing scarier for parents than chemical threats they can't see. And it changes a community when tankers of residual waste chug through two-lane mountain roads, occasionally turning over. Particularly in the twisty vales and hills of the Marcellus Shale, churches, back yards and schools are not just next-door-neighbors to producers. They are sometimes downhill from their waste pits.

In short, politics thrives in such an environment like golden algae in Dunkard Creek! (See Incidents That Have Fueled the Fire, page 25.)

After last year's setbacks on climate change initiatives, anti-fracing campaigns are giving green-energy groups new momentum to push renewables. Since wind and solar can't compete on price, renewable advocates need to show that fraced gas is more harmful to public health than existing fossil fuel extraction.

So reports are circulating like the one from a Cornell professor, who asserted in March that gas production from shale plays may be worse for global warming than coal from mountain-top removal. Although he concedes that gas is much cleaner burning, he guesstimates that additional, unintended gas leaks from wellheads, pipelines, and processing stations counteract that benefit. In fact, he says, emissions from hydro-fraced gas are 60% higher than for diesel and gasoline. "Far better would be to rapidly move towards an economy based on renewable fuels."

Maybe—one day--he will be proven right. But his own press release on his "preliminary assessment" warns that such calculations are "highly uncertain" and "should be treated with caution" because he had so little information on which to assess this scientifically.[36] In our interviews, nonprofits brought up his report without those caveats.

Frac opponents prefer to publicize the problems, not the realistic fixes, like better cement standards or waste protocols. We thought Chris Tucker, a crisis-PR specialist who is managing the energy industry's public response to fracing, made a good point in a recent rebuttal to environmentalists. Even though human error has caused several of the recent problems, blaming blue collar workers doesn't fit with opponents' politics or agenda. "It knows it can't attack the carpenter. So it's decided to attack his tools instead," he said.

[36] http://www.eeb.cornell.edu/howarth/GHG%20emissions%20from%20Marcellus%20Shale%20--%20with%20figure%20--%203.17.2010%20draft.doc.pdf

It is not always in opponents' interest to get too detailed. Many information outlets just keep the message simple: gas drilling bad, renewables good. The best way to do that is to create the perception that no amount of regulation can make fracing safe. This is why you see well-respected environmental organizations offering to publicize incidents based on hunches:

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Amy Mall's Blog

Incidents where hydraulic fracturing is a suspected cause of drinking water contamination

Posted April 6, 2010 in Health and the Environment
Tags: hydraulicfracturing, naturalgas, oilandgas, SDWA, waterpollution

Print this page

NRDC supports federal regulation of hydraulic fracturing under the Safe Drinking Water Act. We believe this is a sensible approach that would ensure a minimum federal floor of drinking water protection in the more than 30 states where oil and gas production occurs.

Opponents of such regulation claim that hydraulic fracturing has never caused any drinking water contamination. They say this because incidents of drinking water contamination where hydraulic fracturing is considered as a suspected cause have not been sufficiently investigated, either because scientists and regulators could not properly investigate (did not have the information or technology needed) or because they chose not to, even where signs clearly point to hydraulic fracturing. Some cases where groundwater was contaminated during hydraulic fracturing operations have been attributed to other causes, such as faulty well structure, even if a well failed during the hydraulic fracturing process.

Below is a list of incidents where drinking water has been contaminated and hydraulic fracturing is a suspected cause. I can't emphasize enough that there are many more cases of drinking water contamination around the country related to oil and gas production; those listed below are cases where a homeowner had enough detailed knowledge to know that a nearby well was recently fractured and specifically included that information in reports. In many cases of drinking water contamination where hydraulic fracturing has not been mentioned as the cause, it may be because the homeowner does not know if the nearby gas well was recently fractured. It does not mean that hydraulic fracturing is completely absolved. As you will see, these cases are not

about
Switchboard is the staff blog of the Natural Resources Defense Council, the nation's most effective environmental group. For more about our work, including in-depth policy documents, action alerts and ways you can contribute, visit NRDC.org.

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Here[37], a Natural Resources Defense Council policy analyst cites well over a dozen "incidents where drinking water has been contaminated and hydraulic fracturing is a suspected cause. I can't emphasize enough that there are many more cases of drinking water contamination around the country related to oil and gas production; those listed below are cases where a homeowner had enough detailed knowledge to know that a nearby well was recently fractured."

[37] http://switchboard.nrdc.org/blogs/amall/incidents_where_hydraulic_frac.html

The list that follows makes *no attempt to dissect evidence or to provide a response from the gas driller in question.* Documentation amounted to links to YouTube. Here are the Arkansas examples:

Arkansas: **In 2008, Charlene Parish of Bee Branch reported contamination of drinking water during hydraulic fracturing of a nearby natural gas well owned by Southwestern Energy Company. Her water smelled bad, turned yellow, and filled with silt.**

Arkansas: **In 2007, the Graetz family in Pangburn reported contamination of drinking water during hydraulic fracturing of a nearby natural gas well owned by Southwestern Energy Company. The water turned muddy and contained particles that were "very light and kind of slick" and resembled pieces of leather.**

Arkansas: **In 2009, a family in Bee Branch, who wishes to remain anonymous, reported changes in water pressure and drinking water that turned gray and cloudy and had noxious odors after hydraulic fracturing of a nearby natural gas well owned by Southwestern Energy Company.**

Arkansas: **In 2007, a family in Center Ridge reported changes in water pressure and water that turned red or orange and looked like it had clay in it after hydraulic fracturing of nearby wells owned by Southwestern Energy Company. They told their story on YouTube.**

Arkansas: **In 2008, a homeowner in Center Ridge reported changes in water pressure and water that turned brown, smelled bad, and had sediment in it after hydraulic fracturing of a nearby well owned by Southwestern Energy Company. He also told his story on YouTube.**

We called Southwestern about these incidents. The company's general counsel said neither its tests nor that of Arkansas regulators found a connection between these water conditions and hydraulic fracturing. Prior to our call, he had already been compiling documentation to send to the NRDC to seek any appropriate corrections.

The Arkansas Oil and Gas Commission's deputy director told us he had no record of the first complaint. He couldn't respond to the anonymous allegation. And his agency issued a determination nearly three years ago, in November 2007, that the Graetz water samples "fall within acceptable ranges" for well water.

