CHAPTER IV

IMPACTS of HYDRAULIC FRACTURING and NATURAL GAS DRILLING OPERATIONS on WATER QUALITY and SUPPLY

One of the most important considerations in a discussion of potential impacts of natural gas drilling operations is the impact on water quality in the Town of Rensselaerville. This chapter will focus upon the potential for surface and groundwater contamination and the impact on water quality.

The purpose of the 1992 GEIS and proposed dSGEIS 2011, is to identify potential environmental impacts, address the impacts, and propose mitigation or prohibition of identified impacts. DEC proposes to require via permit and/or regulation, natural gas extraction operations[1] throughout the State, exclusive of areas that DEC has exempted from such drilling operations.[2]

Both DEC documents sited above list problems that could have significant adverse impacts on water resources: spills or releases as a result of tank ruptures, equipment or surface impoundment failures, overfills, vandalism, accidents (including vehicle collisions), ground fires, or improper operations; spilled, leaked or released fluids could flow to a surface water body or infiltrate the ground, reaching subsurface soils and aquifers. Problems can also result from gas migration to enclosed areas (such as a house, shed) causing explosions, and poor well construction (i.e. cement and casing problems). Mitigation measures for adverse impacts on water resources are described in both documents.

6.1 Water Resources (dSGEIS)

"Protection of water resources is a primary emphasis of the Department."

With regulatory and mitigation measures in place in other states, many cases of surface water and ground water contamination, air pollution, and other environmental impacts can be identified. (See Appendix 4 for a partial listing of incidents.)

IS THERE a HISTORY of SURFACE WATER and/or GROUNDWATER CONTAMINATION in NYS?

Steven Russo, Deputy Commissioner for the DEC, at a recent conference when referring to hydraulic fracturing stated, *"Things happen. Spills occur. Things go wrong."* [3]

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[1] Operations include drilling, completion, stimulation, reclamation, production, maintenance, and plugging and abandonment of a well. 1992 GEIS Chapter 16, p.1.

[2] dSGEIS, September, 2011, Executive Summary, p 2.

[3] Association of Towns of the State of New York Annual Meeting, New York City, February 21, 2012.

Historically, New York State has been a minor producer of oil and gas. During the gas and oil boom of the 1970s-1980s, the majority of active gas wells were in Chautauqua County.[4] These wells were vertical hydraulically fracked wells. In 2007 there were reported to be 6,683 producing natural gas wells in New York, nearly one-half of which were in Chautauqua County.

According to Dr. Ronald E. Bishop, the exact number and types of gas industry incidents that may have polluted ground water in NYS is unknown as some problems are reported to the DEC spills hotline, some problems are reported directly to DEC field offices, or to county health departments. These reports have not been combined.[5]

From DEC dSGEIS, 2011:
"No documented instances of groundwater contamination from previous horizontal drilling or hydraulic fracturing projects in New York <u>are recorded in the Department"s well files or records of complaint investigations</u>. (Underline noting a changed from the 2009 dSGEIS and 2011 dSGEIS.) *No documented incidents of groundwater contamination in public water supply systems could be recalled by the NYSDOH central office and Rochester district office (NYSDOH, 2009a; NYSDOH, 2009b). References have been made to some reports of private well contamination in Chautauqua County in the 1980s that may be attributed to oil and gas drilling (Chautauqua County Department of Health, 2009; NYSDOH, 2009a; NYSDOH, 2009b; Sierra Club, undated). The reported Chautauqua County incidents, the majority of which occurred in the 1980s and which pre-date the current casing and cementing practices and fresh water aquifer supplementary permit conditions, could not be substantiated because pre-drilling water quality testing was not conducted, improper tests were run which yielded inconclusive results and/or the incidents of alleged well contamination were not officially confirmed."*[6]

However, the Chautauqua County Department of Health, Division of Environmental Health Services, received numerous complaints of surface water contamination resulting from above ground well drilling activities and "suspected" groundwater contamination of private drinking water wells associated with drilling operations and hydraulic fracturing. The associated letter states that the recorded complaints were probably *"just a fraction of the actual problems that occurred*." The Chautauqua County Health Department responded to 120 complaints between 1986 and 1988 and, as drilling activity decreased, so did the complaints. A representative from NYS DEC Division of Minerals insisted that the potential for drinking water well contamination from oil and gas well drilling is almost non-existent.[7] (See Letter Dated July 30, 2004, Chautauqua County Department of Health, Appendix 4)

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[4] "Disposal/Recovery Option for Brine Waters from Oil & Gas Production in New York", (Energy Authority Agreement No. 1591-ERER-RIER-91) Mark R. Matsumoto & others, SUNY at Buffalo, October 9, 1992.
[5] "Chemical and Biological Risk Assessment for Natural Gas Extraction in New York," Ronald E. Bishop, Ph.D. CHO, Chemistry & Biochemistry Department, State University of New York, College of Oneonta, March 28, 2011, pp. 8-9.
[6] dSGEIS, p. 2-24.
[7] Letter "Impacts of Gas Well Drilling to Drinking Water Wells," William T. Boria, Water Resource Specialist, Chautauqua County Department of Health, Division of Environmental Health Services, July 30, 2004.

An earlier letter dated October 29, 1984 from Roger Waller, US Department of the Interior, also addresses the "*methane-gas problem*" in Chautauqua County and states *"(methane gas) may also migrate vertically for hundreds or thousands of feet laterally or vertically if a system of interconnected fractures exists to permit this migration."* (See letter dated October 29, 1984, Appendix 4) Or, the contamination reports may be due to poor cement and casing, naturally present fractures that enable migration of fluids and gases when there is a gradient change from drilling activities, earthquakes, or injection pressure.

More questions are raised concerning the impact natural gas drilling operations have on NYS's water quality, environmental and public health from information contained in two letters: one from former DEC Commissioner Alexander Grannis, and one from Walter Hang, President of Toxic Targeting, Inc., Ithaca, NY. (See letters in Appendix 4). There seems to be a difference of opinion as to whether or not the incidents are related to natural gas drilling operations, specifically to *"stimulation"* or hydraulic fracturing, and concern about the handling of regulatory workload.

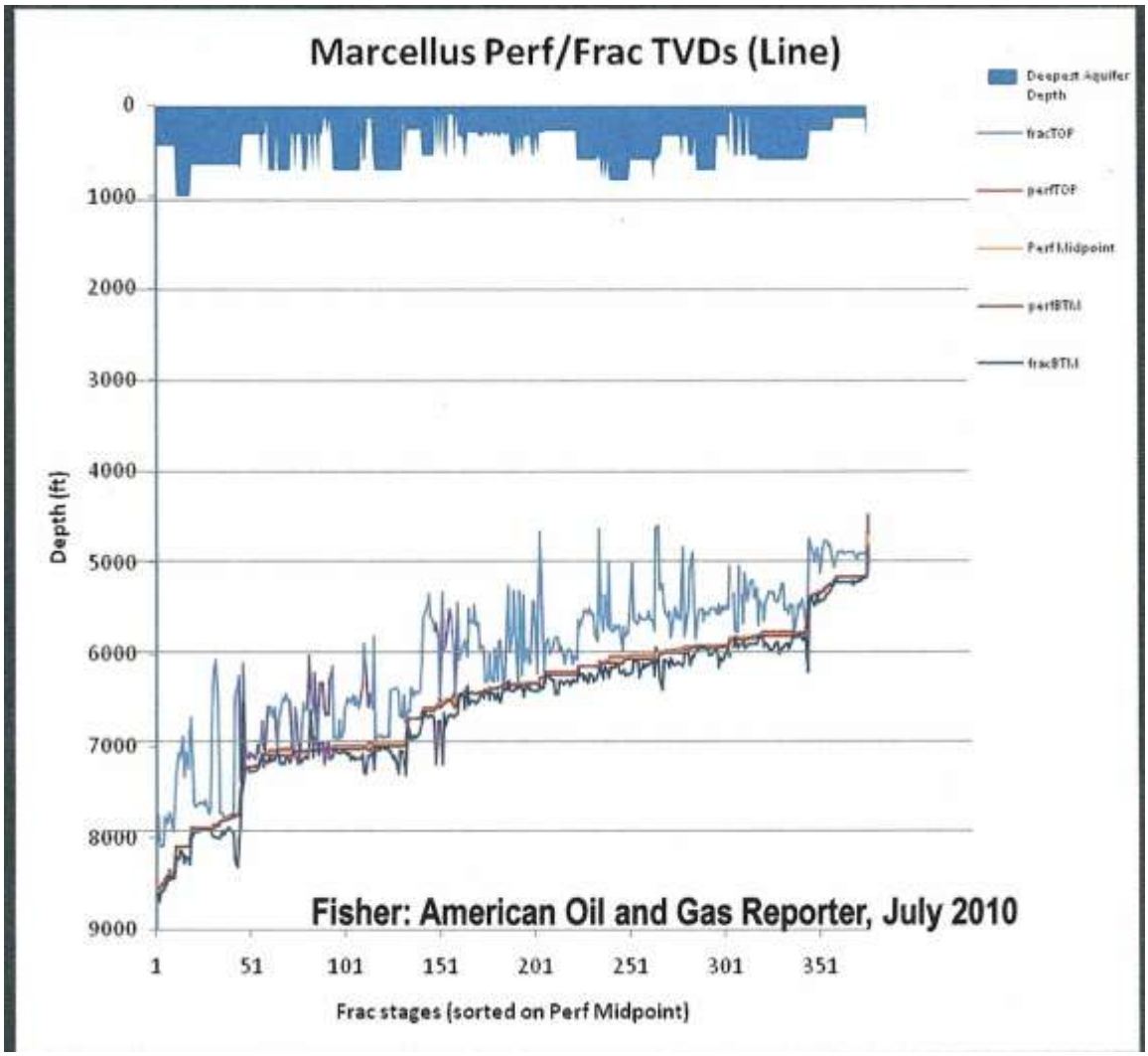
Although DEC officials claim that there have been no instances of groundwater contamination from hydraulic fracturing, the evidence above shows that there is a history of water contamination in NYS from natural gas drilling operations, but the full extent is unknown.

IS THERE POTENTIAL for SURFACE & GROUND WATER CONTAMINATION in the TOWN OF RENSSELAERVILLE?

