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THE UNIQUE ENVIRONMENTAL IMPACTS OF HORIZONTALLY HYDROFRACKING SHALE

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The hydrofracking of horizontal wells in shale gas formations presents a threat to aquifers that is qualitatively and quantitatively different than the threats posed by vertically fracked wells. The rapid development of this technology has outstripped the ability of most regulatory agencies to effectively deal with the environmental threat to aquifers and surface drinking water over wide areas of the United States where shale gas deposits are found.

1. The horizontal hydrofracking (HHF) of shale strata is similar to exploding a bomb underground. The pressures involved and the amount of fluid moved would qualify it as a large, powerful explosion, capable of producing earthquakes in natural faults, such as the tremor measuring 2.8 on the Richter Scale on June 2, 2009 at Cleburne, Texas – the epicenter of shale gas production. Previously, no earthquakes had ever been recorded there. The pressures, volumes, and horizontal configuration of the well make it more likely that chemicals and natural gas will pollute aquifers than a conventional vertical well.

2. The fracking pressure in a shale gas well must be extreme to break up the rock – as much as 15,000 pounds per square inch (psi).[1] That is equivalent to the water pressure six miles deep in the ocean. By comparison, a thermobaric "air bomb" used in Afghanistan has an explosive pressure of about 500 psi, and it can be heard up to 100 hundred miles away.[2] Shale is notoriously hard to frack. And bombs, including at least one nuclear bomb tested in Colorado, have been used in attempts to break it up.[3] **From a pressure standpoint, the horizontal hydrofracturing of shale is effectively the explosion of a massive pipe bomb underground.**

3. Since the fracked area itself can be quite long, the amount of fracking fluids in a shale gas well can exceed a million gallons – the equivalent to about fifty residential swimming pools; or by weight, approximately 2,500 cars. Based on the volume of fluids moved, the fracking of a shale formation amounts to a massive water bomb. Since the lighter fracking chemicals separate out of the frack water, they are more likely to show up as pollutants in aquifers and ground water. This explains their presence in water wells near active shale gas wells.

4. Faulting and Dispersion as Pathways into Aquifers – The fact that the fracked area of a well is horizontal and of a considerable length simply increases the odds that some vertically and inclined faulting or localized faulting will be encountered (Figure 1). Since shale has relatively low permeability, the well has to be fracked repeatedly in order for it to continue to produce. Such multiple fracks simply increase the odds that the gas will either go out of zone via faulting, or out of the well bore via faulty casing. In either case, area ground water and aquifers are vulnerable to be polluted first by escaped natural gas, and subsequently by fracking fluids, including toxic chemicals such as benzene, which will separate out of the frack water over time.

[1] http://en.wikipedia.org/wiki/Hydraulic_fracturing
[2] http://en.wikipedia.org/wiki/Thermobaric_bomb
[3] http://en.wikipedia.org/wiki/Rulison

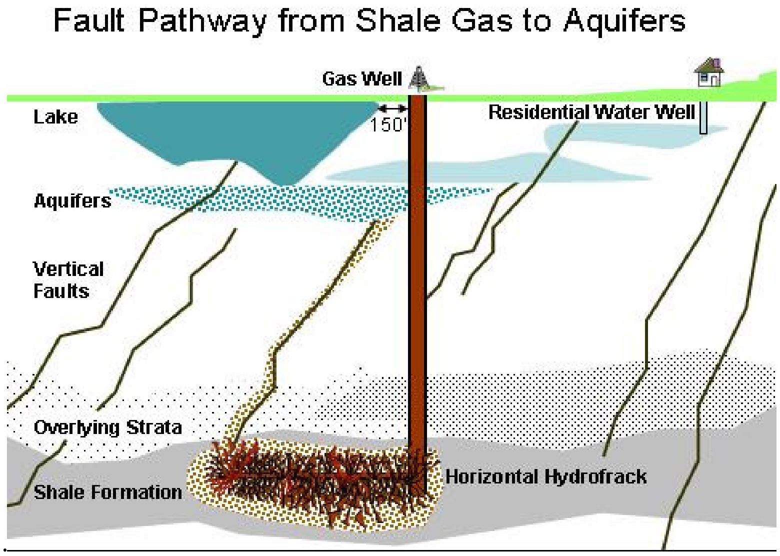

Figure 1.