The NRDC policy analyst says she doesn't have time to investigate most of the cases on her blog and that people wish to remain anonymous because they are intimidated about coming forward. She offered to remove incidents that are proven to be "not due to fracing." Message: two can play this game.

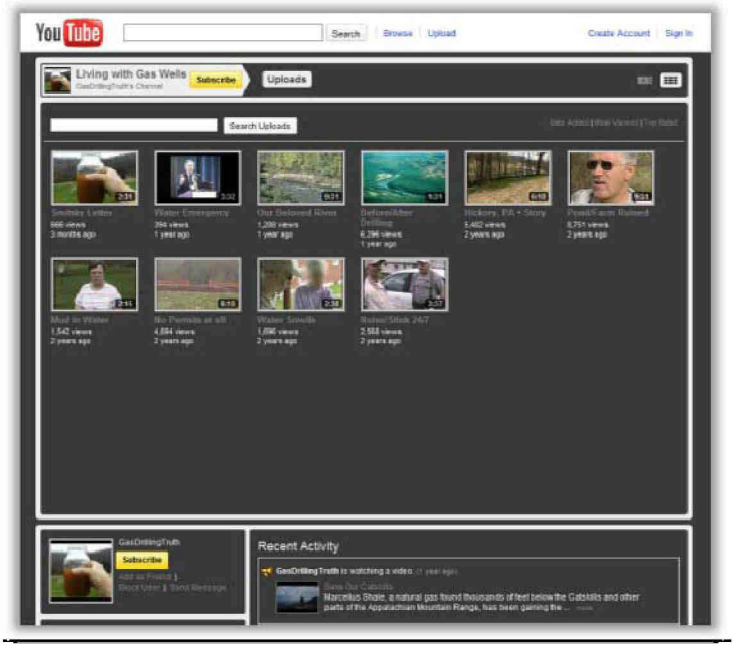
These long lists of alleged incidents make it easier to argue that, despite definitive proof that fracing causes water contamination, the sheer number of complaints are a red flag. In recent submissions to the EPA, the Sierra Club wrote: *"Give communities the benefit of the doubt…Where it is difficult to link a given instance of contamination directly to a given well, for instance, EPA should not dismiss these incidents as 'unsubstantiated,' as it did in 2004, but should instead carefully consider the relative increase in the frequency and severity of water contamination incidents in drilling areas."* Wildlife groups and public officials widely broadcast the decision last month by American Rivers to name the Upper Delaware River "America's Most Endangered River," citing shale drilling.

Opponents also suggest that state regulators are A.W.O.L.—which isn't the case, especially now.

"The oil and gas industry is the only industry in America that is allowed by EPA to inject hazardous materials – unchecked – directly into or adjacent to underground drinking water supplies." Our Drinking Water at Risk: What EPA and the Oil and Gas Industry Don't Want Us to Know about Hydraulic Fracturing, by the Oil & Gas Accountability Project of EARTHWORKS, April 2005.

Granted, standards are not applied consistently state to state and quality of enforcement and levels of staffing can be spotty. And state funding is uneven. But unchecked, fracing is not.

The anti-fracing campaign lends itself to viral marketing over the Internet. Postings stay up years past any facts that later come out. YouTube is a reservoir of flaming water faucets, angry landowners, and homemade videos that wouldn't stand up in court.[38]:

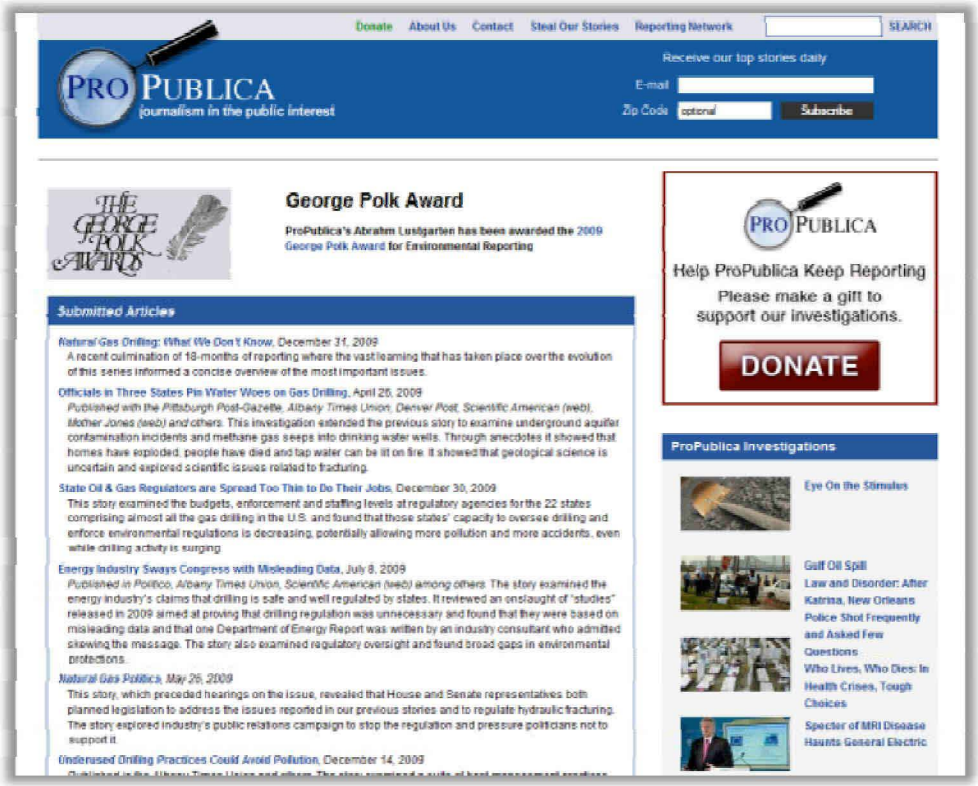


Green groups also are getting powerful help from journalists, filmmakers and "green" investors who have become players in this debate rather than observers.

If only to play defense, those investors that care about fracing should check out what an online investigative-reporting organization, ProPublica,[39] has said about any gas companies you own. ProPublica was founded by the former managing editor of The Wall Street Journal (the longtime employer of one of the authors of this report). ProPublica produces what it calls "Journalism in the Public Interest" and stories "with moral force." It provides articles free of charge to news organizations and is supported by philanthropy.