The natural gas industry claims hydraulic fracturing does not contaminate groundwater or underground drinking water aquifers. Part of the rationale for this argument is:

- the process of hydraulic fracturing occurs thousands of feet deep in the ground and is separated from groundwater by a great distance, and

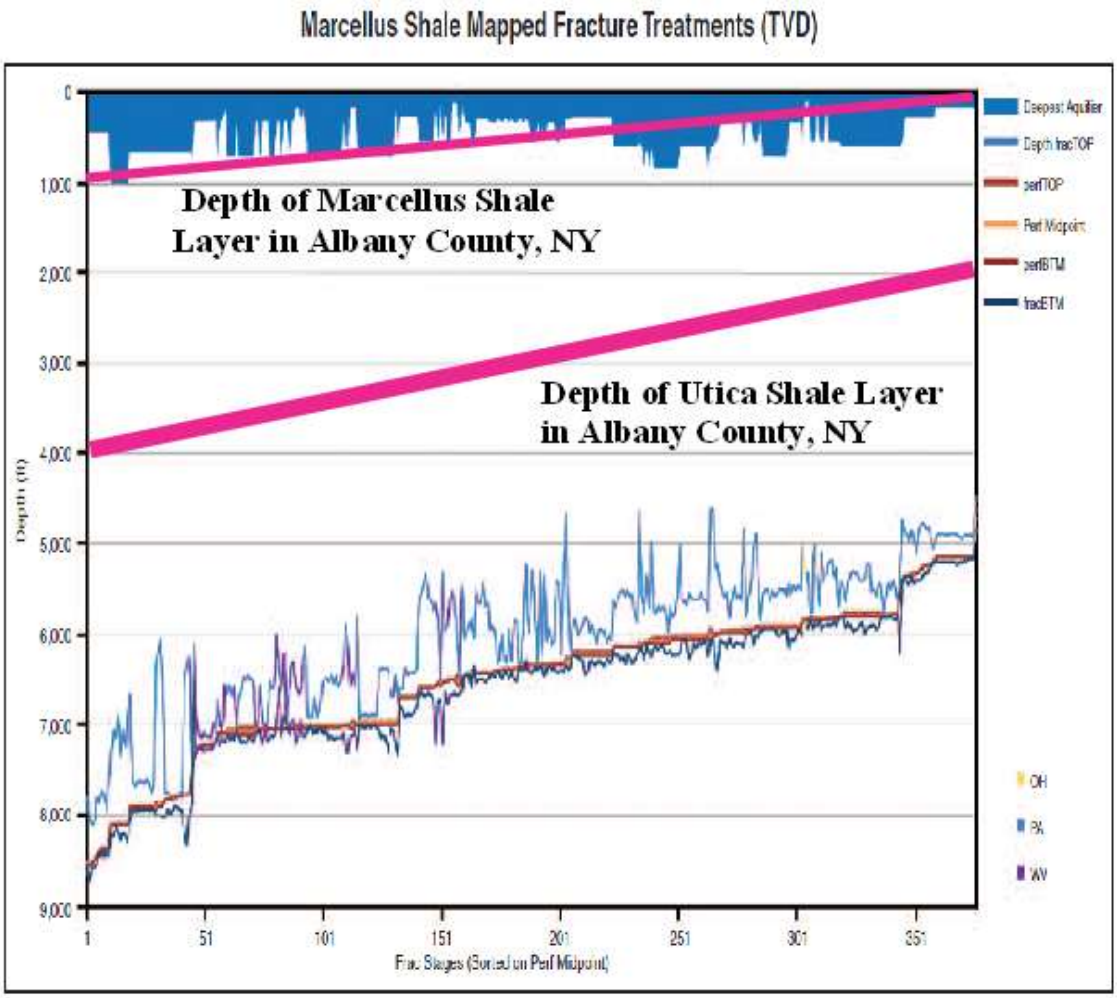
- the process of hydraulic fracturing is also separated by numerous layers of impermeable rocks.



<u>CAN IT BE SHOWN that the PROCESS of HYDRAULIC FRACTURING OCCURS THOUSANDS of FEET DEEP in the GROUND and is SEPARATED from GROUNDWATER by a GREAT DISTANCE THEREBY PROTECTING DRINKING WATER?</u>

A compelling report to support this gas industry rationale stated above comes from an article written by Kevin Fisher, a general manager of Pinnacle, a Halliburton Service. The graph above shows plots of data collected of hydraulic fracturing in the Marcellus Shale in the Appalachian Basin. The report also charts hydraulic fracturing in Barnett Shale since 2001 in the Fort Worth Basin, Texas, at depths between 5,000 to 10,000 feet. The depths shown are in true vertical depth, and places the largest upward growth of all these mapped fractures several thousands of feet below the deepest known aquifer level charted. It is claimed that this is evidence of *"a very good physical separation between hydraulic fracturing and water aquifers."* It is further stated that the shallowest fracture tops are still approximately 4,500 feet below aquifers.

Hydraulic fracturing in the TOR would occur much closer to the surface than the industry graph above indicates.



Marcellus and Utica shale in the Town of Rensselaerville[8]:

Depth of Marcellus shale:	<1,000 feet to rocky outcrop
Thickness of Marcellus shale:	<50 feet to 100 feet
Depth of Utica shale	2,000 feet to 4,000 feet
Thickness of Utica shale	300 feet to 350 feet

Some TOR citizen's drinking water wells are >400 – 800 feet deep, drilled into bedrock aquifers. The depths of the Marcellus shale and Utica shale in the Town of Rensselaerville do not show thousands of feet of vertical separation described by Fisher necessary to claim that bedrock aquifers and unconsolidated aquifers will be protected from contaminants used in the hydraulic fracturing process.

[8] MCOR www.marcellus.psu.edu

A study released in February, 2012 by the Energy Institute at the University of Texas at Austin states *"there is at present little or no evidence of groundwater contamination from hydraulic fracturing of shale at* ***normal*** *depths.** (*footnoted in this study: *'Apparently in some cases, such as the Pavilion area, Wyoming, fracturing has been performed at depths shallower than* ***normal*** *for shale gas wells, which are typically more than 2,000 to 3,000 feet deep.'*)
No evidence of chemicals from hydraulic fracturing fluid has been found in aquifers as a result of fracturing operations. …it appears that the risk of such chemical additives is greater from surface spills of undiluted chemicals than from actual fracturing activities."[9] The report ends with these statements: *"Gaps remain in understanding, especially in cumulative and long-term impacts. We are hobbled by a lack of baseline information."* This is a significant argument against fracking.

The EPA Pavillion, Wyoming Draft Groundwater Investigation released on December 8, 2011 finds that chemicals detected in samples are consistent with migration from areas of gas production, and that samples showing chemicals, like glycols and alcohols are consistent with gas production and hydraulic fracturing fluids, including benzenes in concentrations well above Safe Drinking Water Act standards, and high methane levels. EPA indicates concern about the area's complex geology and the proximity of drinking water wells to groundwater contamination and the migration of contaminants within the aquifer and the safety of drinking water wells over time.[10]

- The drilling depths of Pavillion, Wyoming and drilling depth to Utica shale in the Town of Rensselaerville are similar.

- The domestic water wells in the Pavillion, WY study area range in depth from approximately 20 feet to 800 feet, which are similar to the water well depths in the TOR.

- Pits were used for disposal of drilling cuttings, hydraulic fracturing flowback from the drilling formation. NYS allows such practices under the 1992 GEIS, which may apply to any potential vertical wells if gas drilling were to be permitted in the TOR.

- Encana Oil & Gas (USA) a major stakeholder in the Pavillion gas fields responded that the EPA's findings are "*conjecture, not factual and only serve to trigger undue alarm.*"[11]

- Another major stakeholder, Natural Resources Defense Council, responded that the EPA Draft Report's findings underscore the importance that hydraulically

[9] "Fact-Based Regulation for Environmental Protection in Shale Gas Development," Charles G. Groat, Thomas W. Grimshae, Energy Institute, The University of Texas at Austin, February, 2012, p. 22.
[10] "EPA Releases Draft Findings of Pavillion, Wyoming Ground Water," EPA, December 8, 2011.
[11] "EPA Draft Report of Groundwater Contamination Near Pavillion, Wyoming: Main Findings and Stakeholder Reponses," Peter Folger and others, Congressional Research Service, R42327, January 25, 2011, p. 12.

fractured wells be located in a *geologically suitable location where a confining zone is present*, and that *all potential contamination pathways be identified and mitigated to prevent contamination of underground sources of drinking water*.[12]

- Pro Publica, an independent nonprofit news service stated that some of the findings in the report *"contradict what the drilling industry has argued about why fracking is safe*."[13]

- *"The close vertical proximity of natural gas development activities and the bottom of the drinking water aquifer means that injected fluids would not have to travel far to reach the aquifer, provided the fluids had a suitable pathway. Put another way, at Pavillion there is less rock between the gas development activities and the aquifer. In contrast, deeper shale gas reservoirs, such as the Marcellus Shale in the northeast United States, are separated from overlying drinking water aquifers by* ***thousands of feet of rock*** (HF committee emphasis) *in areas under active development."*[14]

Another study[15] released on March 29, 2011, among its objectives, focuses on NYS's Marcellus shale region and uses simplified models and worst-case release scenarios to evaluate drinking water risks due to surface releases to groundwater and surface water, and hypothetical migration from Marcellus to drinking water aquifers. The study concludes that transport of contaminants via fractures is highly unlikely in Marcellus shale to aquifers as they are separated by thousands of feet of low conductivity rock, and sites Kevin Fisher's report as evidence. The report also claims that HF induced fractures are expected to be constrained. However, Fisher's graph charts induced fractures nearing 2,000 feet in length, at a depth of about 6,000 to 8,000 feet deep. "*Generally at shallower depths there is a greater tendency for more numerous and wider (more transmissive) fractures because of the diminishing confining pressure of overlying rocks. There is some probability that this would be a problem in the Rensselaerville area. There is not enough information to tell for certain, and importing data from other regions lacks site-specificity.*"[16] The study ends with the stated need for EPA case studies to validate their modeling results. One problem with the study is that sometimes modeling and stated conclusions do not fit with the reality of the local hydrogeology, such as in the Town of Rensselaerville. And, needed case studies are coming in, as evident from the Pavillion, Wyoming study that identifies migration of HF contaminants into drinking water wells.