Since 3-D seismic is not typically done on shale gas laterals, there is a significant risk of encountering faulting. As quoted in a recent report on an article in E&P (*Exploration & Production)* Magazine: "One statement of Brooks' that I have trouble with, having myself worked several Gas Shale Plays utilizing 3D Seismic, is that 'Blanket formations have reduced the need for seismic analysis to identify drilling prospects.' (p. 8). With proper interpretation, disasters can be avoided, and the wise operators avail themselves of 3-D Seismic to prevent those disasters. Faulting of the objective Gas Shale, if not addressed, can definitely create completion issues or even cause the horizontal laterals to go 'out of zone' if not recognized." [4] This problem of frack fluid dispersion out of zone is not unknown to the EPA, which has studied the phenomenon in similar situations, namely coal bed methane hydrofracking, where the pressures involved are a fraction of those found in shale HHFs: "Therefore, EPA assumes that a greater volume of fracturing fluid must "leak off" to intersecting smaller fractures than what was assumed in the Draft Report, or that fluid may move beyond the idealized, hypothetical 'edge of fracture zone.' This assumption is supported by field observations in mined-through studies, which indicate that fracturing fluids often take a stair-step transport path through the natural fracture system." [5] In layman's language, this means that in shale formations, once the presence and thickness of the formation is established, the drilling companies do not perform further seismic data collection, which would lead to identifying faulting in the area. (This is not the case with most vertical wells, many of which depend on 3-D seismic for success.) HHF may open faults and may increase permeability along laterally and vertically extensive fault planes and fault zones – thereby increasing the risk of contaminant and gas excursions. The NY DEC has underestimated the risk of faulting in their draft GEIS.[6]

The risk of going out of zone in shale gas wells has already been observed locally in the Marcellus Shale by the Pennsylvania Department of Environmental Protection.[7]

> "Dimock Migration, Dimock Twp., Susquehanna County - Cabot Oil and Gas – NCRO - 2009: The Department is actively monitoring domestic water supplies and investigating potential cause(s) of a significant gas migration that has been documented in several homes along Carter Road. Free gas has been encountered in six domestic water supplies and dissolved has been found in several of the wells. The operator has placed pilot water treatment systems on three water supplies. Of particular note is that this area has not experienced previous drilling and recent gas drilling in the vicinity has targeted the Marcellus Shale. "

The phenomenon of gas and fracking chemicals going out of zone has also been studied extensively in developed shale gas formations. As a 2009 Colorado report found:[8]

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[4] http://www.glgroup.com/News/Excellent-Analysis-of-Gas-Shales-Capabilities-Benefits-and-Problems-for-2010-46505.html
[5] http://www.epa.gov/ogwdw000/uic/pdfs/cbmstudy_attach_uic_ch04_hyd_frac_fluids.pdf page 4-12
[6] http://docs.nrdc.org/energy/files/ene_10010401a.pdf Attachment E Review and Analysis of dsGEIS December 28, 2009 Tom Myers, Ph.D.
[7] "Stray Natural Gas Migration Associated with Oil and Gas Wells", draft report by the Pennsylvania Department of Environmental Protection, Bureau of Oil and Gas Management (10/28/09)
[8] Lustgarten, Abraham, "Digging at Mystery of Methane in Wells", Denver Post, 4/22/2009, http://www.denverpost.com/news/ci_12195167

The Garfield County report[9] is significant because it is among the first to broadly analyze the ability of methane and other contaminants to migrate underground in drilling areas, and to find that such contamination was in fact occurring. It examined more than 700 methane samples from 292 locations and found that methane, as well as wastewater from the drilling, was making its way into drinking water not as a result of a single accident but on a broader basis.

As the number of gas wells in the area increased from 200 to 1,300 in this decade, methane levels in nearby water wells increased too. The study found that natural faults and fractures exist in underground formations in Colorado, and that it may be possible for contaminants to travel through them.

If the surface casing is intact, the most likely source of the gas leak is that the frack has hit a faulting. The solution offered - de-pressurizing the well to stem the flow of the gas - is only a partial fix, since gas and fracking chemicals will still leak out of the well into drinking water.

Unfortunately, the lower tier of New York State is riddled with likely major faults (Figure 2) and with localized faulting that has not been sufficiently mapped.[10] If the frack hits any vertical faulting, the faults can be opened up as pathways for the gas and fracking fluid to enter strata above the shale, including aquifers, as noted by a prominent New York hydrogeologist.[11]