[38] http://www.youtube.com/user/GasDrillingTruth
[39] http://www.propublica.org/

Since it began publishing in 2008, it has made gas drilling and hydraulic fracturing one of its signature issues. Writer Abrahm Lustgarten won a 2009 Polk Award for his coverage. He has attacked claims that state regulators are adequately staffed for the shale boom and highlighted uncertainties in geologic science.[40] One of the results of this free-journalism campaign has been to turn small-town newspapers into powerful mouthpieces in the shale debate, spurring more debate and, we'd guess, significantly more opposition.



The movie industry has been equally active. A handful of documentary filmmakers recently chose shale drilling as their subject. One is Gregory Kallenberg, whose film "Haynesville" presents the impacts of gas drilling on three Louisiana constituents. Another is Josh Fox, a resident of NYC with a home in northeast Pennsylvania. He filmed "Gasland," a dramatic attack on gas drilling and hydraulic fracturing, after getting an offer to lease his land in Wayne County near the New York border. The movie has been screened across many drilling communities and in New York City, and aired on HBO June 21. It has alarmed many New Yorkers, including Wall Street money managers with homes in Marcellus territory.

[40] http://www.propublica.org/awards/item/polk-award-2009/

Gasland does document troublesome stories from residents who link drilling in their backyard to deterioration of their water; one widely-replayed scene shows a man lighting his water on fire.

A clip on the Internet from Gasland shows a man lighting his tap water on fire.

But pyrotechnics aside, no respectable news organization (we'd like to think) could ever have gotten away with its near-total omission of any industry explanation or response. Nor does it strengthen the film that, as proof of industry wrongdoing, he runs tests on a jar of liquid he receives from an anonymous person, which he acknowledges contains an unspecified liquid from an unspecified place. Credits at the end include a long list of interviews denied to him. But diligent professionals can always obtain written comments and regulatory findings that go deeper than a homeowner's hunch—and they should include those responses or results if they contradict an on-air claim.

Pennsylvania's secretary of environmental protection, John Hanger, has called the film "fundamentally dishonest" and "a deliberately false presentation for dramatic effect." Mr. Fox has said Gasland stands up for real people affected by drilling whose concerns were dismissed.

Finally, "socially responsible" investor groups have been filing shareholder resolutions seeking more disclosure of the risks associated with fracing and the chemicals used.

Hey, wait a minute. What happened to all that patriotic good news about natural gas?

The energy industry has not stood still as the debate has raged. IPAA last year formed Energy in Depth,[41] a highly sophisticated website and platform to influence the conversation about fracing. A significant PR group helped turn the site into a spirited, deft refuter of unsupported arguments. The latest: a nearly 4,000-word rebuttal that seeks to debunk key passages of Gasland.[42] E-I-D is pounding the drum about the jobs and economic revitalization occurring in shale territories. Its postings are getting significant traction.

The many landowners in favor of drilling are also growing more vocal. We met with property owners in the shale territories who argued that the opponents of fracing are a loud minority. Numbers bear this out: many more people are leasing their land than sitting it out. In Wayne County, where fracing is effectively on hold due to a water-policy review by the Delaware River Basin Commission, a large portion of the acreage of interest to energy companies is already leased.

[41] http://www.energyindepth.org/
[42] http://www.energyindepth.org/2010/06/debunking-gasland/

Aubrey McClendon, CEO of Chesapeake, told a group of Harvard students (not a friendly audience) earlier this year that "a million Americans…one out of every 300 Americans, has chosen to sign a natural gas lease with Chesapeake."[43]

Aubrey McClendon speaking at Harvard, where he was heckled by students opposed to fracing.

Some environmental groups have publicly embraced natural gas. The Environmental Defense Fund, for example, has publicly argued that "all low and lower carbon energy options, including natural gas, should be considered as part of the nation's energy mix."

But the industry has at times underestimated the power of the "have nots." We aren't just talking landowners who lack shale prospects or sold out for too little too early.

One of the most powerful have-nots in the Marcellus shale debate is New York City. It drinks the water piped in from north of the city but isn't the site of any of the energy exploration. It sees itself as getting all the negatives, none of the positives, no matter the tax revenue that shale drilling could bring to the ailing state budget. NYC environmental authorities are staunchly opposed to gas drilling. Some of the most active grassroots "locals" fighting fracing are actually New Yorkers who own weekend homes in Northeast Pennsylvania.

A similar dynamic is emerging in "have-not" Philadelphia, which lies far from drilling but drinks water flowing above the Marcellus: its City Council called on regional water authorities this spring to halt drilling until further assessments are done.

[43] http://youtube.com/watch?v=e8OSqf77iG8

The industry also can beat the drum too hard. On the heels of the BP disaster, we found ourselves imagining these words blown up on a screen before an angry Senate committee:

- "EPA is now seeking research to justify a solution to a **nonexistent problem**."

  [emphasis added], Ben Wallace, Penneco Oil Co. comments to EPA, March 26, 2010

- "If the regulatory structures prevent pathways to drinking water, there is **no risk**."

  [emphasis added], Lee Fuller, IPAA comments to EPA, March 28, 2010

Regulatory State of Play

When we started work on this report, it appeared unlikely that Congress would rush to regulate fracturing before the EPA finished a multi-year study on the technique's effects. Then, the BP oil spill happened. Any delays are likelier now caused by Congress tackling offshore drilling regulations and can't yet address onshore. As a Washington representative at a large oil company told us in mid-May, *"the regulatory playing field has shifted dramatically both onshore and offshore."* Two competing provisions calling for disclosure of chemicals in frac fluid have already surfaced in negotiations with gas producers.

What follows is our best assessment of where various initiatives stand in Washington, and some key developments in pivotal shale states including NY and PA.

WASHINGTON

- **Bills requiring public disclosure of fracing ingredients are under negotiation now, and stand a decent chance of passing. This would be a small win for green-energy groups.** According to lobbyists and companies we interviewed, a rift has opened between some gas producers aligned with ANGA (America's Natural Gas Alliance) and others in the oil and gas establishment on how far to go with disclosure. A recent proposal hammered out between the gas camp and Rep. Diana DeGette (D-CO) (one of the staunchest fracing opponents in Congress) would require states and/or EPA to collect information on fracturing fluids from companies under a new amendment to the Safe Drinking Water Act (SDWA).