The following should be noted from the dSGEIS, September, 2011:

- *5.8.2 Methods for Limiting Fracture Growth*

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[12] Ibid. p 13.
[13] Ibid. p 14.
[14] Ibid. p 16.
[15] "Modeling Drinking Water Related Human Health Risks from Hydraulic Fracturing (HF) Additives," Manu Sharma, M.S.,P.E., Gradient, Cambridge, MA, EPA Workshop, March 29, 2011.
[16] Dr. Arthur N. Palmer, March 4, 2012 email to J. Rice.

"ICF reports that, despite ongoing laboratory and field experimentation, the mechanisms that limit vertical fracture growth are not completely understood."
Although there are modeling suggestions to predict fracture behavior and improved techniques to predict future growth of fractures, the techniques, however, are still imperfect; it seems as though the process is not fully understood, or controllable.[17]

Furthermore, *Microseismic Monitoring of Hydraulic Fractures:*
*"Microseismic evaluation of hydraulic fracture development is a geophysical method applied by some gas companies to monitor the horizontal and vertical extent of fracture propagation. Data from the gas industry for Marcellus hydraulic fractures suggests that the upward vertical extent of the fractures decreases with decreasing depth with fracture heights of 2,000 feet at a depth of 8,000 feet and 500 feet at a depth of 5,000 feet (Fisher, 2010). In New York State, the Marcellus shale likely will be hydraulically fractured at depths between 3,000 and 5,000 feet, a depth interval for which virtually no microseismic data has been collected. Although microseismic (*monitoring*) is a proven industry technique, mapping the extent of hydraulic fractures using this geophysical method is not required by the revised dSGEIS even during the initial stages of shale-gas development in New York State. Provision to supply these data to the State would allow the public to better understand the lateral and vertical extent of fractures created during the hydraulic fracturing process."*[18]

There is no information in the GEIS or dSGEIS to show what vertical fracture growth height would be in the Marcellus shale or Utica shale at 2,000 – 4,000' depths. Nor is there site-specific information to show the horizontal distance that a fracture would propagate such as at the shallower depths found in the Town of Rensselaerville.[19]

Geophysical investigations of the integrity of hydraulic fracturing barriers are generally done as part of natural gas exploration. However, the documentation of rock or barrier continuity and integrity is not required by the dSGEIS.[20]

A study released on April 24, 2012 from Durham University, UK, states that based on observations, it may be prudent to adopt a minimum vertical separation distance significantly in excess of 0.6 kilometres (1968.5') for stimulated fracturing in shale reserves particularly for new exploration areas where there is no existing data. Again, this points to concern about vertical separation distance of potential hydraulic fracturing and the water aquifer in the TOR area and that induced fractures may intersect with naturally occurring fractures, providing increased pathways for contaminant migration.

The depth and proximity of the Marcellus and Utica shale formations in the Town of Rensselaerville to groundwater or bedrock aquifers indicate that there is *less* vertical

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[17] NYS DEC rdSGEIS, September, 2011, 5-90.
[18] "U.S. Geological Survey, New York Water Science Center Comments on the rdSGEIS," John Williams, jhwillia@usgs.gov pp. 8 – 9.
[19] "Report to NRDC," Harvey Consulting, LLC., January, 2012, p. 77.
[20] "U.S. Geological Survey, New York Water Science Center Comments on the rdSGEIS," p. 8.

separation, or *"buffer zone"* between gas bearing target zones and aquifers, or drinking water sources, as shown in Fisher's graph above.

CAN IT BE SHOWN that the PROCESS of HYDRAULIC FRACTURING is also SEPARATED by NUMEROUS LAYERS of IMPERMEABLE ROCKS, THEREBY PROTECTING DRINKING WATER?

The natural gas industry also claims that any hydraulic fracturing activity will be separated by layers of impermeable rocks, thereby protecting groundwater.[21] The development of natural gas relies upon the vertical separation of distance and low permeability of separating rock strata to prevent migration of fluids between the gas bearing formations and shallow aquifers.

The following is from the Town of Rensselaerville Comprehensive Plan, 2007:

The underlying bedrock in the TOR consists of Middle Devonian rocks. The oldest exposed rock are those of the Lower Hamilton Group and consist of fossil-rich, thin-bedded sandstones inter-bedded with dark bluish to greenish shale. This is exposed at lower elevations in the Town. At the highest elevations, lands consist of inter-layered red and gray shale, siltstone, and sandstone beds. [22]

Most citizens' water wells in the TOR use bedrock aquifers as the sole source of drinking water. Some wells are drilled into unconsolidated aquifers, mainly in the valleys. The wells drilled in areas that are highest in elevation have a median yield of 6 gpm (gallons per minute), while the rest of the town has a median well yield of 8 gpm. Some water wells drilled in valleys and along streams have an average yield of 15.1 gpm.[23]

Water quality data indicates that the majority of bedrock water wells in Rensselaerville have elevated levels of iron (above the maximum contaminant level). About 10% of the wells have elevated chloride. These wells with higher salinity tend to be deeper than less saline wells. The median depth for saline wells is 443 feet, compared to a median well depth of 282 feet for wells without any reported water quality problems. Methane and sulfur is also present in some well water.[24] Chloride levels are slightly elevated in the Ten Miles Creek, Crystal Lake, and Sikule Pond area, and it is likely those areas of higher salt are from surface water run-off from road salting.[25]

The evidence that there is high chloride content, iron, and methane in some deeper Town of Rensselaerville water wells, is an indication that any impermeable barrier has already been naturally compromised, allowing the upward migration of chloride, methane, and iron from deeper layers into water wells. These naturally occurring fractures create hydraulic pathways between formations, and can be further compromised and propagated

[21] "Data Confirm Safety of Well Fracturing," Kevin Fisher, The American Oil & Gas Reporter, July, 2010
[22] TOR CP, p. 261.
[23] TOR CP, pp. 95-99.
[24] TOR CP, p. 266.
[25] TOR CP, p. 291, 297.

to intercept other naturally existing fracture during natural gas well development and stimulation or fracking.[26]

According to internationally known hydrologist, Dr. Arthur N. Palmer, *"It's inevitable that there are some natural fractures in the Town of Rensselaerville that extend to great depth. The town is located in an area of high relief, at the NE edge of the Appalachian Plateaus, where stresses from gravity, plus internal stresses within the earth's rocky crust, are able to produce major fractures that extend to great depth. As is true elsewhere, most fissures are relatively small and tight, but there are probably many major ones in the Rensselaerville area because of its geologic position… The elevated chloride, methane, and sulfur support the contentions that there are deep fissures. Also, the depth of water wells cited[27] is unusually great. Elsewhere, most* (water wells) *do not penetrate more than a few hundred feet."*

There is concern that deep fissures naturally present in the Town of Rensselaerville bedrock extend through the Utica shale:
"The best documentation of deep fissures is the escape of gases and nasty fluids (saline, sulfur-rich) into normal water wells. Bob Jacobi used emanations of that sort to help map his fractures.[28] Except for tracking seismic data generated by movement along faults, traditional geophysical methods are poorly effective in mapping normal fractures. Some large faults (with displacement of beds) can be mapped because the layers don't match on either side. But the geophysical methods capable of mapping simple fractures are very uncertain and require a lot of experience and guesswork. All of the features listed are potential pathways for contaminants, but it would be impossible to say unequivocally that there are fractures that communicate with the Utica Shale. However, there's a chance that some do. As much as we know about geology, when it comes to local details such as specific fractures, not much can be predicted without extraordinary cost and effort. None of the maps show the depths of these features, because the depths vary so much, and their traces are visible only at the surface. Even at the surface, most of them are obscured by soil. The topic has to be approached from the standpoint of probability. The only valid source of this kind of information is contamination events that can clearly document." (Dr. Arthur N. Palmer)

Also, it is *"faulty thinking"* that there is a natural protective barrier between the Marcellus and Utica shale that will unequivocally protect drinking water: "*The Marcellus is underlain by about 100 ft of Onondaga Limestone, which contains large fractures and bedding-plane partings (approx horizontal fissures between layers, very irregular ones). Beneath there's insoluble sandstone, siltstone, and some shale, then another 100 ft of limestone (cliffs at Thacher Park). Beneath that is more shale & sandstone above the Utica Shale. All of them can leak, especially the limestones. Karst is rarely significant at depths of thousands of feet, but it's very abundant near the surface -*

[26] "Final Impact Assessment Report," NYC DEP, Hazen & Sawyer, Environmental Engineers & Scientists, December 2009, p. 13.
[27] TOR CP and NYS DEC "Water Well Information" water well 807' deep, yield (GPM) 5.0.
[28] "Basement Faults and Seismicity in the Appalachian Basin of New York State," Robert D. Jacobi, UB Rock Fracture Group, Geology Department, SUNY at Buffalo, April 26, 2002.

a big threat where leakage at well-heads may take place. Even at great depth a few conduits can form by deep-seated fluids rising toward the surface (natural ones)."
(Dr. A. Palmer)

The Petroleum Technology Transfer Council's manual for independent oil and gas operators outlines the risks of hydraulic fracturing stimulations penetrating into water-bearing zones even when shale barriers are present. *"Even if natural barriers, such as dense shale layers, separate the different fluid zones and a good cement job exists, shales can heave and fracture near the wellbore. As a result of production, the pressure differential across these shales allows fluid to migrate through the wellbore. More often this type of failure is associated with stimulation attempts. Fractures break through the shale layer, or acids dissolve channels through it."*[29]

The following conclusion was made in the Executive Summary, "*Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing Coalbed Methane Reservoirs,"EPA,* 2004 study:

"Based on the information collected and reviewed, EPA has concluded that the injection of hydraulic fracturing fluids into CBM wells poses little or no threat to USDWs and does not justify additional study at this time."[30]

However, the following is also taken from the same 2004 EPA study:

"The extent of the fractures is difficult to predict because it is controlled by the characteristics of the geologic formation (including the presence of natural fractures), the fracturing fluid used, the pumping pressure, and the depth at which the fracturing is being performed. Fracture behavior through coals, shales, and other geologic strata commonly present in coal zones depends on site-specific factors such as the relative thickness and in-situ stress differences between the target coal seam(s) and the surrounding geologic strata, as well as the presence of pre-existing natural fractures. Often, a high stress contrast between adjacent geologic strata results in a barrier to fracture propagation. An example of this would be where there is a geologic contact between a coalbed and an overlying, thick, higher-stress shale."