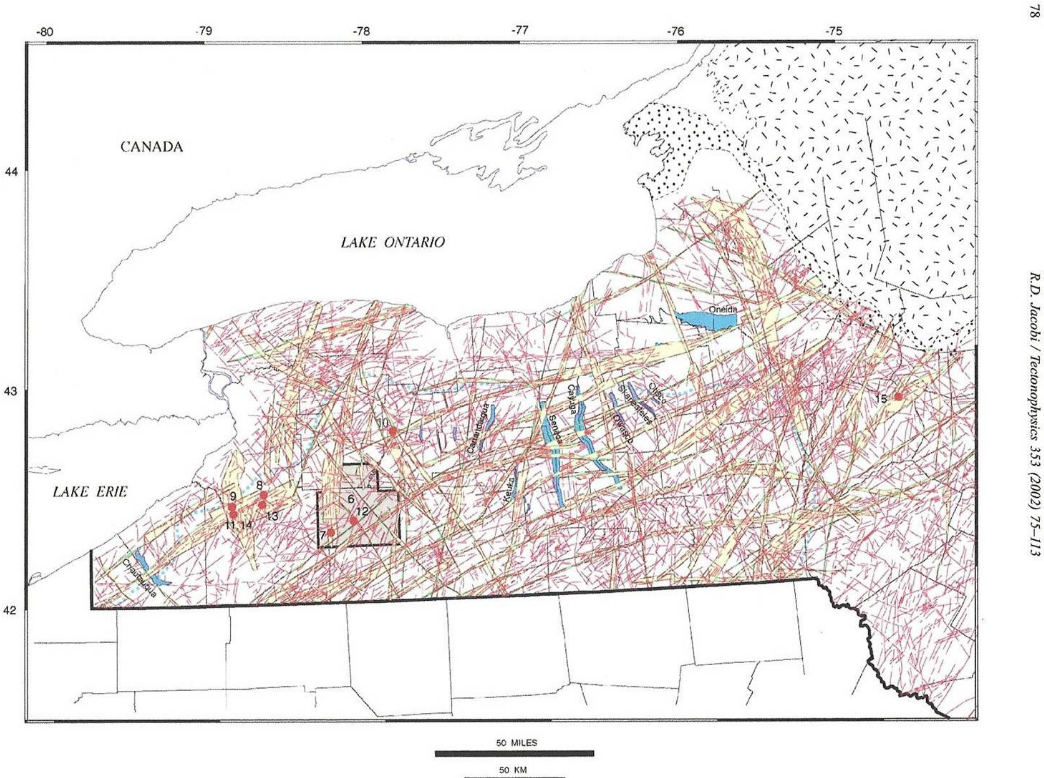

Figure 2: Faults in Southern New York

5. **Higher Porosity and Permeability as Pathways into Aquifers** – In some areas, it is axiomatic that the shale formation is less permeable and less porous than other oil and gas bearing strata. In the Fort Worth

[9]see http://www.garfield-county.com/Index.aspx?page=1143 and Thyne, Geoffrey, "Review of Phase II Hydrogeologic Study Prepared for Garfield County," 12/20/2008. http://cogcc.state.co.us/Library/Presentations/Glenwood_Spgs_HearingJuly_2009/(1_A)_ReviewofPhase-II-HydrogeologicStudy.pdf

[10] Jacobi, Robert D., 2002, "Basement faults and seismicity in the Appalachian Basin of New York State," *in* Neotectonics and Seismicity in the Eastern Great Lakes Basin, R. H. Fakundiny, R. D. Jacobi, and C. F. M. Lewis (eds.): Tectonophysics, v. 353, p.75-113.

[11] Rubin, Paul. "Comments on the Scope of the EPA's Proposed Study of Hydraulic Fracturing." Hydroquest, August 10, 2010. http://63.134.196.109/documents/10aug19_HydroQuestEPAComments.pdf

Basin of Texas, the local Barnett Shale was bypassed for more porous, more permeable strata. When the shale is fractured, the frack may also frack less permeable adjacent strata, or well casing failures can expose such strata to gas pollution. **If these strata communicate with an aquifer, they can serve as a pathway for gas and fracking fluid to get into the aquifer, polluting it. Unfortunately, there are sizeable aquifers over the Marcellus and Utica Shales (Figure 3).**

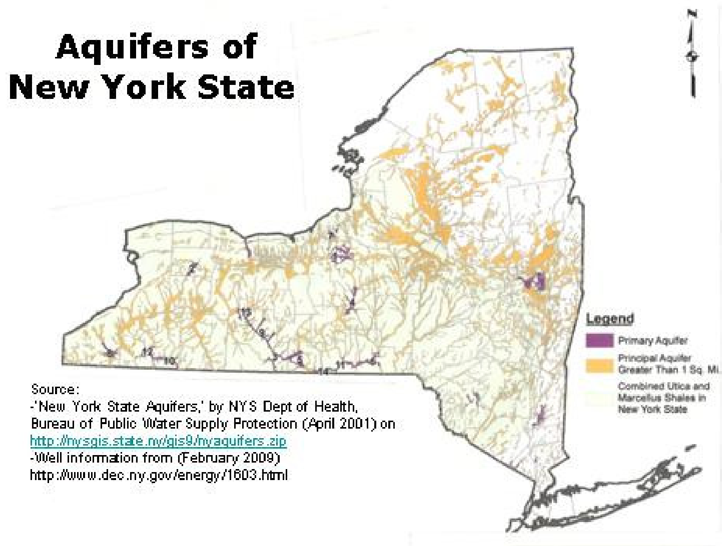

Figure 3.