  The fact that some companies are willing to amend the SDWA is a change to the industry's united front in Washington and lobbyists told us they are drawing lines in the sand. The rift could pit the service companies against producers. Although more disclosure seems inevitable, the IPAA camp (including many big Marcellus producers) sees any disclosure provisions in the SDWA as a nonstarter because of suspicions the EPA would then seek to assert more control over drilling. A competing proposal pushed by some energy majors would disclose fluid components online under the Emergency Planning & Community Right-to-Know Act.

- **Versions of proposed legislation known as the FRAC Act remain under discussion in the House and Senate; they would remove an exemption for hydraulic fracturing from the Safe Drinking Water Act. The FRAC Act would give EPA oversight over the fracturing process; many say it could result in its regulation as an "underground injection" under an EPA program that currently applies to oil and gas waste-disposal wells.** Reps. Diana DeGette (D-Colo.) and Maurice Hinchey (D-N.Y.) in the House and Sen. Bob Casey (D-Pa.) are key backers. Look for this more expansive proposal to stay in the news. But barring a major onshore disaster, we still expect Democrats to be hesitant to go to war for this bill before the EPA study has concluded.

- **Efforts continue in other energy-bill negotiations to create incentives for natural gas use in power generation and in vehicle fleets.** These incentives play well with politicians trying to appear proactive on climate change.

- **The Congressional duo Waxman and Markey have launched a congressional investigation into service companies' use of diesel in fracing operations.**

- **The EPA is moving forward with a multi-year, peer-reviewed study on the potential risks to drinking water posed by fracturing in coalbed methane and shale.** Rep. Hinchey was among those who asked for the study, which has secured $1.9 million in FY10 funding and could get up to $4.4 million in requested funding the following year. We believe it was Hinchey's way to keep pressing the issue when he couldn't get traction with the FRAC Act. The EPA announced in mid-March it would carry out the study and is holding public hearings on the study's design this summer.[44]

The EPA study is the agency's chance to rebut allegations it wasn't thorough enough when it cleared fracing of suspected harm in 2004. It will cover the waterfront.

At April hearings on the scope of the study, Robert Puls, an EPA project manager, stated that "we feel it's necessary to look at the entire life cycle" of shale drilling. He listed several concerns, such as traffic, air quality, fugitive emissions of methane, and higher occurrence of naturally occurring radioactive material in the Marcellus terrain. His tone suggested concern. He said hydraulic fracturing requires five times as much water as a vertical well, citing a "huge" demand on water. He recommended that the study look at "the potential for disproportionate risks to the disadvantaged communities" in shale regions. He said the agency has "not made any definite plans yet" on the study, but we got a different impression. The EPA Science Advisory Board (a body of outside advisors) has endorsed a fairly exhaustive approach to the study.

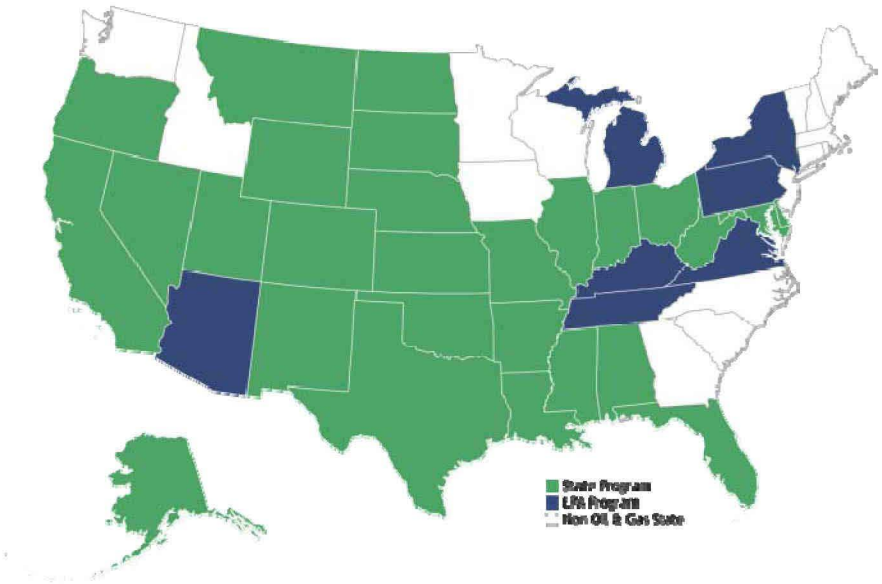
Even with $6+ million in potential funding, it's unclear how extensive and deep a broad study into multiple subjects can be.

Chesapeake Energy reminded the EPA that industry cooperation was critical in an April 7 comment letter, pointing out that the EPA can't just drill a well to simulate the activity and study it. "The $1.9 million that EPA has dedicated thus far to the study amounts to only 25-50% of the cost of drilling a deep shale gas well today." (As mentioned, there are $4.4 million in additional funds requested for the next year.)

[44] The EPA Science Advisory Board's advisory report on the study can be found here: http://yosemite.epa.gov/sab/sabproduct.nsf/0/CC6B2E8803C9BFB985257729004F980F/$File/Advi+on+EPA's+Res+Scoping+Doc+Related+to+Hydraulic+Fracturing+_5-19-10+draft.pdf

We view the chance of passage of federal regulation to be low while the EPA is studying fracing, but not as low as a few months ago. EPA Administrator Lisa Jackson suggested in recent congressional testimony that the EPA was unlikely to make its own move to regulate fracing before the study was complete, saying that under current law, the EPA can "regulate only hydrocarbons or diesel fluid in injections right now."

One of the best arguments for federal regulation is to apply uniform standards. But if the feds take over, it will still be the same overworked state regulators who will have to enforce it. State agencies enforce certain EPA rules under an arrangement called primacy. PA and NY do not have a primacy arrangement with EPA. We heard predictions that the procedures for those states to get primacy, or for the EPA to make arrangements to handle enforcement itself, could take a couple of years. One senior PA regulator told us this rulemaking would "absolutely" put drilling at a standstill. We think PA officials and the industry wouldn't let that happen, and indeed some producers concurred with us in interviews. On New York, a delay wouldn't surprise us.



SOURCE: U.S. Department of Energy and Ground Water Protection Council, "Modern Shale Gas Development in the United States: A Primer," April 2009

To forestall federal regulation, states are making moves to update gas drilling and/or disclosure standards. Wyoming adopted new disclosure standards for fracing chemicals in early June, making clear it was an attempt to forestall federal regulation. "It is imperative that the practice of hydraulic fracing continue, but it is imperative that it continue in a way that is properly supervised and overseen by the Wyoming Oil and Gas Commission," said Gov. Dave Freudenthal. Discussions about similar disclosure standards are taking place in Arkansas, New York, Ohio, Pennsylvania and West Virginia, according to a large producer.