"Fluid injection into gas wells is suspected of opening up and unbalancing existing fractures and faults. An EPA study of 2004 found that fracture fluids 'leak off' and often take a stair-step transport path through the natural fracture system" ("*Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing Coalbed Methane Reservoirs", p. 12***)** *"Some contaminants may arrive [in aquifers and water wells] rapidly via fractures, while others may arrive over decades or centuries….Long term chronic exposure to numerous unknown and untested chemicals [in drinking water] presents a great health risk." (Paul A. Rubin, hydrogeologist, Hydroquest*)

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[29] "Produced Water and Associated Issues – Manual for the independent operator," Rodney R. Reynolds, Prepared for the South Midcontinent Region of the Petroleum Technology Transfer (PTTC) and Oklahoma Geological Survey (OK Geological Survey Open-file Report 6-2003). http://www.pttc.org/pwm/pw_stoc.htm#toc2

[30] "Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs," U.S. Environmental Protection Agency, June 2004, EPA Document #816-R-04-003.

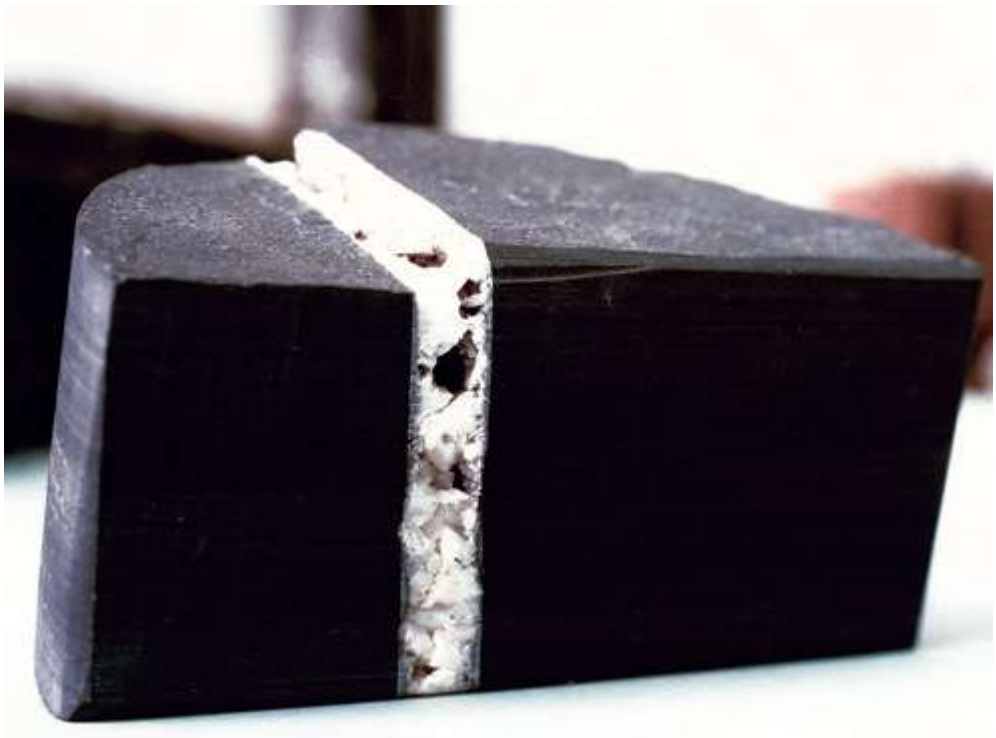


Figure 3. Marcellus Shale drill core from West Virginia, 3.5 inches in diameter, containing a calcite-filled vertical natural fracture. Photograph by Daniel Soeder, USGS.

"From the mid-1970s to early 1980s, the U.S. Department of Energy (DOE) funded the Eastern Gas Shales Project (EGSP) to develop new technology in partnership with industry that would advance the commercial development of Devonian shale gas (Schrider and Wise, 1980). Goals of the project included assessing the size of the resource, estimating recoverable gas, and determining the most effective technology for gas extraction. The EGSP shale stimulation experiments tested a wide variety of hydrofracs and other techniques. Results were somewhat uneven, and DOE concluded that stimulation alone was generally insufficient to achieve commercial shale gas production (Horton, 1982). It was suggested that better success could be obtained by targeting specific formations in specific locations. ***The EGSP results did indicate that if the hydraulic fractures were able to intercept sets of existing, natural fractures within the shale (fig. 3), a network of flowpaths could be created."***[31]

Anecdotal evidence of fractures is reported from a TOR citizen:

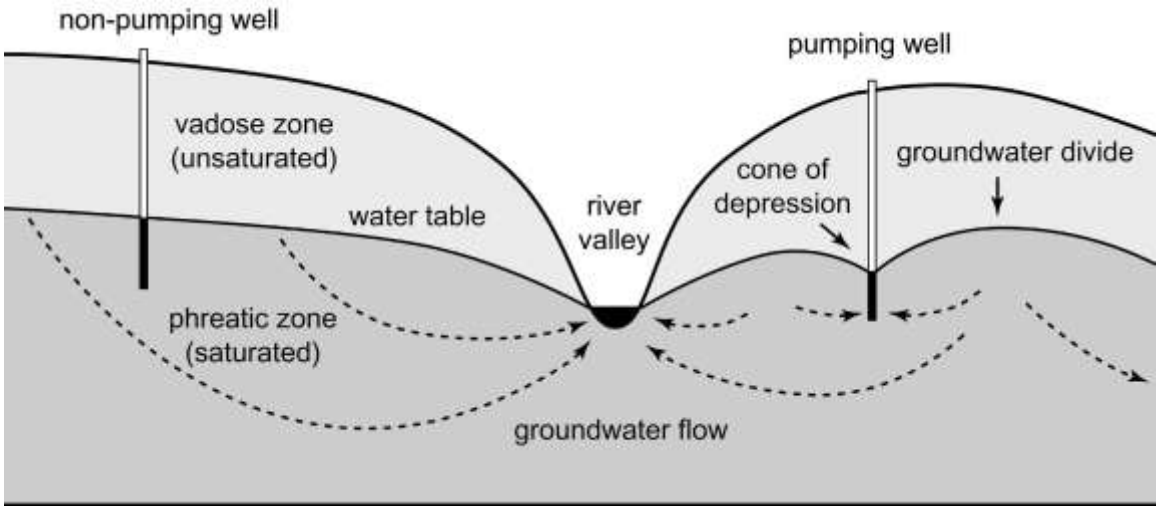
- A Potter Hollow resident, elevation approximately 900 feet, after having their water well drilled to about 200 feet deep (using "pounding" method) learned that a down-hill neighbor, approximately 3/4 of a mile in distance, had their operating well of many years overflow to the point that they had to install a pipe that ran to the road ditch to get the excess water away from their house. The well driller was certain that the fracturing of shale in drilling the water well at 900' induced new

[31] "Water Resources and Natural Gas Production from the Marcellus Shale*,"* Daniel J. Doeder and William M. Kappel, U.S.Geological Survey, May, 2009, p 2.

fractures or widened old fractures, which opened the flow to the neighbor's well. Since that incident, the neighbor's well has returned to normal.

Groundwater Flow:

Water and/or contaminants will follow a natural flow from higher elevations to areas of lower elevations, and will eventually end up in hamlet aquifers of Potter Hollow, Cooksburg, Medusa, Preston Hollow, and Rensselaerville, as the hamlets are in valleys. Should gas extraction operations come to the Town of Rensselaerville, and should contaminants be released into the groundwater, contaminants would spread following this natural pattern of flow. The presence of fractures would increase the contaminant level and speed at which contaminants would move.



Local Pattern of groundwater flow in the vicinity of water wells, before and after gas production. Note the flow paths toward the valleys, interrupted only locally by pumping of wells. (Dr. Arthur N. Palmer)

During hydraulic fracturing activities, the purpose of fracking is to increase the permeability of rock, thereby providing a larger conduit for releasing natural gas. This fracking pressure forces fluids in all directions, especially vertically or horizontally, and the fluids can be driven upward through other layers of rock into aquifers. *"Although typical aquifers are only hundreds of feet below the surface while shale gas production is thousands of feet below, gas and fracking fluid can be driven by the high fracking pressure all the way to the surface if a significant and continuous network of fractures is present."* Naturally present fractures and those that have been created and enlarged by fracking will provide a pathway for fluid migration. Natural fractures tend to get wider upward; they offer the path of least resistance for fluid flow. Movement of contaminants toward the surface is most likely in the vicinity of valleys, where upward-flowing groundwater is dominant.[32]

[32] "Some Concerns about High-Pressure Hydrofracturing of Shale Gas Reservoirs," Arthur N. Palmer, Professor Emeritus, Water Resources, SUNY Oneonta, January 23, 2012.

Groundwater, in addition to any potential natural gas, is the most abundant resource found in bedrock formations. These fluids, along with saline groundwater ("brine") that is characterized by high total dissolved solids, chloride and sulfate concentrations is also common in this kind bedrock. All of these fluids maintain a hydrostatic equilibrium.[33] Disturbance in this equilibrium by hydraulic fracturing is a concern regarding the potential for polluting groundwater. The force applied during hydraulic fracturing can release contaminants and overburden the hydrostatic balance, increasing the travel time of pollutants following natural fractures and the natural groundwater flow to as little as a few years. After stimulation or fracking, the chemicals left underground are still being pushed away from the drill site long after drilling is finished and it can take five to six years before the natural hydrostatic balance returns.[34]

This natural flow of groundwater, in light of natural gas drilling operations, doesn't seem to present a very promising picture for water quality in the TOR.

Setback from Public Drinking Water Supplies:

The Comprehensive Plan identifies three central water supply systems: 1. Rensselaerville Water District No. 1, that serves 82 residences and places of business; 2. NYS Park Police Training Academy (formerly Camp Cass); and 3. The (now) Carey Center for Global Good, which has a privately owned system that serves the public.

dSGEIS September, 2011 Executive Summary, Page 21: *No High-Volume Hydraulic Fracturing Operations within 2,000 feet of Public Drinking Water Supplies*
"The dSGEIS seeks to mitigate the risk of significant adverse impacts on water resources from the risk of surface discharges from high-volume hydraulic fracturing well pads by proposing that high-volume hydraulic fracturing operations at any surface location within 2,000 feet of public water supply wells, river or stream intakes and reservoirs should not be permitted. The dSGEIS proposes that the Department re-evaluate the necessity of this approach after three years of experience issuing permits in areas outside of this setback." This "sunset clause" could potentially allow future drilling closer to water supplies.