6. Separation and Migration of Fracking Fluids into Aquifers - While the amount of chemicals in the fracking fluid are small on a percentage basis, they include hydrocarbons, such as benzene and diesel fuel,[12] which are lighter than water (Light Non-Aqueous Phase liquids, LNAP) and can separate from the water after being introduced into the fracked area. If communication is established with an aquifer – either via faulting or via well casing failures - the fracking chemicals, none of which are potable, can rise into aquifers, polluting the water. **When water wells are contaminated by hydrofracking, this separation of the lighter oils accounts for their disproportionate presence in water samples.**

7. Introduction of Natural Gas into Aquifers – Either via faulting or by well casing failure, the natural gas released can enter aquifers. **Since natural gas is made up of non-potable chemicals – propane, butane, methane, etc. – it can and does pollute water-bearing strata.**[13]

8. Horizontal Orientation Increases Likelihood of Pollution – Unlike a vertical well, the lateral section of an HHF is much more likely to go under surface water sources - lakes, streams, springs, and rivers. This in turn increases the likelihood of exposing such water bodies via faulting to fracking fluids and natural gas.

9. Size of the Formation – The extent of shale gas formations in the United States is extensive – far greater than other oil and gas formations, including some considered giants, like the Permian Basin.[14] These shale gas deposits are often located near heavily populated areas – as in New York – which are far more environmentally fragile than oil fields in flat, xeric environments, such as the Yates Field in New Mexico. **The extent of the shale gas deposits should be sufficient reason for heightened environmental controls.**

10. Lack of Protection for Municipal Surface Drinking Water – Regulatory oversight of HHF near drinking water sources varies dramatically from state to state. For instance, in Texas, virtually all municipal surface drinking water sources are reservoirs owned or controlled by municipal water districts or municipalities. Drilling next to or under such a reservoir would come under the scrutiny of the municipality that owns the water. No such protections are available to most New Yorkers. The municipalities that use state-owned lakes for drinking water do not control the lakes or the shoreline. New York City is an exception to this, since it owns and operates its drinking water reservoirs. **Other New York citizens have no such jurisdictional safeguards.**

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[12] http://en.wikipedia.org/wiki/Hydraulic_fracturing
[13] http://en.wikipedia.org/wiki/Benzene
[14] http://en.wikipedia.org/wiki/Marcellus_Formation

11. **Conclusions and Recommendations** – While the toxicity of the chemicals used in horizontal hydrofracking of shale gas may be no worse than in vertical conventional wells, the process has unique characteristics that make aquifers more vulnerable to this technology, particularly in areas where significant faulting exists but is poorly understood, such as New York. **The horizontal hydrofracking of shale gas is a potential delivery mechanism for toxic chemicals and natural gas into aquifers on a regional scale.**

    a. The pressures involved in HHF shale gas wells are massive. If the frack enters verical faulting or if the well casing fails, the immense pressures can expose areas outside the shale to gas and fracking fluids.

    b. The horizontal orientation of the fracked area increases the odds that faulting will be encountered. Such horizontal orientation also increases the likelihood that a HHF well will go under surface water sources – rivers, streams and lakes – potentially exposing them to pollutants via faulting.

    c. Municipal surface drinking water is particularly vulnerable to being polluted by HHF activity, if the users of the drinking water – the municipalities – do not own the water source. They will have no oversight over drilling near or under the lakes that supply their water. The extent of shale gas deposits in the United States threatens many such water supplies.

` **We recommend the following:**

Drilling And Fracking Should Be Subject To The Safe Drinking Water Act, as they were prior to 2005.

Collect and Analyze Seismic Data On Each Lateral To Be Fracked. Such seismic data will show if any faulting is present in the target fracking zone and if that faulting communicates with any aquifers. This will address the risks of polluting aquifers via localized faulting. If the seismic data show that there is any chance that the frack zone will communicate with an aquifer, drilling and fracking should not be allowed to proceed. Seismic data should be used as a risk mitigation measure before and after fracking in order to show that the frack has not exacerbated the fault aperture.

Eliminate Toxic Fracking Fluids Many of the problems associated with chemicals going into aquifers can be addressed by using non-toxic MSDS benign fracking chemicals[15] and/or by greatly reducing the volume of fluids and chemicals employed, as with propane fracking.[16] However, the risk of natural gas escaping into aquifers is best addressed by preventative seismic analysis and more rigorous well bore controls.

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[15] http://www.ewg.org/agmag/2010/01/fractured-logic-the-peril-in-“fracking”-chemicals/
[16] http://www.gasfrac.com/fracforward.pdf