Local towns, parishes and townships in some shale states are also trying to impose additional requirements (and occasionally bans).

Here are the latest regulatory developments in four critical shale-gas producing states.

PENNSYLVANIA

- We see no risk of a ban on fracing in PA: The financially ailing state has leased state forest to gas companies to fill large holes in its budget. Wells are currently being drilled on these lands. A new deal with Anadarko allows the company to drill just outside of state land and extend horizontally under state forest without disturbing the surface.
- Further cutting that risk, the PA gubernatorial candidates for both parties have recently affirmed that they oppose a drilling moratorium.
- In North Central and Southwest PA, permitting by the **Susquehanna River Basin Commission has gotten faster and more efficient** and regulators have gone up a learning curve on hydraulic fracturing, making producers' planning process more predictable and efficient. The SRBC just opened a field office in North Central PA. Though it acts faster, **it is scrutinizing permits more carefully.**
- **Activity in Northeast PA is at close to a standstill.** The Delaware River Basin Commission (a multistate federally-mandated commission that protects interstate waterways and watersheds) is holding up all new permits in Northeastern Pennsylvania while it reviews its regulations on fracing. It was allowing exploratory, or test, wells (in which no fracing takes place.) In June, the commission stated that it will no longer allow test wells until it completes further reviews, though it grandfathered test wells that already had permits. The DRBC told us it expects to have draft regulations out by summer's end, but a lengthy public comment and review period will ensue, making any timetable for drilling highly uncertain (2010 drilling is highly unlikely). We do not allocate any value (in our NAV analysis) to this region of the Marcellus shale. However Newfield Exploration is the most leveraged if this area opens up.
- The governor is pushing hard to pass a severance tax that would potentially charge 5% of gas revenues at the wellhead and 4.7 cents per MCF; negotiations continue. Passage is likely by fall, according to several regulators and industry lobbyists, despite industry arguments that oil and gas already sends $1 billion in revenue to Harrisburg. TPH's Marcellus models already assume 5.5% severance tax.
- State oil and gas regulators have proposed new well design standards on casing and cementing. Industry is unlikely to fight it; the standards are not unusual.
- The Department of Environmental Protection Secretary summoned nearly 90 Marcellus producers to a meeting in May to deliver a stern warning on steps to prevent well design accidents.

- **Waste disposal regulations are getting stiffer and much more costly.** PA has just passed a tough standard that forces companies to dilute the salts in produced water to far lower levels before it is disposed. The proposal of the new standard, and a lack of underground disposal wells, had already pushed many producers to recycle wastewater and spawned a new shale wastewater-treatment industry. Range Resources and Chesapeake Energy claim 100% recycling.
- Discussions are ongoing to raise required bonds that companies must post to plug abandoned wells.
- Cabot was hit hard in recent violation cases. Regulators grew frustrated by media coverage of the Dimock situation and have ordered tougher sanctions including drilling halts for Cabot and EOG Resources.
- Regulators told us of other wells experiencing "leakage" from poorly cemented casing when drillers hit shallow gas zones. More companies now test for methane in water *before* they drill; one company told us they find it in 20% of water wells.

NEW YORK

- **All "high volume" hydraulically fractured wells in the Marcellus Shale are effectively on hold** while the State Department of Environmental Conservation (DEC) finishes assessing the need for special regulatory procedures. Although this has been described as a ban, it isn't.
- DEC's 804-page **preliminary impact statement last fall stated that it didn't see risks to groundwater from fracing.** It is contemplating how to permit such wells and is reviewing voluminous new comments before it issues a final assessment, likely late 2010 or early next year.
- Opponents are attacking the impact statement as incomplete and seeking to delay permitting in the meantime at the Delaware River Basin Commission. Industry is arguing to both NY and the DRBC that agriculture, industrial manufacturing and conventional oil and gas wells have been permitted in the Delaware River region for 150 years. One producer suggested to us that if drilling is not permitted, we could see legal challenges by drillers calling the denials "a regulatory taking" and asking for compensation.
- **NYC environmental regulators and city leaders have been staunchly opposed to drilling.** The NYC Department of Environmental Protection contends allowing drilling in the watershed that supplies city water would force the city to construct a filtration plant at a cost of $10 billion to $20 billion and to raise water rates a minimum of 30 percent.
- **Watershed-area drilling is effectively stymied.** In April, DEC announced a stricter, separate review for drilling in shales under watersheds that supply NYC and Syracuse water. The case-by-case process effectively makes these Marcellus wells nearly impossible to permit, but not banned. No applications are even pending in these regions, however. Chesapeake announced last year it wouldn't drill in the watershed despite holding leases there.

- Underground injection permits for wastewater are a sticky issue. Some legislators want to ban PA producers using NY disposal wells. Chesapeake withdrew a permit earlier this year to do so at a converted gas well near Finger Lakes (upstate New York).
- DEC is expected to allow for drilling, but procedures could be the strictest of any state. *We believe **it is entirely possible that the state remains "on hold"** pending completion of the EPA study for two reasons: politics and litigation. Several advocacy groups told us they are planning on suing as soon as DEC announces it will allow drilling.*

LOUISIANA:

- **Oil and gas regulators in Louisiana are experienced, but underfunded and understaffed.** Our visit to the threadbare Shreveport offices of Louisiana's oil and gas regulators stood in stark contrast to the posh setting of the EPA meetings on fracing at the St. Regis in Washington.
- The state has added new disclosure requirements to report a company's source of water and to track consumption volume used.
- Urban drilling rules went in effect in the Haynesville last year that include requirements on fencing, noise, dust, work hours, and water use.
- We heard lots of discussion about well standards, **but detected no clear effort by regulators to stiffen the rules.** Regulators are asking operators to supervise more drilling that has been farmed out to subcontractors.
- Recent incidents and warnings from regulators are causing companies to **change well designs without new requirements.**

ARKANSAS

- Legislators, state oil and gas regulators, and company representatives are meeting this month to discuss potential changes to regulations on hydraulic fracturing.
- Potential ideas include 1) requiring companies to publicly detail more about their well design and fracturing process both before and after a well is drilled and 2) enhancing well integrity.