"A 2000-ft setback is inadequate for a major water supply, whether it's a reservoir or sand-gravel aquifer in a valley. Groundwater converges on these areas, with much of it moving upward. Chances of contamination may not appear for many years, and they may be undetectably dilute. But if a problem develops, it will be impossible to remediate, no matter what the budget is. Waiting to accumulate three years of data is inappropriate."
-Dr. Arthur Palmer

In addition to having a "sunset clause" after three years of issuing permits, there is a concern of unequal protection of public drinking water supplies. NYC's setback for its

[33] "Impact Assessment of Natural Gas Production in the New York City Water Supply Shed," Hazen and Sawyer, Environmental Engineers and Scientists, December 22, 2009, p. A-6.
[34] "Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers," Tom Myers, April 17, 2012

public drinking watersheds is 4,000 feet. NYC DEP initially requested a **seven mile** setback to protect its watershed and infrastructure from the inherent risks of natural gas extraction operations. DEC Commissioner Joseph Martens could not explain the reason why NYC did not get the protection that they wanted.[35] Seven miles is not excessive, considering that flow into tributaries can contaminate reservoirs.

PRIVATE DRINKING WATER SOURCES

The 500 foot setback distance of gas well pads from private water wells is quite inadequate to protect well water quality, nor is that distance part of the "best regulations" in the country. Indeed, Santa Fe County, New Mexico has a 750 foot setback, and the Town of Flower Mound, Texas has a 1,500 foot setback distance.[36]

"The revised dSGEIS affords limited protection to domestic well owners with a proposed 500 ft buffer around domestic wells and springs unless waived by the homeowner. The 500 ft buffer around domestic wells does not take local geohydrologic conditions and topographic setting into account. Nearly all domestic wells in upland areas tap the fractured bedrock aquifer. The low storage in these aquifers relative to a sand and gravel aquifer means that changes brought about by drilling, including water quality changes, can be felt rapidly at significant distance from a disturbance –especially if a domestic well is downgradient of a well pad. Upland areas of thick till provide some level of protection to local domestic wells from drilling related accidents at land surface. Protection of individual wells on a site by site basis is not feasible; however, siting gas well pads immediately upslope of domestic wells in bedrock aquifer areas should be avoided and well pads should not be sited (as much as possible) where bedrock is exposed at land surface."[37]

The TOR has many areas of bedrock that is exposed at land surface, and bedrock that is close to the surface.

In Chapter 7.1.4.1 of the dSGEIS, the operator will be responsible to test all residential water wells within 1,000' of the well pad, and if no contamination is detected a year after the last hydraulic fracturing event on the pad, then further routine monitoring should not be necessary. And, NYSDOH recommends the water well analysis listed in Table 7.3, which is not intended to constitute a comprehensive evaluation.

- There is no recommendation to pre-test water wells for methane pollution. This pre-test needs to include methane analysis, as methane, as a result of HVHF operations, has compromised and polluted water sources. (Riverkeeper, Sept. 2010, and PA DEP)
- There is no requirement for gas operators to test private water wells for many chemical constituents of fracking fluids, before or after operations cease.

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[35] NYS Assembly Hearing on the rdSGEIS, October 6, 2011.
[36] "Worst Fracking Regulations in the United States", James L. Northrup, Cooperstown, NY. http://www.scribd.com/doc/72545747/Worst-Fracking-Regs
[37] "U.S. Geological Survey, New York Water Science Center Comments on the rdSGEIS," John Williams.

- According to the proposed regulations, gas operators may dispose of any water well testing records 5 years after the completion of gas well activities. Time and example have taught that sometimes contamination doesn't show up until years later. Ex: Love Canal. This can leave the homeowner and user of private water wells as their sole source for drinking water in a discouraging situation.
- If there is suspected pollution, the only recourse a private water well user has is to file a complaint. See dSGEIS, Sept., 2011, Ch. 7, pg. 48. This places the burden of proof on the citizen, leaving them with great legal, financial, and emotional stress.

A 500' setback does not fully protect a Rensselaerville citizen's clean water well resources from the risks involved with gas drilling operations, and should a citizen suspect water well contamination, a large legal, financial, and emotional burden will be placed on the owner of the allegedly contaminated well.

Crystal Lake and Triangle Lake, located in the Northwest corner of the Town of Rensselaerville, are partially fed by springs, and a few Town residents use springs as their sole source of drinking water. *"The impact* (of natural gas drilling operations) *on springs would be about the same as on streams and water wells – all part of the same hydrologic picture."* (Dr. Arthur Palmer)

Water from potentially gas-bearing shale formations is generally not drinkable. However, it is evident from the methane, iron and chloride content in some Town of Rensselaerville water wells, that there are existing fractures that transmit fluids from deeper formations, and should hydraulic fracturing occur in the Town of Rensselaerville, fluids from such operations, including chemicals used in hydraulic fracturing could migrate to water wells. Some chloride detected in surface water downhill from roads probably comes from de-icing salts.

Evidence shows it is not likely an impermeable layer of rocks exists in the TOR separating groundwater aquifers from potential shale layers that may be hydraulically fractured.

In addition to evidence of naturally occurring fractures, the gas industry cannot reliably predict or control the future growth of induced fractures. This leaves the clean water resources of citizens potentially vulnerable to groundwater contamination should HF and gas extraction operations occur in the Town of Rensselaerville.

Well Casing Integrity and Fluids Remaining in the Ground:

According to research by Dr. Ron Bishop, Chemistry & Biochemistry Department, SUNY Oneonta, two to eight percent of shale gas wells developed by the intensive new technologies commonly fail. *"The results have been fouled surface waters and aquifers, polluted soil, contaminated groundwater, decreased livestock birth rates, and deaths from at least one explosion caused by infiltrating gas."* (report sustainableotsego)

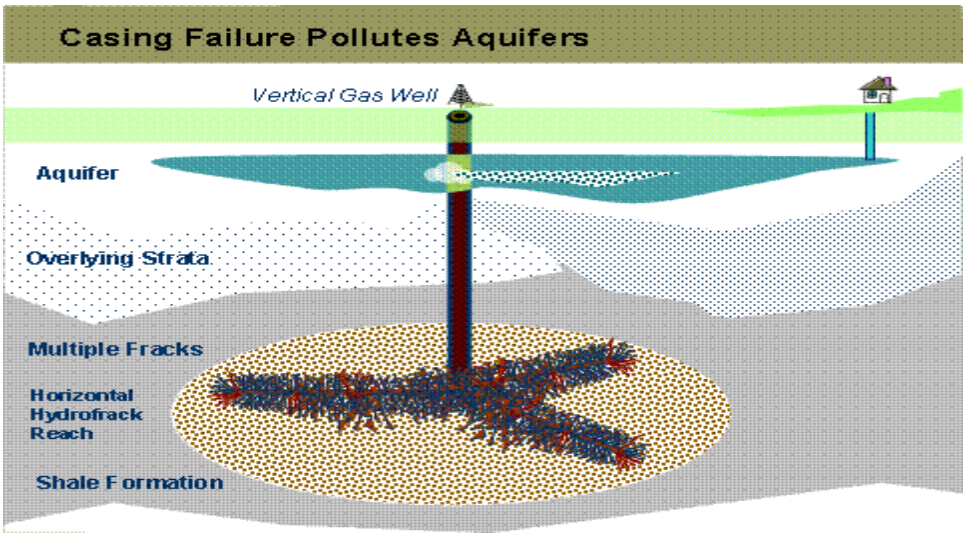

Figure above, *"Potential Leaks from High Pressure Hydro-fracking of Shale",* James Northrup.

"In 1992, the US Environmental Protection Agency (EPA) estimated that of 1.2 million abandoned oil and gas wells in the U.S., 200,000 were leaking. This represents a 16.7% failure rate; one of every six abandoned wells is releasing its contents to the surrounding area, including the surface."[38]

There is evidence that chemical contaminants used for drilling and hydraulic fracturing, and the volume of chemicals that will remain in the ground after natural gas extraction operations cease can leach off or leak into the surrounding area.

The 1992 GEIS addresses well casing corrosion and deterioration due to the corrosive chemical environment and age. Although the gas industry states that it will be using improved materials, the dSGEIS does not address the cumulative impact of millions of gallons of chemicals remaining in the ground and well shafts. It is suggested that wells will have to be monitored into the future and possibly re-caulked if there are signs of deterioration. However, given that the NYS DEC Division of Mineral Resources (the lead agency in regulating natural gas extraction) has *"consistently neglected to plug 89% of its depleted wells,"* monitoring of future wells is of concern. As of 2008, 57,000 gas wells in NYS remain unplugged.[39] In addition, leaks have been shown to develop in half of well casings studied in just fifteen years.[40] (Also see 1992 GEIS, Chapter XI Plugging and Abandonment of Oil and Gas Wells)

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[38] "Chemical and Biological Risk Assessment for Natural Gas Extraction in New York, Ronald E. Bishop, Ph.D. CHO, Chemistry & Biochemistry Department, State University of New York, College of Oneonta, March 28, 2011, p 9.

[39] "History of Oil and Gas Well Abandonment in New York", Ronald E. Bishop, Ph.D. C.H.O., Chemistry & Biology Department, SUNY College at Oneonta.

[40] Claudio Brufatto, Jamie Cochran, Lee Conn, David Power, Said Zaki Abd Alla El-Zeghaty, Bernard Fraboulet, Tom Griffin, Simon James, Trevor Munk, Ferderico Justus, Joseph R. Levine, Carl Montgomery, Dominic Murphy, Jochen Pfeiffer, Tiraputra Pornpoch, and Lara Rishmani (2003), "From Mud to Cement – Building Gas Wells", Oilfield Review (Schlumberger), August 2003, p 62-76.