What's the Tab?

Increased regulatory scrutiny can, and likely will, increase the costs of drilling and production in the shale plays. As we have stated before, an outright ban or severely restricting hydraulic fracturing is unlikely. The gas-price spike that would follow would cause a serious rethink of any punitive regulatory structure. So in this section, we look at the potential increased costs and the economic impact on Marcellus shale wells. We focus on the Marcellus as it is currently ground zero of potential changes to industry practices…but the impact will be similar in other shale plays if other states adopted changes already underway in Pennsylvania and New York. Companies are making some changes not yet required.

Potential increased costs can be lumped into three main baskets:

Improved well design ($285k per well)

- Additional casing string/cement to further ensure wellbore integrity across fresh water aquifers - $120k
- Cement bond log (after BP Macondo incident very likely) - $15k
- Increased regulatory and compliance costs - $150k

Surface disturbance mitigation ($85k per well)

- More robust on-site materials handling (Tarps, liners under pumps etc.) - $30k
- Road repair - $25k
- Temporary sound barriers - $30k to $100k

Fracturing-related costs ($600k)

- Treating post-frac flowback water to remove salts/impurities etc. where deep well disposal is not available (Marcellus). This cost is high and can be significantly mitigated by onsite filtering and recycling. - $350k
- Microseismic on certain wells to show the created fracture path (likely not required on every well) - $100k to $250k per well

An additional cost, which is harder to quantify, may result if the EPA regulates hydraulic fracturing under the underground injection well program (UIC). The EPA might require fracturing via a workstring (steel drill pipe) with downhole pressure monitoring. In addition to the direct costs of the additional workstring, more surface pumping horsepower would be required to pump the fracturing treatment at the designed rate/bottom hole pressure due to the additional pipe friction caused by the smaller diameter work string. We assume an additional $500k per well with a large variance around this number. As we think it is unlikely that the EPA will regulate hydraulic fracturing under the UIC program, we are not including this additional cost in our base case consideration.

Not all costs will be required on every well as the regulatory environment is still being vetted, and industry might find ways to reduce some of the above costs (via scale)…we have assumed well costs could increase ~500k per completed well. As shown in the following table, the sensitivity to rate of return (IRR) is not a game changer. Our base case Marcellus well IRR declines from 36% to 29% if completed well costs increase from $3.5mm to $4.0mm. This is a similar impact to well economics as a 50c decrease in the assumed long term gas price. A smaller increase in well costs due to regulatory considerations has a smaller impact. If well cost increased only $250k (to $3.75mm), the IRR would only decrease to ~32%.

Marcellus Completed Well Cost, $1,000's

Gas Price, $/mcf	$3,000	$3,250	$3,500	$3,750	$4,000
$4.00	17%	15%	13%	11%	9%
$4.50	24%	21%	18%	16%	14%
$5.00	31%	27%	24%	21%	18%
$5.50	39%	34%	30%	27%	24%
$6.00	47%	41%	36%	32%	29%
$6.50	55%	49%	43%	38%	34%
$7.00	63%	56%	50%	45%	40%
$7.50	72%	64%	57%	51%	46%
$8.00	80%	72%	64%	58%	52%

The tables mentioned on page 21 show the leverage of our coverage universe to some of the key shale plays. As the individual well economics are not meaningfully impacted by a $500k increase in well costs, our long term NAV's would not be materially impacted. That said, those companies with Marcellus leverage have more risk of increased costs and, not quantified, a delayed ramp in drilling programs.

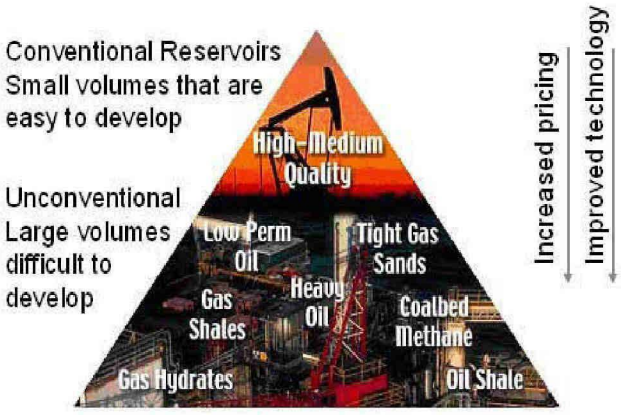
Conclusions

1. Hydraulic fracturing is unlikely to be banned. Shale gas drilling is here to stay.
2. The threat of new federal oversight is more serious in the wake of the BP oil spill disaster.
3. Whether or not the federal government regulates hydraulic fracturing, compliance costs will increase in states that are ramping up their oversight of fracing.
4. Increased costs are not an economic game changer. A $500k/well increase in costs on a Marcellus well reduces IRR from 36% to 29%. The impact will be less significant in higher costs region (i.e. Haynesville) as "new costs" are a smaller % of total well capex.
5. An EPA study, just underway, could slow down the push for federal legislation, as any meaningful changes will likely be based on the results of this study…due out likely in 2012 or 2013.
6. Underground hydraulic fracturing itself hasn't been proven to contaminate groundwater. However, any time a fresh water aquifer is penetrated (with gas well, water well, or mine shaft) the potential exists to harm aquifers. We believe the conversation will shift away from fracturing to focus on best-practice well design (gas wells *and* water wells) to address valid landowner concerns.
7. Ingenuity will prevail. Already, new businesses/technologies are emerging to deal with produced water discharge in the Marcellus.

Appendix: Hydraulic Fracturing Primer

Resource Triangle

Why fracturing? Simple - that's where the gas is. The resource triangle shows that in most natural resources, there is a small amount of high-quality resource (triangle tip) and a large amount of low quality resource (base). As high quality resource is depleted (conventional gas), a combination of higher commodity price and technology are required to move "down" the resource triangle to economically develop lower quality resources. Thus, $6/mcf gas and hydraulically fractured horizontal shale gas wells are the result!



Source: Holditch

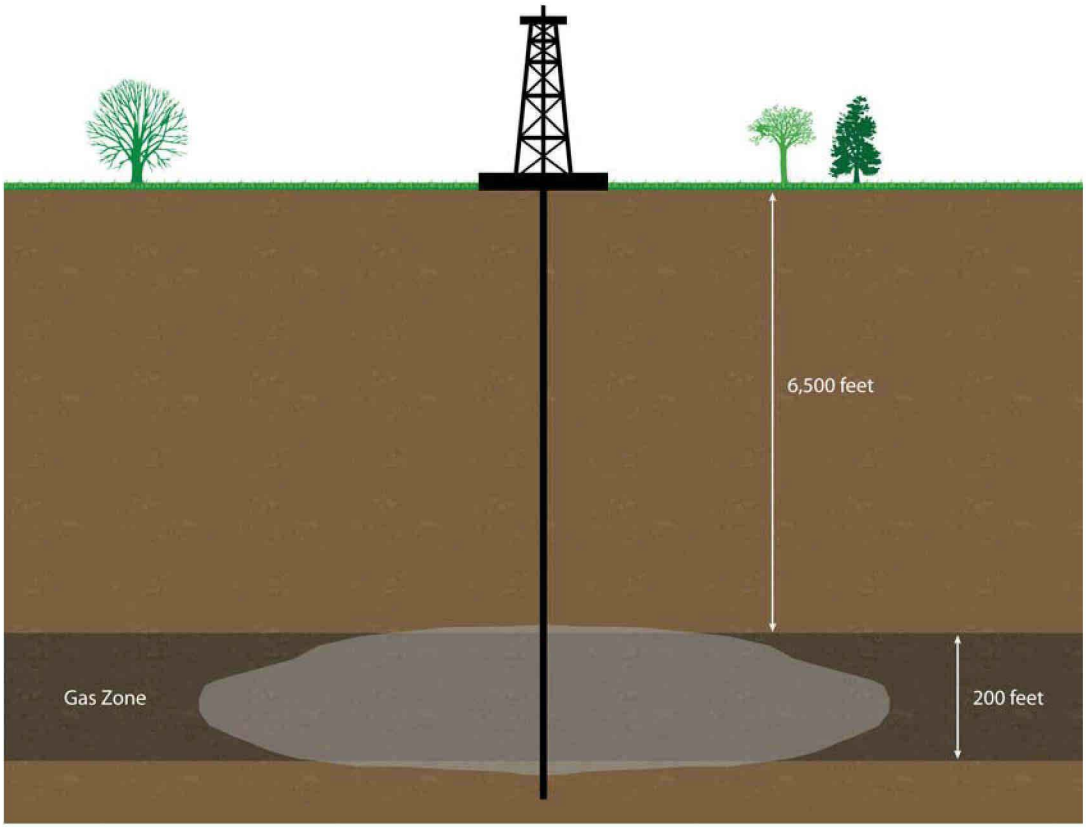
So what is hydraulic fracturing?

In low permeability (low flow capacity) formations, the reservoir rock does not allow for natural gas to flow into the well at commercial rates. The goal of a hydraulic fracturing treatment is to provide a highly conductive flow path from deep in the reservoir to the well. This technology has been around for 60 years and has, until recently, been applied mainly to vertical wells. Large hydraulic fracture treatments, which aimed to create very long fractures, became more common in the early 1980s.

How does it work?

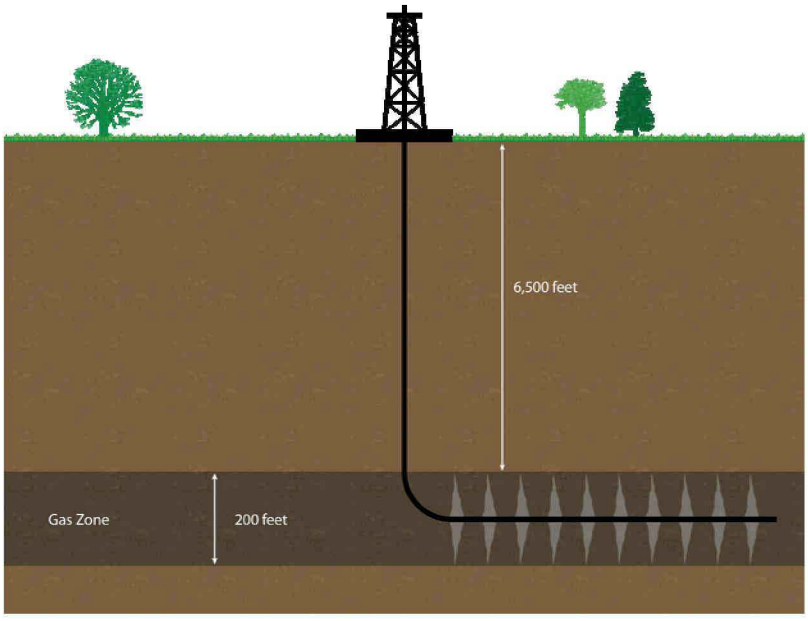
Hydraulic fractures are created by pumping fracturing fluids down the well at high rates and pressures exceeding the fracturing (breakdown) pressure of the formation rock. The created fracture is most often oriented vertically (and not horizontally) and will continue to extend until pumping ceases. The resulting fractures are typically less than an inch wide near the well and can extend 1,000 feet or more in opposite directions from the well. Before pumping into the well, the fracturing fluid is mixed with sand (or ceramic based propping agents) so that when pumping ceases, the fracture will be held open by the proppant. The result is a long, narrow, high-conductivity flow path from the reservoir to the well which allows the well to flow at commercial rates.

The role of fracturing fluids is two-fold: 1) to induce and extend the fracture via high pressure exerted from surface pressure pumping equipment and 2) to transport the proppant along the length and height of the created fracture.



What is so unique about gas shales?