Cement and steel corrosion is inevitable. Corroded well casings can provide a pathway for gas and well fluids to leak into aquifers and corrosive fluids are known to compromise the quality of cement barriers in well casing. Also, the bond between casing and cement can be compromised creating a space between the outer pipe wall and cement sheath allowing vertical migration of contaminants along the outside of the pipe wall.[41] The unpredictable frequency of this type of gas migration is of concern to the gas industry and regulatory agencies. These failures in well integrity may occur during initial cementing, or later in the well's life, due to pipe wall thinning, cement deterioration, the shock of additional well work activity in the area, pressure or temperature changes, or by seismic vibrations.[42]

The immediate and long-term effect of casing failure and deterioration, and release of chemical contaminants into groundwater is of concern.

Naturally Occurring Seismic Activity

The effect of induced and naturally occurring seismic activity on well structure integrity is a concern.

1. Seismicity in Albany County (Earth Quakes)[43]

- Table 4.2 Of all the counties that overlay Marcellus and Utica Shales, Albany County has a disproportionately high number of recorded seismic events. (Dec. 1970 – July 2009) Albany County has 50 recorded events (<2 – 3.9 magnitude), followed by Wyoming Co.- 13 recorded events (<2 – 2.9 mag.), and Erie Co. – 12 recorded events (<2 – 2.9 mag.) 16 counties show no seismic events, 6 counties show 1-3 seismic events, and 3 counties show 7-8 seismic events.
- There have been 26 seismic events recorded between August 22, 2011 and August 28, 2011. According to Won-Young Kim, research professor at Columbia's Lamont-Doherty Earth Observatory, *"…one of the issues that we do not understand, what is going on at this depth."* There have been clusters of earthquakes in Knox and nearby Berne: 91 in total dating back to the 1980s, 37 earthquakes were recorded between February 2009 and March 2010. (Times Union Sept. 3, 2011)
- Table 4.1 *"Modified Mercalli Intensity Scale"* indicates the effects that are *"typically observed near the epicenter of a seismic event".* Subsurface effects of naturally occurring seismic events are not indicated; the significance of rupturing of well sealants and casings has not become an issue until fairly recently.

("Schlumberger is the leading oilfield services provider, trusted to deliver superior results and improved E&P performance for oil and gas companies around the world. Through our well site operations and in our research and engineering facilities, we are working to develop products, services and solutions that optimize customer performance in a safe and environmentally sound manner.")

[41] "From Mud to Cement-Building Gas Wells, Oilfield Review, Schlumberger, Autumn 2003, pgs 62-76.

[42] "Review of NYS 2011 RDSGEIS and Proposed Revisions to NYCRR", Report to NRDC, Harvey Consulting, LLC, January, 2012.

[43] NYS DEC dSGEIS, September 2011.

- The epicenter for recorded seismic events for Albany County are mapped in SW Albany County. (Figure 4.15)
- Figure 4.13 shows two mapped fault lines and other smaller geologic faults mapped throughout the County.
- 6.12.1.1. states *"Avoiding pre-existing fault zones minimizes the possibility of trigging movement along a fault through hydraulic fracturing… avoid injecting fluids into known, significant, mapped faults when hydraulic fracturing. Generally, operators <u>would</u> avoid faults because they disrupt the pressure and stress field and …. causing … slippage."*
- 6.12.2 *"By definition, faults are planes or zones of broken or fractured rock in the subsurface. Geologic conditions associated with a fault generally are unfavorable for hydraulic fracturing and economical production of natural gas."*
- dSGEIS, Sept. 2011 6.12.1.4 Effects of Seismicity on Wellbore Integrity. Naturally occurring seismic activity in California damaged 14 (oil) wells. Also, see Youngstown, Ohio quake, Dec. 31, 2011 associated with 1.7 mile deep wastewater disposal well.
- The dSGEIS gives no scientific study or consideration to the potential environmental impact of naturally occurring seismic activity or to areas of special geological risk. See Executive Summary page 12-13: *"… would be reviewed on a site-specific basis..."*

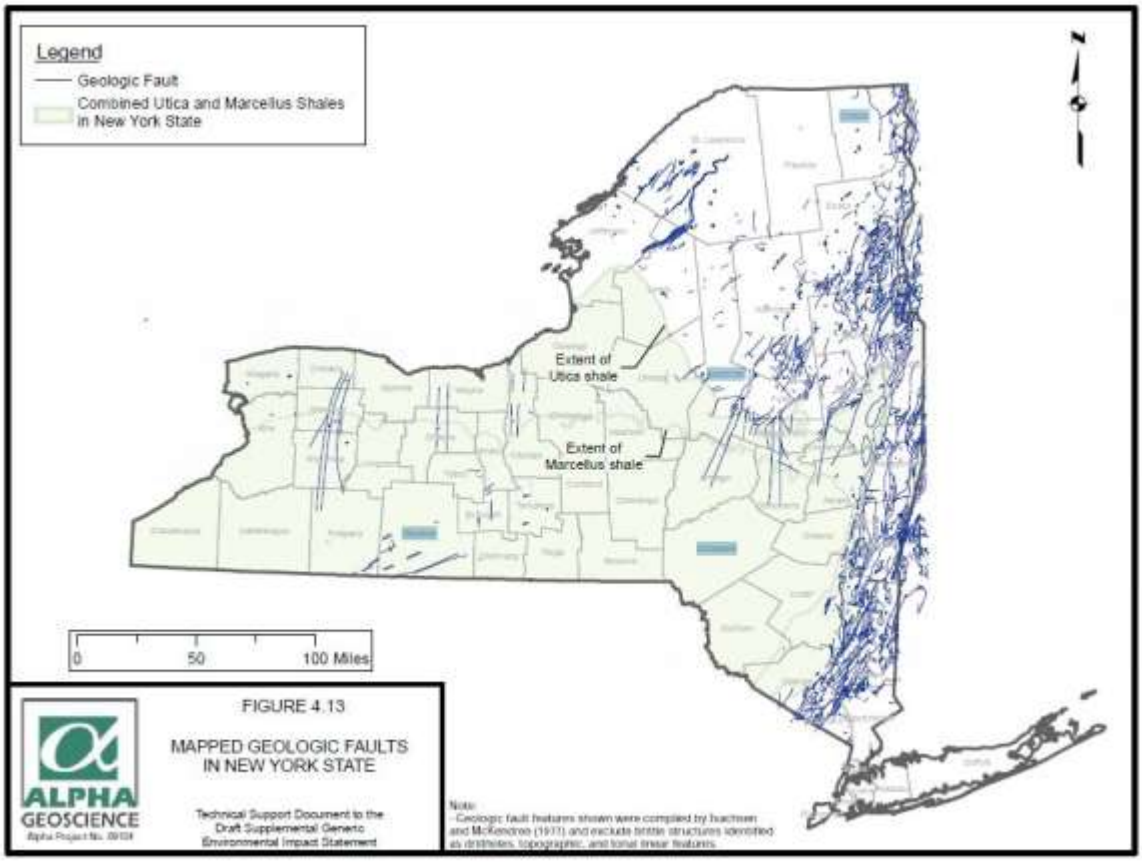
From the 1992 GEIS:

- 9-11 *"During the Waiting-On-Cement (WOC) time, there should be no activity… any jostling can disturb the cement."* It is suggested that there not be any truck traffic movement in the area while cement is drying, in addition to natural seismic activity concerns. (also see 16-18,19,20)
- The incidence of earthquake activity in the Town of Rensselaerville and surrounding area has the potential to jostle or disturb the best cementing process.

Other unique geologic characteristics of Albany County: *"intensely folded strata", "consists of fault blocks that have been thrust over…", "thick accumulation of glacial lake clay…", "exposed rock…"* see "*Soil Survey of Albany County*", New York, USDA, June, 1992.

The integrity of well casings, caps, plugs, and waste disposal wells have an increased risk of failure due to the naturally occurring seismic events in Albany County; that, along with inevitable casing deterioration, increase the potential for surface and groundwater contamination.

FAULT LINE MAPS Seismic activity is associated with faults.

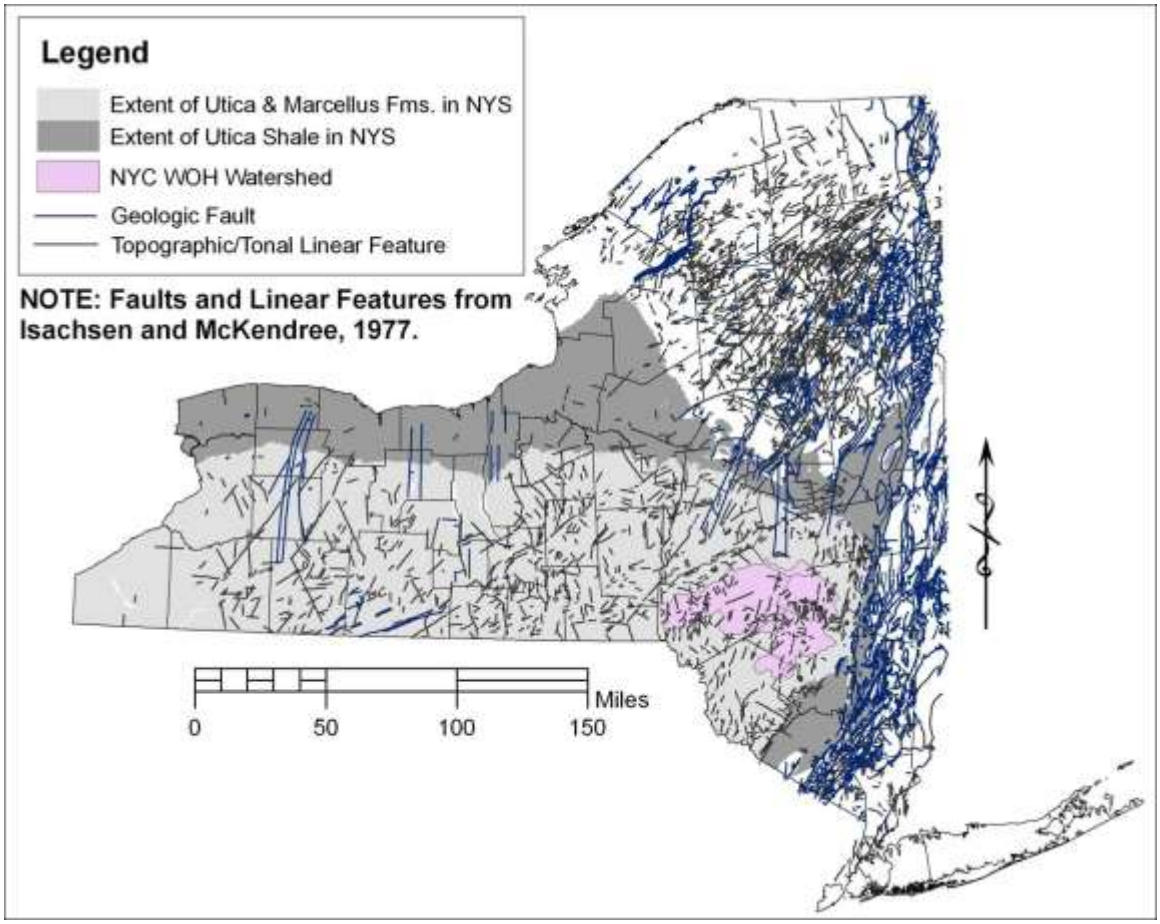


1) This map by Isachsen and McKendree, 1977, is included in the dSGEIS.