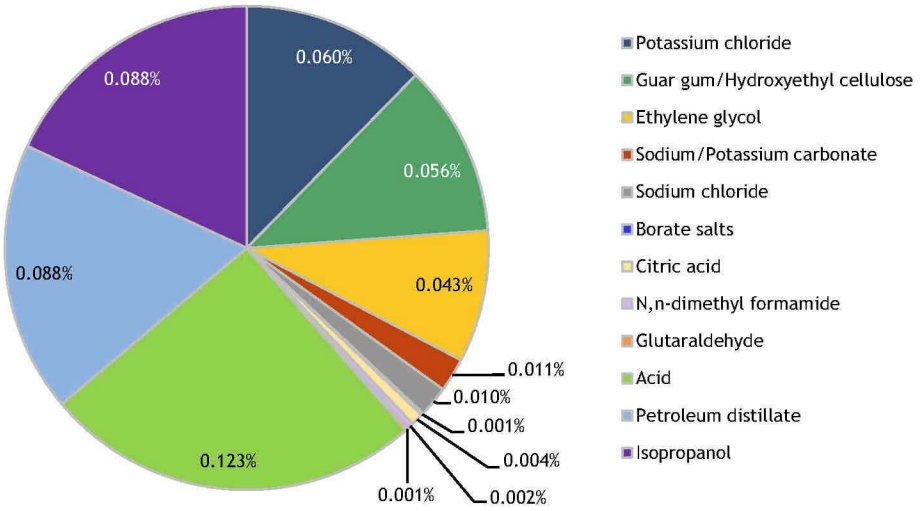
The reservoir flow capacity of a gas shale is typically low enough (tight, low-permeability) that a large hydraulic fracture stimulation in a vertical well often does not create sufficient flow to render the well economic. The "new-technology" in shale gas development is marrying old fracturing technology with horizontal drilling and instead of a one-stage fracture treatment, many (often times 10+) separate fracture stimulations are performed along the horizontal segment. A vertical well is drilled above the top of the target formation and is then, using directional-drilling equipment, drilled horizontally in the formation for several thousand feet.



Although more total fracturing fluids may be pumped in a horizontal well than a vertical well stimulated the older way using what oil hands call a "massive" hydraulic fracture treatment, each individual fracture stage in a horizontal well is comparatively small. Each stage fracture may be designed to extend hundreds of feet from the well…making direct linkage with a fresh water aquifer several thousands of feet shallower highly improbable if not outright impossible.

What is in the frac fluid?

Service companies keep their exact formulas confidential, but most fluids have certain components in common.



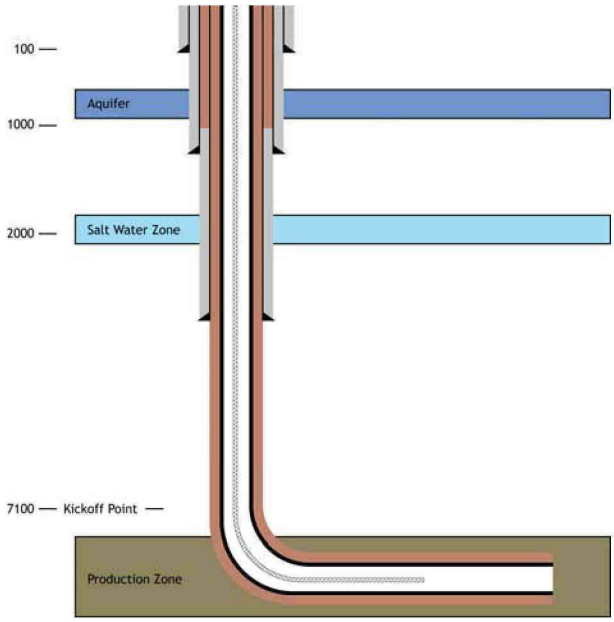
Note: Frac fluid is still 99.5% water.

Compound*	Frac Job Purpose	Common Non-energy Application
Acids	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant; Sterilizer for medical and dental equipment
Sodium Chloride	Allows a delayed break down of the gel polymer chains	Table salt
N,n-Dibethyl formamide	Prevents corrosion of the pipe	Used in pharmaceuticals, acrylic fibers and plastic
Borate salts	Maintains fluid viscosity as temperature increases	Used in laundry detergents, hand soaps and cosmetics
Polyacrylamide	Minimizes friction between fluid and pipe	Water treatment, soil conditioner
Petroleum distillates	"Slicks" the water to minimize the friction	Make-up remover, laxatives, and candy
Guar gum	Thickens the water to suspend the sand/proppant	Thickener used in cosmetics, baked goods, ice cream, toothpaste, sauces, and salad dressing
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice
Potassium chloride	Creates a brine carrier fluid	Low sodium table salt substitute
Ammonium bisulfite	Removes oxygen from the water to protect the pipe from corrosion	Cosmetics, food and beverage processing, water treatment
Sodium or potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers	Washing soda, detergents, soap, water softener, glass and ceramics
Proppant	Allows the fissures to remain open so the gas can escape	Drinking water filtration, play sand
Ethylene glycol	Prevents scale deposits in the pipe	Automotive antifreeze, household cleansers, deicing, and caulk
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, and hair color

Source: Chesapeake Energy

Some thoughts about drilling and well construction

Shale gas wells are drilled vertically from the surface to just above the formation where the direction drilling operation begins to drill the horizontal section in the shale. During the drilling of the vertical section, a series of steel casings are place and cemented in place to protect the fresh water aquifers from potential contamination.



Contrary to perception, steel drill pipe is relatively flexible and can bend as the drill bit transitions from vertical to horizontal. Drilling engineers determine the direction and placement of the horizontal section very precisely using geologic and engineering factors that help maximize natural gas recovery. They run production casing through the horizontal section of the hole and then fill the void (annulus) between the pipe and the sides of the well with cement. The casing and cement barriers are put in place 1) to prevent migration of natural gas behind the pipe, 2) to prevent any salt water zone from eroding the casing from the outside or from flowing into the gas bearing formation, and 3) to control the entry point of the gas into the well by controlling placement of the hydraulic fracture treatments.

The next step is to perforate the casing where the operator wants to initiate each stage of the hydraulic fracture. The operator uses shaped charges (focused, armor-piercing technology) to perforate the pipe…each shaped charge creates a tunnel through the casing and cement and into the formation. The dimensions of each "tunnel" vary but are roughly 1.5" in diameter and 10" long. For each fracture segment, there might be a total of 40 perforations (4 shots per foot for 10 feet). The operator makes enough holes to initiate a hydraulic fracture but focuses them in a tight grouping to control where it initiates the fracture. This technology has been used in the industry for decades.

Now the well operator performs the hydraulic fracture stimulations …one stage at a time (refer to prior discussion on hydraulic fracturing). The "typical" shale gas well will have ~10 separate fracture stages. The number of stages and the lateral length of wells are generally increasing. After the fracturing is complete, the fluid is removed and the operator can assess its productivity. The operator installs new production pipe and connects the well to a gathering and pipeline system. The well begins producing. The expected life of the well is 20+ years.

Because of the ability to accurately control the well path using directional drilling equipment, more companies now drill multiple wells from a single well site (or pad). This can minimize the surface disturbance without materially increasing the well costs/complexity.

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