Many brittle geological features that were documented by Isachsen and McKendree have been excluded. The deletion of such information could lead those who are responsible for making sound evaluations of data and risk to water quality from natural gas extraction to a different, and/or erroneous conclusion.

"Lineaments observed on remote sensing data have been found to be coincident with zones of fracture concentration (Jacobi, 2002). In the interbedded shale and sandstone bedrock overlying the Marcellus shale-gas play, the fracture frequency within these zones typically is an order of magnitude greater than that in the surrounding area. Zones of fracture concentration have been associated with nearby faults as inferred from outcrops, well logs, and (or) seismic reflection data, and some zones have been associated with methane gas anomalies in the soil (Jacobi, 2002)."[44]

[44] U.S.G.S. NY Water Science Center Comments on the rdSGEIS, John Williams, p. 9.

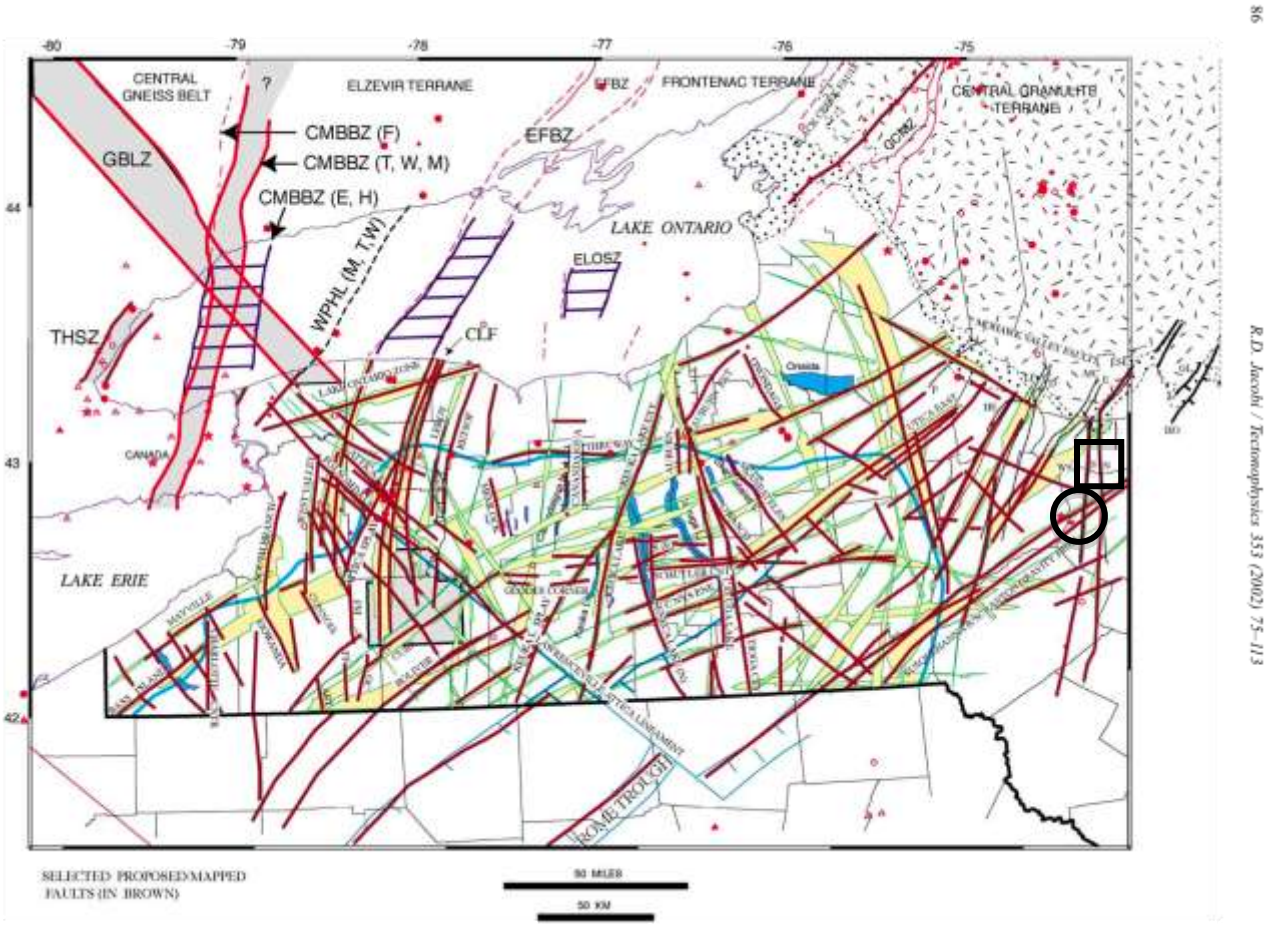


2) This map was *not* included in the dSGEIS. This map, **Faults and Linear Features** developed by Isachen and McKendree, 1977, mainly as an aid to geologic interpretation, **was revised** and included in the dSGEIS (see map 1 above)

Notice the faults, shear zones, fractures, and other linear features shown in and near the Town of Rensselaerville. These features represent breaks in the bedrock and may act as potential migration pathways for fluids from deeper formations.

The mapped structures are only those that are observable, and geologists assume that there are many more fractures present and are not mapped, simply because of the brittle nature of the bedrock. Based on this mapping by Isachsen and McKendree, the Marcellus shale in the Town of Rensselaerville should not be considered an impermeable barrier, since there are fragmentations and fractures.[45]

[45] "Final Impact Assessment Report," NYC DEP, Hazen and Sawyer, Environmental Engineers and Scientists, December 2009, pp.14-15.



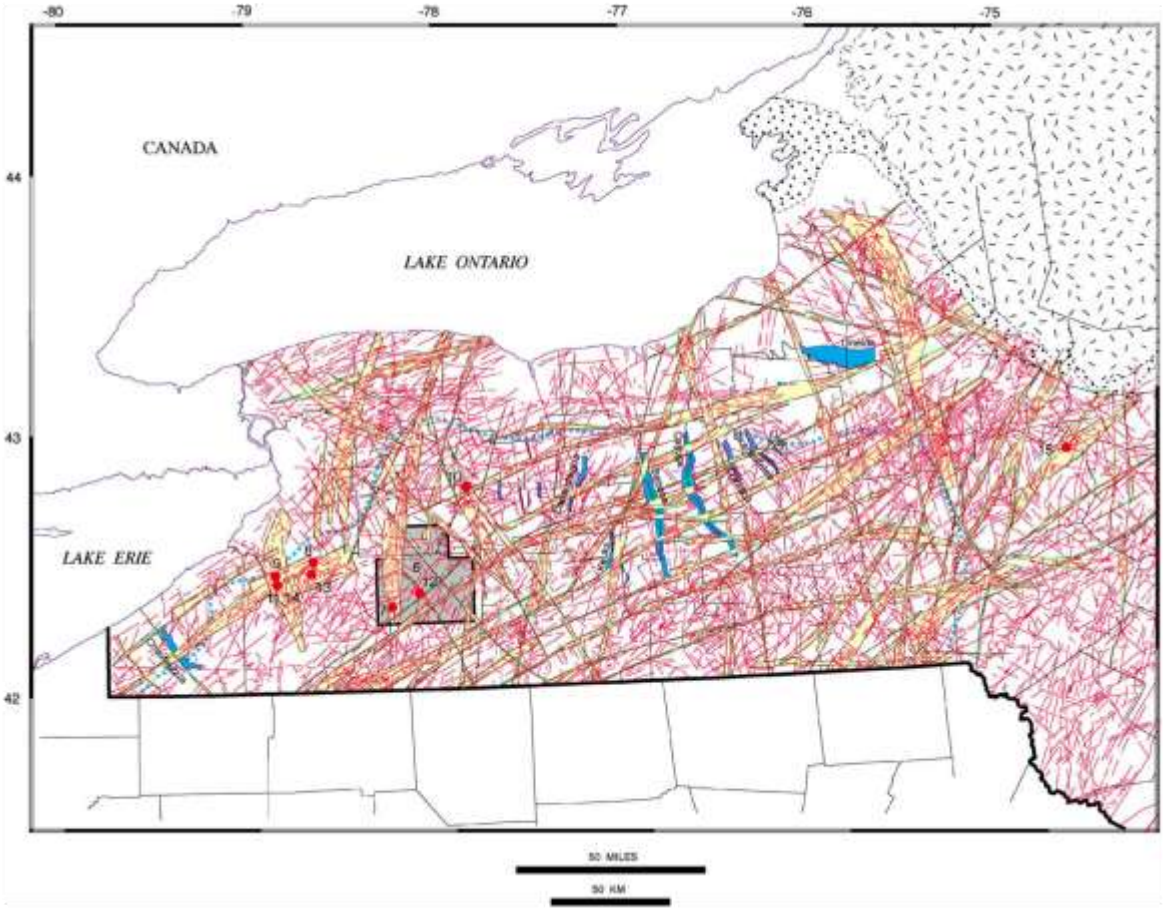
3) MAP OF CONFIRMED AND PROPOSED EARTHQUAKE FAULTS: (This map NOT included in dSGEIS)

"This map by Jacobi depicts some of the proposed fault lines that extend great distances and intersect with known faults (RD Jacobi, 2002, Basement Faults and Seismicity in the Appalachian Basin of New York State, Tectonophysics (TTP) V.353).

The far right of this map depicts a complex network of faults in proximity to the NYC Watershed. The Sprakers Fault (S) and Noses Fault (N), in black box, both known to be seismically active, are parallel faults oriented north-south through Schoharie and Delaware Counties. They intersect with another pair of parallel faults running west into Otsego County through a known seismic high-risk area (star and dots, in black circle). Jacobi lists other examples of fault intersections and risk areas throughout NYS.

He hypothesizes that the epicenters of three seismic events in easternmost Otsego County are related to the nearby Sprakers Fault in Schoharie County which, in turn, is linked with two seismic events in Delaware County. All this known seismic activity is just to the north and west of the NYC Watershed.

There is need for further research before pursuing hydrofracking amongst this web of faults, a need recognized by the gas industry: ***"fractures and faults…. make predicting hydraulic fracture behavior difficult"*** *and* ***"models fail to predict fracture behavior precisely, and in many cases, models fail completely…"*** *(Bennett et al, Oilfield Review, Winter 2005-2006, p 44). Contaminants can "stair-step" through faults toward aquifers, according to 2004 EPA study (EPA 816-04-003.pdf, p.12)."*
(research by L. Maher-Johnson Skyhill Farm, maherjohnson@gmail.com)



78 R.D. Jacobi / Tectonophysics 353 (2002) 75–113

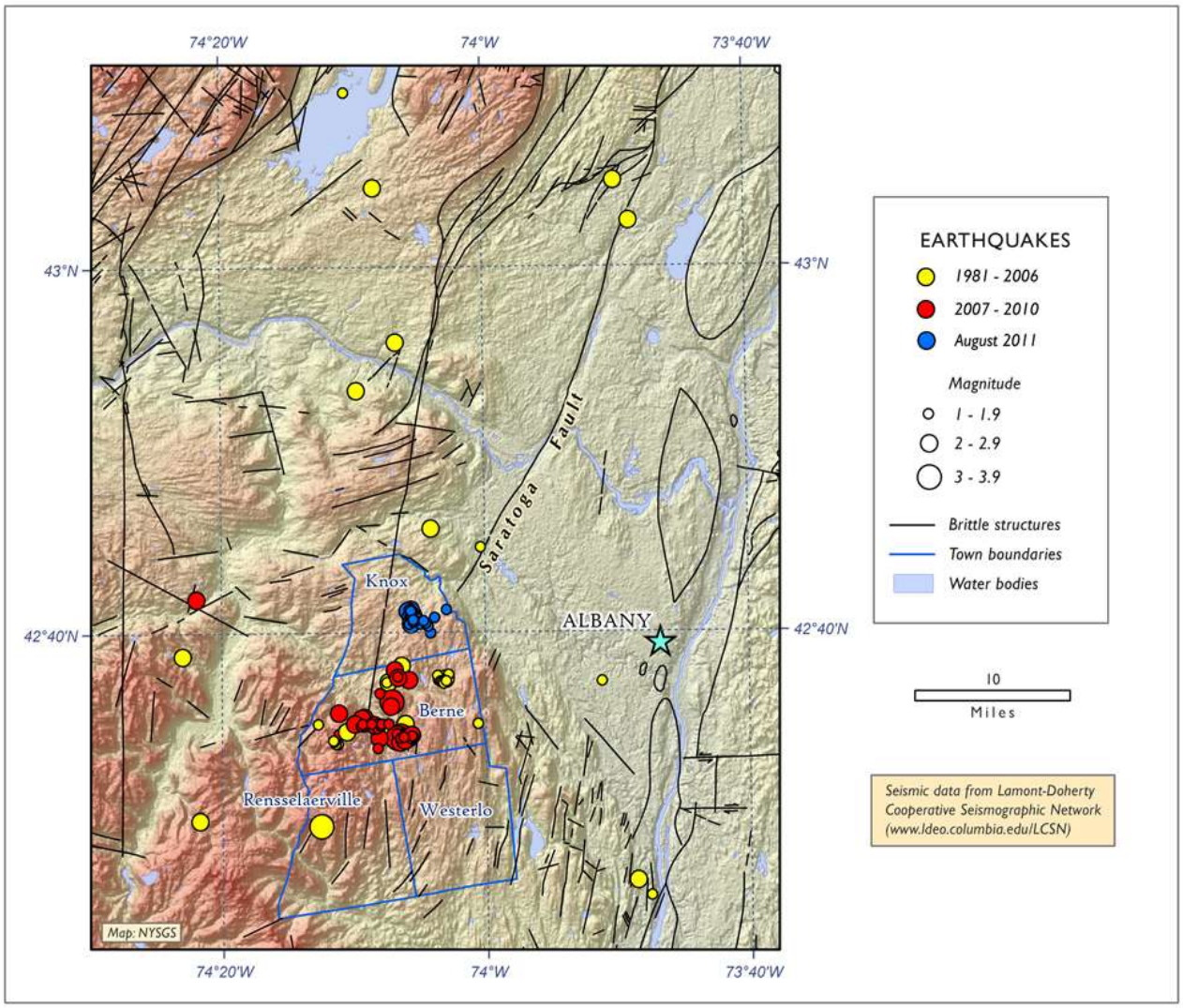
4) WEB OF CRISS-CROSSED EARTHQUAKE FAULTS: (This map NOT included in dSGEIS.)

"Jacobi's map shows a web of deep basement faults that criss-cross NYS. He concluded: "not only are there more faults than previously expected in NYS, but also, many of these faults are seismically active." Further, ***"most cultural facilities (e.g., waste disposal sites, bridges, pipelines) are not far from a potentially seismically active fault"*** *(Jacobi, Basement Faults and Seismicity in the Appalachian Basin of NY, p.75, 105).*

NY has a history of earthquakes, e.g., ***91 earthquakes since 1973 in an area Jacobi denoted as "high risk"- just 30 miles from the NYC Watershed*** *(USGS Earthquake DataBase). There is also a "history" of induced earthquakes and fluid injection into gas wells from the 1960s, e.g., the UK (Bowland Study), OK (OK Geological Survey), TX, AK, Alberta, BC, and CO. (Nikiforuk, http://www.energybulletin.net/print/59848) and OH (Fountain, NYT, Jan 1, 2012).*

Fluid injection into gas wells is suspected of opening up and unbalancing existing fractures and faults. An EPA study of 2004 found that fracture fluids "leak off" and "often take a stair-step transport path through the natural fracture system" (Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing Coalbed Methane Reservoirs, p. 12) "Some contaminants may arrive [in aquifers and water wells] rapidly via fractures, while others may arrive over decades or centuries….Long term chronic exposure to numerous unknown and untested chemicals [in drinking water] presents a great health risk" (Rubin, hydrogeologist, Hydroquest)."

(research by L. Maher-Johnson Skyhill Farm, maherjohnson@gmail.com)



(Earthquake information & map courtesy of the New York State Museum and State Geological Survey)

5) MAP SHOWING FAULT LINES, BRITTLE STRUCTURES AND EARTHQUAKE EVENTS 1981-2011 – showing Hilltowns to be in an active seismic area.

Brittle structures include joints, faults, crevices, and striae. These joints may serve as reservoirs and conduits for fluid movement through rock.

The Town of Rensselaerville shows one seismic event 3 – 3.9 magnitude and many brittle structures. Specific information: Date: 9/2/1991 10:58 AM 42.491 N, 74.209 W
Magnitude 3.1 Depth 5 km (=3.1 mi)
This would be one of the shallowest Helderberg earthquakes.

The disproportionately* high number of seismic events in Albany County and evidence of faults and brittle structures increases the risk of adverse impacts to surface and groundwater resources from natural gas extraction operations.
*Disproportionately: comparing the number of seismic events in Albany County to all other counties in NYS overlying the Marcellus shale as evident in Table 4.2 *"Summary of Seismic Events in New York State December 1970 through July 2009,"* dSGEIS, 2011.

Water Withdrawals and Water Supply

The water supply for citizens in the Town of Rensselaerville is regarded as good and is recharged or replenished from rainfall or snowmelt. The Comprehensive Plan states that *"groundwater can become depleted if withdrawal rates exceed natural replenishment rates."* (Always true anywhere.)

Experiences of water wells going dry, or having diminished water well quality have been reported by citizens of the Town of Rensselaerville when there is nearby water well drilling. It is not known if natural gas drilling would have the same effect on water wells in the area but it is possible that there could be a similar effect.

Should natural gas extraction operations be permitted in the Town of Rensselaerville the issues of *where, how,* and *how much* water would be withdrawn would be out of Rensselaerville citizen or local official control, as according to ECL 23-0301, NYS DEC would have legal authority to *regulate* gas industry operations. Water withdrawal for natural gas drilling operations is one of those regulated processes.

Disposal of Waste Products Associated with Natural Gas Drilling

To date, NYS DEC has not specifically identified how, or where any waste products associated with HVHF natural gas drilling operations would be "properly" disposed of.

Should natural gas extraction operations occur in the TOR, it is unknown at this time if permitted wells would be low volume vertically drilled wells, or HVHF multi-well pads. Waste products from different types of wells would have different potential impacts on water quality as the process would be guided by the 1992 GEIS or 2011 dSGEIS, with regulations still being reviewed. See Chapter 6 of this report which addresses "road spreading."

CONCLUSION

Given the potential problems described in this document, hydraulic fracturing, the extraction of natural gas, and the disposal of waste products associated with natural gas extraction operations in or near the Town of Rensselaerville, would pose significant risk to its water supply. Natural gas extraction operations are inconsistent with the goal of providing clean water resources to its residents. These statements are based on documented case histories, uncertain distribution of natural fractures, and the known patterns of natural groundwater flow, as described in detail in this document.

Arthur Palmer, who is quoted in several places in this document, is Professor Emeritus of Hydrology and Geochemistry, SUNY at Oneonta, and former director of the Water Resources program at that school. He has been awarded a SUNY Distinguished Teaching Professorship and Chancellor's Award for Excellence in Research. He is a fellow of the American Association for the Advancement of Science, National Speleological Society, and Geological Society of America, as well as a GSA Kirk Bryan Award recipient (based on his work in groundwater hydraulics of limestone caves). He has also worked as a consultant to several oil and gas companies.